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वार्षिक रिपोर्ट
ANNUAL REPORT
2007 - 2008

भाकृअनुप
ICAR

भारतीय कृषि अनुसंधान संस्थान
INDIAN AGRICULTURAL RESEARCH INSTITUTE
(भारतीय कृषि अनुसंधान परिषद)
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
नई दिल्ली - 110 012
NEW DELHI - 110 012

भा.कृ.अ.सं.वार्षिक रिपोर्ट 2007-2008 IARI ANNUAL REPORT 2007-2008

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Annual Report
2007-2008

भारतीय कृषि अनुसंधान संस्थान

Indian Agricultural Research Institute

(मानद विश्वविद्यालय)

(Deemed University)

नई दिल्ली.110 012

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Preface

At a time the agricultural sector in India is passing through a difficult phase and the world is facing a food crisis, the Institute is devoting greater attention to the goal of achieving food security for the country's ever increasing population by contributing to higher agricultural production, productivity, and quality. In the process, the protection of environment and natural resources base also received due attention. The programmes of the Institute were pursued in a multi-disciplinary mode. Recently, the Institute has launched a national level collaborative extension programme to develop village based models of agricultural development catering to different regions of the country. As in the past, the Institute also continued to make emphasis on building the desired human resource in the agricultural sector.

This report summarises the various activities and achievements of the Institute during the year 2007-2008 under the major heads: (i) crop improvement, (ii) genetic resources, (iii) crop and resource management and environment, (iv) crop protection, (v) basic and strategic research, (vi) social sciences and technology transfer, (vii) empowerment of women and mainstreaming of gender issues, and (viii) post-graduate education and information system.

The basic material for this report was provided by the joint directors, project directors, heads of divisions/establishments and regional stations, project coordinators and other scientists of the Institute. The photographs included in the report were provided by the scientists of the Institute as well as by the Central Photo Laboratory.

The report was prepared by Mr. Chacko Thomas, Editor (English) in association with Dr. Kehar Singh and Mr. D.K. Parashar, Technical Officers (T-7/8), and Mr. G.K. Kaushik, Technical Officer (T-6) under the technical guidance and supervision of Dr. K.R. Koundal, Joint Director (Research) & Incharge, Publication Unit. The research material included in this report was vetted by Dr. R.K. Sairam, Principal Scientist, Division of Plant Physiology, Dr. A.R. Sharma, Principal Scientist, Division of Agronomy, Dr. V.V. Ramamurthy, Principal Scientist, Division of Entomology, Dr. B.R. Atteri, Principal Scientist, Division of Agricultural Economics, and Dr. S.K. Chakraborty, Sr. Scientist, Division of Seed Science & Technology. The Hindi version of the 'Executive Summary' was prepared by Mr. A.K. Dubey, Editor (Hindi). The computer typesetting of the manuscript was done by Mr. Mukesh Kumar, Upper Division Clerk, and Ms. Sunita Joshi, Stenographer Gr. III.

My thanks are due to all.

(S.A. Patil)
Director

September 11, 2008
New Delhi

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IARI : AN INTRODUCTION

Originally established in 1905 at Pusa (Bihar) with the financial assistance of an American Philanthropist, Mr. Henry Phipps, the Indian Agricultural Research Institute (IARI) started functioning from New Delhi since 1936 when it was shifted to its present site after a major earthquake damaged the Institute's building at Pusa (Bihar). The Institute's popular name 'Pusa Institute' traces its origin to the establishment of the Institute at Pusa.

The Indian Agricultural Research Institute is the country's premier national Institute for agricultural research, education and extension. It has the status of a 'Deemed-to-be-University' under the UGC Act of 1956, and awards M.Sc. and Ph.D. degrees in various agricultural disciplines.

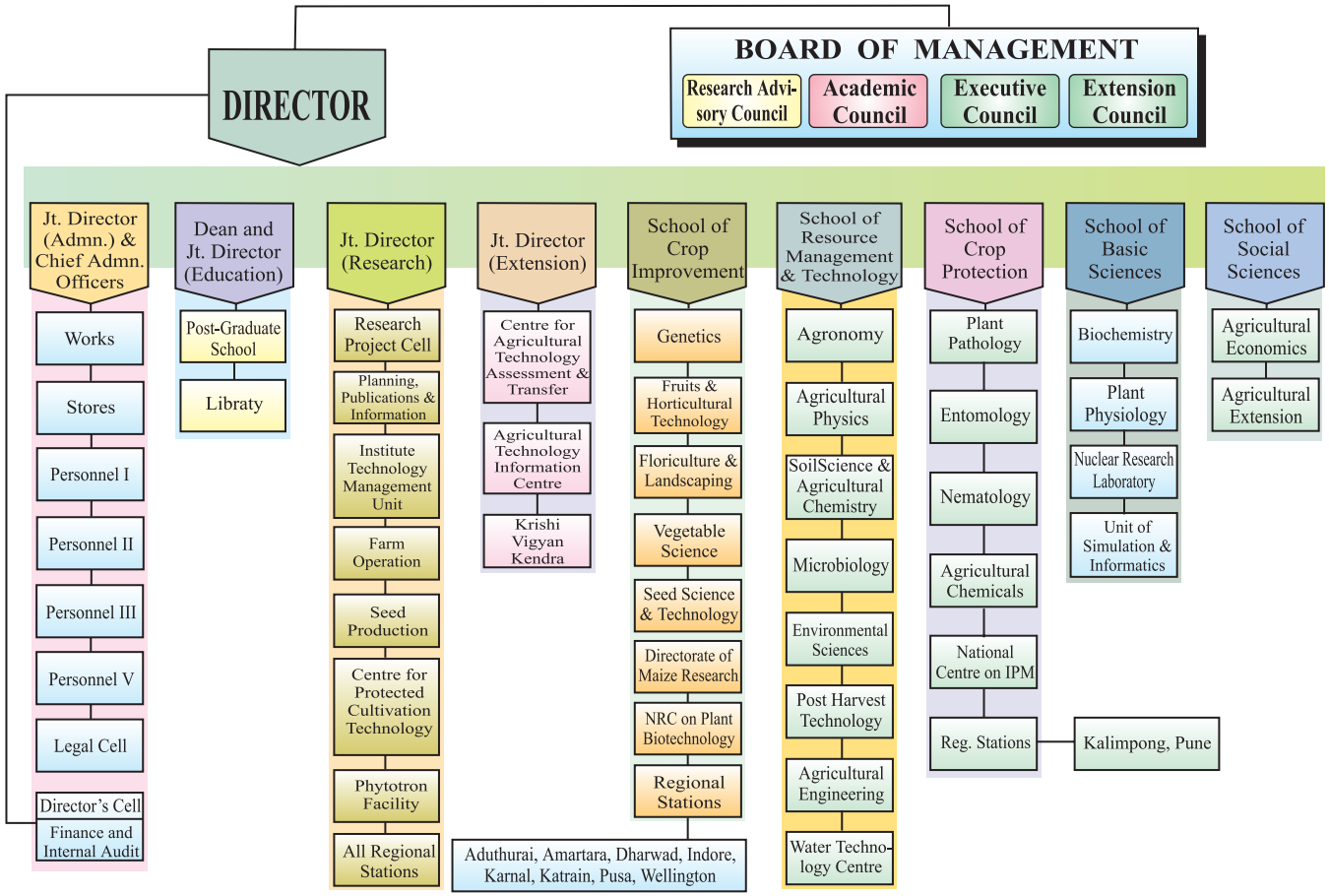
The growth of India's agriculture during the past more than 100 years, is closely linked with the researches done and technologies generated by the Institute. The Green Revolution stemmed from the fields of IARI. Development of high yielding varieties of all major crops which occupy vast areas throughout the country, generation and standardization of their production techniques, integrated pest management and integrated soil-water-nutrient management have been the hallmarks of the Institute's research. The Institute has researched and developed a large number of agrochemicals which have been patented and licensed and are being widely used in the country. Over the years, IARI has excelled as a centre of higher education and training in agricultural sciences at national and international levels.

The mandates of the Institute are as follows:

- To conduct basic and strategic research with a view to understanding the processes, in all their complexity, and to undertake need based research, that lead to crop improvement and sustained agricultural productivity in harmony with environment.
- To serve as a centre for academic excellence in the area of post-graduate and human resources development in agricultural sciences.
- To provide national leadership in agricultural research, extension, and technology assessment and transfer by developing new concepts and approaches and serving as a national referral point for quality and standards.
- To develop information systems, add value to information, share the information nationally and internationally, and serve as a national agricultural library and database.

The present campus of the Institute is a self-contained sylvan complex spread over an area of about 500 hectares (approx. 1250 acres). It is located about 8 km (5 miles) west of New Delhi Railway Station, about 7 km (4 miles) west of Krishi Bhavan, which houses the Indian Council of Agricultural Research (ICAR), and about 16 km (10 miles) east of Indira Gandhi International Airport at Palam. The location stands at 28.08° N and 77.12° E, the height above mean sea level being 228.61 metres (750 feet). The climate is sub-temperate and semi-arid. The mean maximum daily temperature during the hot weather (May-October) ranges from 32.2 °C to 40 °C and the mean minimum temperature from 12.2 °C to 27.5 °C. June to September are rainy months during which about 500 mm of rainfall is received. Winter sets in from mid-November and is delightful. The mean maximum temperature during winter (November-March) ranges from 20.1 °C to 29.1 °C and the mean minimum temperature from 5.6 °C to 12.7 °C. During winter, a small amount of rainfall (about 63 mm) is received.

The Institute has 20 divisions 5 multi-disciplinary centres situated in Delhi, 8 regional stations, 2 off-season nurseries, 3 all India coordinated research projects with headquarters at IARI, and 10 national centres functioning under the all India coordinated research projects. It has a sanctioned staff strength of 3540 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute for the year 2006-2007 was Rs. 11214 lakh.



Organizational set-up

विशिष्ट सारांश

संस्थान ने वर्ष 2007–2008 के दौरान कृषि अनुसंधान, शिक्षा और प्रसार के अपने अधिदेशित क्षेत्रों में उल्लेखनीय योगदान किए हैं।

फसल सुधार संबंधी कार्य की उल्लेखनीय भूमिका निरंतर बनी रही तथा विभिन्न फसलों में कई परीक्षण सफलतापूर्वक संचालित किए गए।

गेहूं में, तीन किस्मों नामतः पूसा 111 (एचडी 2932), एचआई 1544 (पूर्णा) तथा एचआई 8663 (पोषण) जारी की गईं। पूसा 111 किस्म को मध्य अंचल तथा प्रायद्वीपीय अंचल में पछेती बुवाई की सिंचित स्थितियों में उगाने के लिए सिफारिश की गई। इसमें प्रोटीन अंश 12.5% है, तथा इसकी औसत पैदावार मध्य अंचल में 4.2 टन/है. तथा प्रायद्वीपीय अंचल में 4.33 टन/है. रिकॉर्ड की गई। एचआई 1544 तथा एचआई 8663 किस्मों को क्रमशः मध्य अंचल तथा प्रायद्वीपीय अंचल में समय पर बुवाई, उच्च उर्वरता वाली सिंचित स्थितियों में उगाने के लिए जारी किया गया। एचआई 8663 किस्म में उच्च पोषणिक मान है तथा यह चपाती तथा शीघ्र तैयार किए जाने वाले खाद्य के लिए उपयुक्त है।

चावल में, इम्प्रूव्ड पूसा बासमती (पूसा 1460) जारी की गई। यह किस्म जीवण्विक अंगमारी के प्रति प्रतिरोध की उच्च श्रेणी में है तथा कृषक खेतों में इसकी औसत उपज 6.0–6.5 टन/है. दर्ज की गई। संस्थान द्वारा विकसित अन्य किस्म नामतः, पूसा 1121 ने पैदावार के क्षेत्र में निरंतर वृद्धि प्रदर्शित की है। खरीफ 2007 के दौरान, कुल बासमती चावल का क्षेत्र लगभग 60 प्रतिशत अधिकृत था। निम्न निवेश की स्थितियों के लिए उपयुक्त पाई गई यह किस्म कार्बनिक खेती के लिए उपयोगी हो सकती है।

जौ, में संस्थान द्वारा बीएचएस 380, आवरण जीनप्ररूप विकसित किया गया, अनाज के साथ–साथ दोहरे प्रयोजन के अंतर्गत किए गए परीक्षणों में इसने श्रेष्ठ निष्पादन दिया है।

मक्का में, चार प्रविष्टियों, नामतः एएच 31021 और एएनईपी कम्पोजिट 04, एएच 56191 और एएच 5506 ने विभिन्न अंचल में 4.0 टन/है. से 8.0 टन/है. उत्पादकता श्रेणी प्रदर्शित की।

बाजरा में, उच्च उपज सम्मिश्र जनसंख्या वाली एमपी 443 (पीपीएमपी 579) किस्म ने मृदुरोमिल आसिता रोग के विरूद्ध अच्छी प्रतिरोधिता प्रदर्शित की है।

चारा फसलों में, एक बार काटी जा सकने वाली ज्वार की प्रविष्टियों, नामतः पीसी 1002 और पीसी 1003 किस्मों ने अखिल भारतीय समन्वित अनुसंधान कार्यक्रम में सर्वश्रेष्ठ निष्पादन दिया।

चने में, मोटे दानों वाली देसी किस्म बीजी 2065 ने अखिल भारतीय समन्वित अनुसंधान परीक्षणों में सर्वश्रेष्ठ निष्पादन दिया। मूंग, मटर तथा मसूर में, देश के विभिन्न अंचलों से कई परीक्षणों में जीनप्ररूपों ने प्रवेश किया। अरहर में, संकर परीक्षणों में कई उच्च हेटरोटिक संकर संयोजनों को पहचाना गया।

ब्रैसिका में, भारतीय सरसों की इकहरी शून्य गुणवत्ता (निम्न येरुयिक अम्ल) वाली किस्म एलईएस 1–27 (पूसा मस्टर्ड 21) को राजस्थान, पंजाब, हरियाणा, जम्मू व कश्मीर के मैदानों, दिल्ली तथा पश्चिम उत्तर प्रदेश के लिए जारी किया गया। इस किस्म की औसत पैदावार शून्य गुणवत्ता (निम्न यूरुसिल अम्ल) वाली किस्म एलईटी 18 (पूसा मस्टर्ड 24) पहचानी गई।

कपास में, एक जीनप्ररूप पूसा 72–9–37 ने सर्वोच्च बिनौला उपज, जैसिड के प्रति सहिष्णुता तथा कुल 37 प्रतिशत उच्च ओटाई क्षमता प्रदर्शित की।

शाकीय फसलों में, कोल फसलों, कद्दूवर्गीय फसलों, सोलेनेसियस फसलों, जड़दार व बल्बदार फसलों, फलीदार फसलों और माल्वेसियस फसलों पर कई परीक्षण सफलतापूर्वक किए गए। मध्य–पछेती समूह में, फूलगोभी की किस्म डीसी 76 जारी करने के लिए पहचानी गई। अन्य किस्म डीसी 5 को दिसम्बर–जनवरी में परिपक्वता के लिए आशाजनक पाया गया। सीएमएस वंशक्रमों का उपयोग करते हुए चैक पीईएस (25.0 टन/है.) की तुलना में डीसीएच 3 (28.5 टन/है.) और डीसीएच 9 (29.1 टन/है.) अधिक आशाजनक पाए गए। इसी प्रकार, 3 संकरों, यथा, डीसीएच 801 (49.0 टन/है.), डीसीएच 804 (45.0 टन/है.) तथा डीसीएच 814 (43.0 टन/है.) को चैक पूसा शरद (37.5 टन/है.) की तुलना में सर्वश्रेष्ठ पाया गया। घीया में, हाल ही में जारी की गई पूसा संतुष्टि किस्म (सेल पी 6) अंचल IV और VII में व्यावसायिक खेती हेतु राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए पहचानी गई। गाजर में, भा.कृ.अ.सं. की दो किस्मों आईपीसी 122 (लाल) और आईपीसी 126 (काला) को जारी करने के लिए सिफारिश की गई। भा.कृ.अ.सं. द्वारा गार्डन पी की किस्म डीजीपी 4 विकसित की गई। इसकी हरी फलियों की उच्चतम उपज 83.73 टन/है. है।

फलवर्गीय फसलों में, कई विभिन्न भौतिक–रासायनिक प्राचलों के लिए विभिन्न देसी आमों की किस्मों/चयनों का मूल्यांकन किया गया। इसमें से आम की 15 देसी किस्मों में, ज़र्दालू और पूसा सूर्या की तुलना में, मल्लिका का सर्वाधिक फल भार पाया गया। मल्लिका की तुलना में आम्रपाली में कुल घुलनशील ठोस (टीएसएस) सर्वोच्च रिकॉर्ड किया गया। फल बढ़वार तथा गुणवत्ता प्राचलों के लिए इनमें से पांच विदेशी फल–किस्मों का मूल्यांकन किया गया। सर्वाधिक फल भार टॉमी एटकिंस का पाया गया, जबकि सबसे कम भार वाले फल सैंट एलैंक्जैंड्रिया किस्म द्वारा उत्पन्न हुए। अंगूर, नींबूवर्गीय फलों, आंवला, बेल, अनार, सेब, खुबानी, किवी फ्रूट, नाशपाती, स्ट्राबेरी और अखरोट जैसे अन्य फलों पर भी मूल्यांकन संबंधी अध्ययन किए गए। सेब के दो संकर, सेब की किस्मों, नामतः पूसा अमरतारा प्राइड (लाल रंग का) और पूसा गोल्ड जारी किए जाने के लिए चुने गए। पूसा अमरतारा प्राइड के फल अगेती पकते हैं (एक सप्ताह अगेती) जो बड़े आकार के होते हैं और इनमें रस अधिक होता है तथा कुल घुलनशील ठोस (टीएसएस) मान भी उच्च होता है।

शोभाकारी फसलों में गुलाब, ग्लेडियोलस, गेंदा, ट्यूबरोज, लिलियम और एल्सट्रोमेरिया पर मूल्यांकन संबंधी अध्ययन किए गए। 15 Gy के किरणन से गुलदाउदी की तीन किस्मों नामतः सद्भावना, थाइ चैन क्वीन तथा अजय में रेडियो–उत्प्रजनकों का उत्प्रेरण हुआ। अजय तथा सद्भावना प्रकाश व ताप के प्रति असंवेदनशील किस्में हैं और ये किस्में वर्ष में कम से कम तीन बार पुष्पित होती है, अतः ऐसी किस्मों में विविधता का सृजन गुलदाउदी के वर्षभर पुष्पोत्पादन की दृष्टि से विशेष रूप से लाभकारी सिद्ध हो सकता है।

संस्थान ने उत्तर भारत की परिस्थितियों में टमाटर व बैंगन के संकर बीजोत्पादन हेतु उपयुक्त तकनीकें विकसित की हैं। संकर बीजोत्पादन जालगृह में खुली खेती की स्थिति की तुलना में अधिक लाभदायक पाया गया (जहां फसल पुष्ट, कीटरहित होती है, वर्तिकाग्र लंबे होते हैं, परागों में विविधता होती है, फल अधिक संख्या में लगते हैं, बीज उपज अधिक होती है तथा बीज की गुणवत्ता भी बेहतर होती है) फूलगोभी के मामले में गैर–समकालिकता की समस्या से GA_3 (250 पीपीएम) तथा आईएए (50 पीपीएम) का विभिन्न अवस्थाओं पर छिड़काव करके निपटा गया।

बाइपोलिस ओराइज़ी द्वारा उत्पन्न होने वाला चावल का भूरा धब्बा रोग चावल उगाने वाले सभी देशों में विद्यमान एक प्रमुख बीज वाहित रोग है। इस रोगाणु के प्रभेदों को रोकने के लिए 8 वानस्पितिक और जैव–नियंत्रक एजेंटों के प्रभाव संबंधी अध्ययन से यह स्पष्ट हुआ कि चार पृथक्करों के विरूद्ध 1 प्रतिशत की दर से पैटकाउली तेल सर्वाधिक प्रभावी था, जिसके बाद क्रमशः सिट्रोनेला तेल और लैमन ग्रास तेल का स्थान था। कैलिसेना @$4x10^8$cfu से *बाइपोलेरिस ओराइज़ी* का प्रभावकारी नियंत्रण हुआ।

संस्थान ने औषधीय पौधों की बीजोत्पादन प्रौद्योगिकी; बीज गुणवत्ता परीक्षण और औषधीय पौधों में वृद्धि; बीज पुष्टता का मूल्यांकन; शिमला मिर्च की पौध के अंकुरण पर बीज प्राइमिंग के प्रभाव तथा नर्सरी में पौधों की पुष्टता; मृदा नमी प्रतिबल की स्थिति के अंतर्गत मक्का की पौदों की बढ़वार पर स्थिर चुम्बकीय क्षेत्र सम्पर्क में आने का पूर्व बुवाई बीजोपचार संबंधी प्रभाव; तथा फलीदार चारे की फसल स्टाइलों *सीब्राना* के माइक्रोवेव में उपचारित बीजों में जल–निरोध के दौरान एनएमआर रिलेक्सेशन संबंधी अध्ययन किए। संस्थान की नई दिल्ली स्थित बीज उत्पादन इकाई तथा संस्थान के करनाल, पूसा, इंदौर और कटराईं स्थित क्षेत्रीय केन्द्रों में अनाजों, दलहनों, तिलहनों, सब्जियों और शोभाकारी फसलों की विभिन्न किस्मों के नाभिक, प्रजनक और भा.कृ.अ.सं. बीज कड़ी गुणवत्ता नियंत्रण वाली स्थितियों में उत्पन्न किए गए। बीज उत्पादन इकाई (दिल्ली) में बीजोत्पादन के अतिरिक्त, 28 गुलाब की कलमें तथा 932 फल पौधे उत्पन्न किए गए। करनाल स्थित क्षेत्रीय केन्द्र में लगभग 4000 बागवानी पौधे उत्पन्न किए गए।

फसल आनुवांशिक संसाधनों पर अनुसंधान के अंतर्गत विभिन्न फसलों के अनेक जीनप्ररूप रोग प्रतिरोध, गुणवत्ता तथा अन्य आर्थिक गुणों की दृष्टि से उपयुक्त पाए गए। गेहूं के मामले में भा.कृ.अ.सं. क्षेत्रीय केन्द्र अमरतारा कॉटेज, शिमला के टूटीकंडी केन्द्र द्वारा विकसित दो नए प्रतिरोधी स्रोत डब्ल्यूबीएम 1587 (आईएनजीआर संख्या 07009; आईसी 549931) तथा डब्ल्यूबीएम 1591 (आईएनजीआर संख्या 07010; आईसी 549932) राष्ट्रीय पादप आनुवंशिक संसाधन ब्यूरो (एनबीपीजीआर) में धारी रतुआ रोगप्ररूप 46 S119 के विरूद्ध विविध तथा नए प्रतिरोधी स्रोत के रूप में पंजीकृत कराए गए। मक्का में मेइडिस पत्ती झुलसा (आईएनजीआर 070025) के लिए एक मक्का वंशक्रम (एससी 7–2) के प्रतिरोधी स्रोत के रूप में राष्ट्रीय पादप आनुवंशिक संसाधन ब्यूरो में पंजीकृत कराया गया। एक अन्य वंशक्रम आईसी 549904 को मेइडिस पत्ती झुलसा प्रतिरोध के लिए आनुवंशिक स्टॉक के रूप में एनबीपीजीआर में जमा कराया गया।

सूक्ष्मजैविक आनुवंशिक संसाधनों में, संस्थान के संवर्धन संकलन में 41 नए साइनोबैक्टीरियाई पृथक्कर जोड़े गए।

जैववर्गिकी और पहचान सेवाओं के अंतर्गत एचसीआईओ में सात सौ सोलह (716) कवकीय प्रतिदर्श जोड़े गए। इस प्रकार यहां प्रतिदर्शों की कुल संख्या 47,335 हो गई। हाइफोमासिटीज़ की आठ प्रजातियों नामतः *कोरिनेस्पोरा बैलियोस्पर्मिजेना, सी.क्लेरोडेंड्री–विस्कोज़, सी. नैनोस्पोरा, सी. सैपोटेसीरम, सी. ज़ाइलोस्मा–लॉन्गिफोली, सर्कोस्पोरा प्रोसोपिडिकोला, क्लैडोस्पोरियम साइकैडेसीरम* तथा *टीनियोलैला सैपिंडी* तथा मैलियोलेसिस कवक की 10 प्रजातियों नामतः *एमेज़ोनिया इलेइओकॉर्प, इरेनॉप्सिस साइडी, मैलिओला कैनियाकुमारियाना* किस्म *ब्रह्मगिरिएंसिस, एम. पालकाडेंसिस, एम. सेलिकोलो, एम. टेबरनेमोंटेनी* किस्म *राइटी, एस्टेरिना कैंथिज़ेरा, स्टेरोस्टोमेला, बैलियोस्पर्मी, ए. स्ट्रोबोसिई* तथा *सार्सीनेला राइटीएई* तथा डिमेटिसिएस हाइफोमाइसिटीज़ की दो प्रजातियों नामतः *डेइटोनिएला मायई* तथा *डिस्क्लोरीडियम गंगवानेई* को नई प्रजातियों के रूप में प्रस्तावित किया गया। एक नए कवक, *पोलिरोस्ट्राटा इंडिका* का *एरिएंथस मुंजा* के तनों से प्राप्त करके वर्णन किया गया।

भारतीय किस्म संवर्धन संकलन या इंडियन टाइप कल्चर कलेक्शन (आईटीसीसी) को 108 विभिन्न कवकीय संवर्धनों के नए योग द्वारा समृद्ध किया गया। प्रविष्ट किए गए कुछ उल्लेखनीय पादप रोगजनकों में जीरे का *फ्यूजेरियम फ्यूसोरियोडिस,* बांस के फुदके से प्राप्त *ट्राइकोडर्मा सिट्रिनोविरिडे* तथा *मेटासाइज़ियम एनिसोप्लीई,* हल्दी से प्राप्त *कोलेटोट्राकम कैप्सिसी,* चावल के पीले तना वेधक से प्राप्त *म्यूकर हियेमेलिस,* बैंगन से प्राप्त *ट्राइकोडर्मा फेसिकुलेटम* तथा *फ्यूज़ोरियम इक्विसेटी* और केसर से प्राप्त *स्क्लेरोशिम रॉल्फसी* सम्मिलित हैं।

विभिन्न समूहों नामतः ज़ाइगोमाइसिटीज़ (25), हाइफोमाइसिटीज़ (156), एस्कोमाइसिटीज़ (17), पेनिसिली (46), एस्पर्जिली (36), सीलोमाइसिटीज़ (65), और फ्यूजेरिया (84), के चार सौ उनत्तीस (429) वैध कवकीय संवर्धन आपूर्त किए गए।

तीन सौ पैंतीस (335), संवर्धन/प्रतिदर्श जो अधिकांशतः पादप रोगजनक, कटाई उपरांत रोगजनक, जैव–नियंत्रक एजेंट तथा औद्योगिक कवक थे, पहचाने गए। पहचाने गए कुछ महत्त्वपूर्ण कवक हैं– *डोलिकॉस लब लब* से प्राप्त *फोमा ट्रोपिका,* खीरा के बीज से प्राप्त *स्टैकाइबोट्रिस,* अरंड से प्राप्त *ग्लोमेरेला सिंगुलेटा* तथा *कोलेटोट्राइकम ग्लोइओस्पोरॉइडस, फाइकस रिलिगिओसा* से प्राप्त *फोमा ग्लोमेरेटा* तथा इलायची से प्राप्त *फ्यूज़ेरियम ऑक्सीस्पोरम*।

कीट पहचान सेवा के अंतर्गत, 847 कीट प्रतिदर्शों की पहचान की गई। *कैंपोनोटस (आर्थोनोटोमायरमैक्स)* प्रजाति समूह के *कैंपोनोटस सेरिसियस* को मेटाप्लूरल ग्रंथि से युक्त पाया गया। यह गुण पूरे विश्व में पाई जाने वाली कैंपोनोटस की अधिकांश प्रजातियों में नहीं होता है और यह गुण केवल इंडोनेशिया से प्राप्त *सी. गिगास* और आस्ट्रेलिया से प्राप्त *सी. थेडियस* में पाया जाता है। इस प्रकार, *कैंपोनोटस* की एक भारतीय प्रजाति में मेटाप्लूरल ग्रंथि की उपस्थिति की पहली व विश्व की तीसरी रिपोर्ट है। हेमिप्टेरा में तीन किस्म प्रजातियों नामतः *टेट्राडा हिस्टेरोरॉइडिस, एक्टोमोपोरिस क्वाड्रिगुप्टेटस* और *फेलेंटस गेनिकुलेटस* को उनके वर्गीकरणविज्ञानी गुणों के विवरणों के साथ पुनः वर्णित किया गया।

उत्तरी पहाड़ी क्षेत्र में आडू और सेब के जड़ क्षेत्र से प्राप्त किए जाने वाले पादप रोगजनक सूत्रकृमियों को पृथक किया गया। इनके विस्तृत आकृतिविज्ञानी अध्ययन से तीन नई प्रजातियों की पहचान हुई – एक उत्तराखंड से प्राप्त *पैराटाइलैंकस* वंश से था तथा दो हिमाचल प्रदेश और भूटान से प्राप्त *ज़ैनोक्राइसोनेमेला* वंश से थे।

rNDA के आईटीएस के तीन जीन क्रम – कीटरोगजनक सूत्रकृमि की देसी प्रजाति का एक (*स्टेइनर्नेमा* प्रजाति मेघालय प्रभेद प्रविष्टि सं. ईएफ 219458) जिसमें 516 आधार युग्म था; तथा जीवाणु प्रजाति के दो (*ज़ैनोरेब्डस इंडिका* प्रविष्टि सं. डीक्यू 211718; और *प्रोविडेंसिया वर्मिकोला* प्रविष्ट सं. ईएफ 192136), जो *एस. थर्मोफिलम* से सम्बद्ध थे, जीन बैंक में जमा कराए गए।

भारतीय राष्ट्रीय सूत्रकृमि संकलन या नेशनल नेमोटोड कलेक्शन ऑफ इंडिया (एनएनसीआई) को, नव–वर्णित सैप्रौफैगस सूत्रकृमि प्रजातियों (*लांगिडोरेला रेटेंटा, एल. रोटुंडा, एल. रेशिडी, एल. सादी, एल. परप्लेक्सा, एल. पैकीडर्मा, एल. पैपिलॉइडिस* तथा *एल. टुनिकेटा*) और 218 गीले सूत्रकृमि सस्पेंशन की 22 टाइप स्लाइडों से, समृद्ध किया गया। इस प्रकार, यहां 2211 किस्म प्रविष्टियां और 3212 गीले संकलन हो गए। किस्म प्रविष्टियों का डेटाबेस पूर्ण करने के पश्चात् इस वर्ष गीले सस्पेंशनों को डेटाबेस डिज़ाइन किया गया तथा 620 रिकॉर्ड प्रविष्ट किए गए।

उत्तराखंड, उत्तर प्रदेश, जम्मू व कश्मीर, गुजरात, पश्चिम बंगाल और असम से प्राप्त एक सौ पन्द्रह (115) सूत्रकृमि प्रतिदर्श पहचाने गए। पहचानी गई महत्वपूर्ण प्रजातियां थीं : *मेलाइडोगाइने इन्कॉग्निटा, रोटीलेंकलस रेनिफॉर्मिस, पेराट्राइकोडोरस क्रिस्टेई, ज़िफीनेमा इलॉन्गेटम, प्रेटिलेंकस थॉर्नेई, एफेलेंकस एवेनी, एफेलॉन्कॉइडिस कम्पोस्टिकोला, स्टेइनर्नेमा कार्पोकैप्सी, एस. रिओब्रेव* तथा *हेटेरोहैब्डिटिस बैक्टीरियोफोरा;* तथा कुछ मुफ्तजीवी रैब्डिटिस (*सिफेलोबस पर्सेग्निस, मेज़ोरैब्डिटिस* प्रजाति)।

संस्थान में अल्पावधि ग्रीष्मकालीन चारा फसलों और उसके पश्चात परवर्ती सुगंधित धान की उत्पादकता पर फास्फोरस–जिप्सम से समृद्ध यूरिया के प्रभाव; सोयाबीन आधारित फसल प्रणाली की उत्पादकता पर कार्बनिक व अकार्बनिक उर्वरक प्रबंध के प्रभाव; पोषक तत्वों के विभिन्न स्रोतों और स्तरों के अंतर्गत *ब्रैसिका* जीनप्ररूपों की गुणवत्ता के मूल्यांकन और परवर्ती लोबिया की फसल पर पड़ने वाले उनके अवशिष्ट प्रभाव; आलू आधारित अंतरफसल प्रणाली में जल उपयोग की किफायत; बारानी स्थितियों के अंतर्गत जलीय–उर्वरक और उर्वरता की स्थितियों के अंतर्गत सरसों के निष्पादन; सिंचित स्थितियों के अंतर्गत सामान्य और पछेती बुवाई की तिथियों पर गेहूं के नए जीनप्ररूपों के निष्पादन; सिंचित स्थितियों के अंतर्गत पछेती और अति पछेती बुवाई की तिथियों की अवस्था

में गेहूं के नए जीनप्ररूपों का निष्पादनः बुआई की विभिन्न तिथियों में सिंचित, समय पर बोई गई व पछेती बोई गई किस्मों के तुलनात्मक मूल्यांकन; सिंचित लवणीय व क्षारीय स्थितियों में गेहूं के नए जीनप्ररूपों के निष्पादन; परंपरागत जुताई व शून्य जुताई की स्थितियों में गेहूं की उपयोगी किस्मों के मूल्यांकन; गेहूं पर *एज़ोटोबैक्टर* तथा पीएसबी के साथ बीजोपचार के प्रभाव; बढ़वार की विभिन्न स्थितियों के अंतर्गत गेहूं के जीनप्ररूपों के निष्पादन; सुगंधित चावल की उपज व गुणवत्ता के लिए विभिन्न सस्यविज्ञानी घटकों के अंतर्गत चावल गहनीकरण प्रणाली (एसआरआई) और परंपरागत प्रणाली के तुलनात्मक मूल्यांकन; तथा चावल की किस्म पूसा 1460 की बीजोपज पर रोपाई की तिथियों, नाइट्रोजन उर्वरक और पौद से पौद की दूरी के प्रभाव संबंधी कई महत्वपूर्ण अध्ययन किए गए।

मृदा प्रबंधन के अंतर्गत मृदा में ह्यूमस–कार्बन की स्थिरता पर चावल–गेहूं तथा मक्का–गेहूं फसल प्रणालियों के दीर्घावधि प्रभावः पूर्वी भारत की अम्लीय मृदाओं में सल्फेट शोषण संबंधी गुणों; विभिन्न कृषि पारिस्थितिक प्रणालियों में मृदाजनक प्रवर्धन के संदर्भ में मृत्तिका खनिजों की स्थिरताः पौधों के लिए उपलब्ध मृदा फास्फोरस के अनुमान हेतु आयन विनिमय विधि; विभिन्न जुताई प्रणालियों तथा फसल चक्रों के अंतर्गत कार्बन क्रमीकरण तथा नाइट्रोजन चक्रण को बढ़ाने के लिए मृदा जैव विविधता के मूल्यांकन; सोयाबीन–गेहूं फसल चक्र के अंतर्गत मृदा गुणवत्ता सूचकांक और उत्पादकता पर खनिज उर्वरकों तथा कार्बनिक खाद के प्रभाव; वायवीय स्थितियों में उगाई गई चावल की फसल में लौह की कमी को सुधारने में लौह का पत्तियों पर उपयोग और मृदा की सापेक्ष प्रभावशीलता; चावल–गेहूं तथा मक्का–गेहूं फसल क्रमों में मृदा में उपलब्ध सूक्ष्म पोषक तत्वों की स्थिति पर जल एवं पोषक तत्व प्रबंध संबंधी प्रथाओं के प्रभाव; मृदा रासायनिक पर्यावरण पर यमुना के जल से अनवरत की जाने वाली सिंचाई के प्रभाव; पादप–निष्कर्षण क्षमता के लिए *ब्रैसिका* किस्मों की छंटाई; मलजल खत्ते तथा चावल की भूसी से खनिज नाइट्रोजन के विमोचन; लोबिया के पोषण तथा मृदा के स्वास्थ्य पर धान की पुआल से समृद्ध कम्पोस्ट के प्रभाव; बाजरा पर समृद्ध कम्पोस्टों के प्रभाव; तथा सूक्ष्मजैविक रूप से उपचारित माइका से उर्वरीकृत मृदा में पोटेशियम के विमोचन की गतिकी तथा सूडान घास द्वारा उसके उद्ग्रहण पर अध्ययन किए गए।

जल प्रबंधन के अंतर्गत संस्थान ने जलसंभर, सिंचाई सस्यविज्ञान, दबावयुक्त सिंचाई, भू–जल, चावल की वायवीय खेती और जल की गुणवत्ता के अतिरिक्त जलवायु परिवर्तन संबंधी अन्वेषणों में CLIMGEN मॉडल के अनुप्रयोग तथा कृषि के लिए सूखा सूचकांको के विकास पर मौसम विज्ञानी अध्ययन किए।

समेकित पोषक तत्व प्रबंधन के अंतर्गत मक्का–गेहूं क्रम में फसल उत्पादकता तथा मृदा उर्वरता पर उर्वरकों व खादों के दीर्घावधि प्रभावों; बाजरा–सरसों फसल प्रणाली में समेकित पोषक तत्व आपूर्ति और प्रबंधन; बाजरा–सरसों फसल क्रम में फास्फोरस उपयोग की दक्षता पर शैल फास्फेट से समृद्ध प्रैसमड कम्पोस्ट का गुण–निर्धारण; बाजरा और सरसों के लिए मृदा परीक्षण पर आधारित उर्वरकों का अनुप्रयोग तथा मूल आंकड़ों का विकास; स्वीट कॉर्न में समेकित पोषक तत्व प्रबंध तथा एकल और अंतर–फसलित कपास में समेकित नाइट्रोजन प्रबंध के प्रभाव संबंधी अध्ययन किए गए।

पोषक तत्व प्रबंध के क्षेत्र में मृदा में बहु–पोषणिक कमियों के मूल्यांकन तथा स्थल विशिष्ट पोषक तत्व प्रबंध के माध्यम से उनका सुधार; और बैंगन पर आधारित फसल प्रणालियों में कार्बनिक स्रोतों के माध्यम से पोषक तत्व प्रबंध पर अध्ययन हुए।

चावल–गेहूं फसल प्रणाली; बागान प्रबंध प्रथाओं; तथा संरक्षित खेती प्रौद्योगिकी पर महत्वपूर्ण अध्ययन किए गए।

इष्टतम फसल उत्पादन तथा श्रमिकों के श्रम में कमी लाने की दृष्टि से फार्म संबंधित अनेक उपस्कर, यंत्र तथा प्रौद्योगिकियां विकसित की गई या विकास की अवस्था में हैं। दाल के पूरे दानों की दिखावट और भौतिक गुणवत्ता में सुधार के लिए दाल के पूरे दाने की पॉलिश करने के लिए एक

पॉलिश यंत्र विकसित किया गया। संस्थान में मक्का और ज्वार के फुल्लित उत्पाद तैयार करने के लिए अनाज को फुल्लित करने का एक यंत्र विकसित किया। संतरों व नारंगी जैसे फलों को श्रेणीकृत करने के लिए एक यंत्र विकसित किया जा रहा है जो फलों को उनके भार के आधार पर श्रेणीकृत करता है।

कटाई उपरांत प्रौद्योगिकी और प्रबंधन के अंतर्गत मेथाइल साइक्लोप्रोपेन (1–एमसीपी) के उपयोग द्वारा आम के परिपक्वन को नियमित करने की एक वैकल्पिक विधि का अध्ययन किया गया क्योंकि इसमें इथिलीन को बाइंड करने की अनूठी क्षमता होती है जिससे फलों के परिपक्वन का निरोध होता है। किए गए अन्य अध्ययनों में सम्मिलित हैं– नियंत्रित वातावरण में सेब के व्यावसायिक भंडारण में 1–एमसीपी की भूमिका; प्वाइंटिड गाउर्ड *(ट्राइकोसेंथेस डिओइक)* की निधानी आयु तथा गुणवत्ता पर कटाई उपरांत उपचार तथा पैकेजिंग का प्रभाव; सेबों की निधानी आयु को बढ़ाना; सक्षम रंगकारक और क्रियात्मक घटक के रूप में काली गाजर के एंथोसियानिन का उपयोग; घन (क्लाउड) स्थिरता प्राप्त करने के लिए फलों के रस में हाइड्रोकोलाइडों का उपयोग; जीओजी पाउडर तैयार करना; मेथी की पत्तियों का निर्जलीकरण; शुष्कन या निर्जलीकरण के लिए गाजर की नई किस्मों की छंटाई; शिशु जनन के कारण फलों का चटकना और इसका नियंत्रण; सेबों में कटाई के उपरांत होने वाले रोगों के कारण उत्पन्न होने वाली विकृति को कम करने पर किए गए अध्ययन; दाल को शीघ्र पकाने के लिए प्रक्रिया प्राचलों का इष्टीकरण; अरहर की दाल के भौतिक तथा भौतिक–रासायनिक गुणों के बीच सह–संबंध का अध्ययन; मक्का और ज्वार के जलीकरण संबंधी गुण; तथा ज्वार के जलीकरण संबंधी गुण; तथा ज्वार के भौतिक गुण।

सूक्ष्मजीवविज्ञान में, टिकाऊ और जैविक खेती में कृषि अपशिष्टों के पुनश्चक्रण व उनके उपयोग; फसलोत्पादन के लिए सूक्ष्मजीवों के दोहन; कृषि की दृष्टि से महत्वपूर्ण सूक्ष्मजीवों के आण्विक गुण निर्धारण; तथा कृषि और उद्योगों के लिए साइनोबैक्टीरियाई आनुवंशिक संसाधनों व *एज़ोला* के दोहन व उपयोग पर महत्वपूर्ण अध्ययन किए गए।

पर्यावरण विज्ञान के क्षेत्र में हुए प्रमुख अध्ययन थे–जलवायु संबंधी जोखिमों से निपटने के लिए मूल्य आधारित सुनिश्चित उत्पादों का विकास; कृषि मृदाओं की वैश्विक ऊष्मन संबंधी क्षमता; गेहूं तथा चावल की फसलों से ग्रीन हाउस गैसों के उत्सर्जन को कम करने के लिए अपनाई जाने वाली रणनीतियां; जलवायु परिवर्तन संबंधी अध्ययनों के लिए अनुसंधान अवसंरचनाओं की स्थापना; गेहूं के पराग अंकुरण पर उच्च तापमान का प्रभाव; फसल उपज पर तापमान में निरंतर होने वाली वृद्धि का प्रभाव; फसल उपज पर कार्बन डाइऑक्साइड के बढ़े हुए स्तर का प्रभाव; विभिन्न मृदा कार्बन परिदृश्यों में तापमान के प्रत्युत्तर में मृदा सूक्ष्मजैविक समुदाय की गतिकी; चावल–गेहूं पारिस्थितिक प्रणाली में जल प्लवन के विरुद्ध कृषकों द्वारा अपनाई जाने वाली रणनीतियां; अपघटित भूमि में जैट्रोफा की खेती; की आर्थिकी; जलीय घोल से सीसा, कैडमियन और क्रोमियन के जैव सुधार हेतु जैट्रोफा के फल और बीजकवच का उपयोग; मक्का के अनाज से बायोइथोलॉन तैयार करना; कृषि में इथोनॉल उत्पादन से उत्पन्न होने वाले अपशिष्ट पदार्थो का भौतिक–रासायनिक गुण निर्धारण तथा उसका वैकल्पिक उपयोग; कृषि में कागज कारखानों के बहिर्स्राव का उपयोग; फसल उत्पादकता पर सतह ओज़ोन का प्रभाव; राष्ट्रीय राजधानी क्षेत्र के आर्थिक दृष्टि से दो विपरीत परिस्थितियों वाले जिले में भूमि–जल संसाधनों का अपघटन; बीटी कपास (एमईसीएच 162+बीटी) के अपघटन का मूल्यांकन तथा मृदा में बीटी आविषों के बने रहने का पता लगाना और निकटतम समजनक वंशक्रम (एमईसीएच 162–बीटी) की पत्तियों पर आविषों के अपशिष्टों से संबंधित अध्ययन; और विभिन्न निष्कर्षों द्वारा प्रभावित मृदाओं से रेडियोसेसियम का अवशोषण।

फसल सुरक्षा के क्षेत्र में संस्थान द्वारा पादप रोगविज्ञान, कीटविज्ञान, सूत्रकृमिविज्ञान का व कृषि रसायन विषयों से संबंधित महत्वपूर्ण खोजें हुईं।

पादप रोगविज्ञान के अंतर्गत गेहूं, चावल मक्का, चना, उड़द, मूंग, मटर, अरहर, तोरिया और सरसों, सब्जियों, फल–फसलों और बड़ी इलायची को प्रभावित करने वाले कवकीय

रोगों पर महत्वपूर्ण अध्ययन किए गए। फलीदार फसलों और सब्जियों सहित अन्य फसलों पर लगने वाले जीवाण्विक रोगों पर भी उल्लेखनीय अध्ययन हुए। विषाण्विक रोगों पर अनुसंधान किए गए जिनके अनेक महत्वपूर्ण परिणाम प्राप्त हुए। 25 सीटीवी पृथक्करों से सम्पूर्ण कवच प्रोटीन (सीपी), तथा 5 ORFla की विविधतायुक्त क्षेत्रीय जीन (1074 और 1478 nt के बीच 5' पर स्थित) के 404–न्यूक्लियोटाइड (nt) खंड को क्लोन किया गया और आनुवंशिक विविधता के लिए इसे क्रमीकृत भी किया गया। होशियारपुर (पंजाब) के किन्नो मेंडारिन को संक्रमित करने वाले इंडियन सिट्रस रिंगस्पॉट वाइरस (आईसीआरएसवी) के सम्पूर्ण जीनोम (आईसीआरएसवी–एच) तथा त्रिची से लिए गए केले (पूवन) के पृथक्कर से प्राप्त बीएसवी के सम्पूर्ण जीनोम को क्रमीकृत किया गया। किन्नों मेंडारिन में हरीतिमा कारक जीवाणु [*(कैंडीडेटस लाइबरबैक्टर एशियाटिकस (Cla)*] के राइबोसीमी डीएनए के 16S (1417 bp), 23S (247 bp) तथा 16S –23S अंतरप्रजातीय स्पेसर क्षेत्र (620 bp) को भारत को पहली बार क्रमिक किया गया तथा इसकी अन्य देशों से प्राप्त Cla क्रमित सम्बद्ध क्षेत्र से उच्चतम समानता पाई गई। GBNV (मूंग पृथक्कर) के छोटे (S) (AY871098) आरएनए खंड के जीनोम संगठन तथा सम्पूर्ण न्यूक्लियोटाइड क्रम का पता लगाया गया।

कीटविज्ञान में अनाजों, दालों, तिलहनों, सोयाबीन, कपास और सब्जियों के कीट–नाशकजीव प्रबंध पर अध्ययन किए गए। अन्य अध्ययनों में जैविक नियंत्रण; कीट कार्यिकी; तथा कीट आविषालु विज्ञान पर किए गए अध्ययन प्रमुख थे। सूत्रकृमिविज्ञान के क्षेत्र में जैवविविधता, प्रतिरोध की यांत्रिकी तथा निमेटोड प्रबंध पर महत्वपूर्ण अध्ययन हुए। कृषि रसायनों में प्राकृतिक व कृत्रिम कृषि रसायनों और उनके सहयौगिकों के विकास; नए कृत्रिम उत्पादों; नाशकजीवों के जोखिम संबंधी मूल्यांकनों व पर्यावरण पर पड़ने वाले उनके प्रभाव व उनसे निपटने के उपायों; और नाशकजीवों संरूपणों की सुरक्षा और दक्षता में सुधार जैसे विषयों पर महत्वपूर्ण कार्य किए गए।

खरपतवार प्रबंध के मामले में कपास की फसल के निष्पादन पर जुताई तथा खरपतवार नियंत्रण की विभिन्न विधियों के प्रभाव; सोयाबीन में खरपतवार प्रबंधन के लिए मेट्रिब्यूजेन के क्रमिक अनुप्रयोग; सोयाबीन में *साइपेरस रोटेंडस* के समेकित प्रबंध; पूरे पंजाब व हरियाणा में गुल्ली डंडा या *फेलेरिस माइनर* में पार–प्रतिरोध के मूल्यांकन व प्रबंध; प्याज में समेकित खरपतवार प्रबंध की क्रियाओं; खरपतवारों की वृद्धि पर विभिन्न खरपतवार या शाकनाशियों की तुलनात्मक दक्षता; और सीधे रोपे गए धान की उत्पादकता पर अध्ययन किए गए।

मौलिक तथा रणनीतिपरक अनुसंधान के क्षेत्र में संस्थान में अनेक महत्वपूर्ण खोजें हुईं।

पादप जैवप्रौद्योगिकी में *एरेबिडोप्सिन थेलियाना* में नरवंध्यता सहित सीएमएस सम्बद्ध जीन की पराजीनी अभिव्यक्ति; सरसों के चेंपा (*लिपेफिस इराइसिमी*) के प्रतिकर्षण के लिए β फार्मेसीन सिंथेटेज को व्यक्त करने वाली भारतीय सरसों (*ब्रैसिका जुंसिया*); मूंग के लैक्टिन के सम्पूर्ण लंबाई वाले cDNA के पृथक्करण; *ब्रैसिका जुंसिया* के रूपांतरण व पुनर्जनन; अरहर की जीनोमिक्स; चाव की किस्म सीएसआर 27 में लवणता सहिष्णुता के लिए क्यूटीएल का सूक्ष्म मानचित्रण; बासमती चावल की पृष्ठभूमि में जीवाण्विक झुलसा प्रतिरोध के योग की पिरामिडिंग; *AtDREBIA* जीन के उपयोग द्वारा पराजीनी चावल के विकास; प्रध्वंस प्रतिरोधी जीनों से युक्त पराजीनी चावल वंशक्रम; सेब के आण्विक गुण–निर्धारण; तथा फलदार फसलों के ऊतक संवर्धन के माध्यम से सूक्ष्म प्रवर्धन व सुधार पर अध्ययन किए गए।

जैव–रसायनविज्ञान में सोयाबीन से ω–6 डिसेचुरेज़ कोडिकृत करने वाले *fad2-I* जीन के पृथक्करण व गुण–निर्धारण; *ई. कोलाई* में DGAT जीन की अभिव्यक्ति; *बी. जुंसिया* से प्राप्त लाइसोफेसफेटिडिक अम्ल एकाइलट्रांसफरेज़ जीन के पृथक्करण व गुण–निर्धारण; चावल में नमी प्रतिबल की स्थिति के अंतर्गत विभिन्न प्रकार से विनियमित जीनों के पृथक्करण व गुण–निर्धारण; *बोगेनविलिया एक्सब्यूटियाना* से

प्राप्त प्रतिविषाण्विक प्रोटीन (BBAP-II) के cDNA क्रम इनकोडिंग के *इन–सिलिको* विश्लेषण तथा *ई.कोलाई* में अभिव्यक्ति संबंधी अध्ययन हुए।

पादप कार्यिकी के क्षेत्र में उत्पादकता को सीमित करने वाली कार्यिकीय बाधाओं; कार्यिकीय दृष्टिकोणों के माध्यम से फसल पौधों में अजैविक प्रतिबल सहिष्णुता में सुधार; फलों, सब्जियों और फूलों की कटाई उपरांत कार्यिकी; वैश्विक जलवायु परिवर्तन के संदर्भ में फसलों का गुणनिर्धारण; पौधों की प्रतिक्रिया को परिवर्तित करने के लिए गामा किरणन; कृषि उत्पादों की सूक्ष्मजैविक वृद्धि और पोषणिक गुणवत्ता; गेहूं के बीजों के गामा किरणों के सम्पर्क में आने का उसके कार्यिकीय व आकृतिविज्ञानी गुणों पर प्रभाव; गामा किरणन का कपास के रेशों की शक्ति पर पड़ने वाले प्रभाव; और गेहूं की फसल को जस्ते और लौह तत्वों की जैव–सुरक्षा प्रदान करने के लिए संभावित फाइटोसाइडेरोफोर के उपयोग पर महत्वपूर्ण अध्ययन हुए। संस्थान में जिन पर महत्वपूर्ण आनुवंशिक अध्ययन किए गए उनमें सम्मिलित है : गेहूं, चावल, मक्का, बाजरा, चना, मसूर और मटर, अरहर, और ब्रैसिका, लोबिया, कपास और सोयाबीन; तथा ड्रोसोफिला मेलानोगेस्टर।

कृषि भौतिकी में, मृदा भौतिकी; सुदूर संवेदन और जीआईएस तथा कृषि मौसम विज्ञान से संबंधित अध्ययन हुए।

संस्थान की राष्ट्रीय फाइटोट्रान सुविधा में महत्वपूर्ण अध्ययन हुए जिससे संस्थान के विभिन्न संभागों व अन्य स्थापनाओं के अलावा बाहर की संस्थाओं की आवश्यकताओं की पूर्ति भी हुई।

कृषि अर्थशास्त्र के क्षेत्र में संस्थान में भारत के गंगा–यमुना के मैदानों में फार्म आर्थिकी पर संसाधन संरक्षण संबंधी प्रौद्योगिकियों को अपनाने के प्रभाव; भारत के गंगा–यमुना के मैदानों में श्रमिकों के पलायन के ग्रामीण अर्थव्यवस्था पर पड़ने वाले प्रभाव; भारत में बागवानी जिंसों के लिए विपणन सूचना प्रणाली; भारतीय कृषि पर व्यापार उदारीकरण के प्रभाव; दिल्ली में परि–नगरीय खेती तथा इसके प्रबंध; भारत के बागवानी जिंसों के निर्यात पर खाद्य सुरक्षा संबंधी उपायों के पड़ने वाले प्रभावों; और भारत में बागवानी जिंसों के बाजारों के सह–समेकन पर अध्ययन हुए। कृषि प्रसार में, टिकाऊ विकास हेतु फार्मिंग प्रणाली अनुसंधान एवं प्रसार; कृषि प्रौद्योगिकियों के सामाजिक–आर्थिक व पर्यावरणीय प्रभाव के मूल्यांकन; प्रसार संगठन की दक्षता को बढ़ाने; अंतरक्षेत्रीय सूक्ष्म–योजनाओं व भागीदारी युक्त विस्तार विधिविज्ञान के विकास; कृषि विस्तार में सीएएस के अंतर्गत चलाए जाने वाले प्रशिक्षण कार्यक्रमों के प्रभाव के विश्लेषण; ग्रामीण संसाधन प्रबंध में क्षमता निर्माण के मूल्यांकन; गेहूं की खेती की प्रौद्योगिकी को सुदूर स्थित जनजातीय क्षेत्रों में ले जाने और ड्यूरम गेहूं की खपत को लोकप्रिय बनाकर कुपोषण को मिटाने जैसे विषयों पर अध्ययन किए गए। प्रौद्योगिकी मूल्यांकन व हस्तांतरण के अंतर्गत संस्थान ने विभिन्न कृषि–पारिस्थितिक क्षेत्रों में फसलों की उत्पादकता बढ़ाने से संबंधित कई कार्य किए जिसमें अग्र पंक्ति के अनेक प्रदर्शनों का आयोजन भी सम्मिलित है। देश के सुदूर उत्तरी–दक्षिणी, पूर्वी और पश्चिमी भागों में संस्थान द्वारा कई चुने हुए राज्य कृषि विश्वविद्यालयों/भा.कृ.अ.प. के संस्थानों के सहयोग से रबी 2007–08 से अनेक कार्यक्रम, राष्ट्रीय प्रसार योजना के तहत, आरंभ किए गए। संस्थान में 24 से 26 फरवरी 2007 को वार्षिक पूसा कृषि विज्ञान मेला आयोजित किया गया जिसका मुख्य विषय था 'भा.कृ.अ.सं.– किसानों की सेवा में'। इस मेले का उद्घाटन माननीय केंद्रीय कृषि, उपभोक्ता मामले, खाद्य एवं सार्वजनिक वितरण मंत्री श्री शरद पवार ने किया। संस्थान द्वारा प्रसार से जुड़े अन्य अनेक क्रियाकलाप आयोजित किए गए जैसे परिसर से बाहर प्रदर्शनियों/खेत दिवसों, कृषक दिवसों आदि का आयोजन। संस्थान के कृषि प्रौद्योगिकी सूचना केन्द्र ने 'एक ही स्थान पर सभी सुविधाएं उपलब्ध कराने की प्रणाली' के तहत कार्य करना जारी रखा जिससे उत्पादों, सेवाओं, प्रौद्योगिकियों तथा सूचना को विभिन्न पणधारियों को प्रभावी ढंग से उपलब्ध कराया गया।

संस्थान के शिकोहपुर स्थित कृषि विज्ञान केन्द्र ने प्रौद्योगिकी सशक्तीकरण, कृषकों की जागरूकता में सुधार लाकर तथा प्रशिक्षकों के प्रशिक्षण कार्यक्रमों के माध्यम से फार्म उत्पादकता

को बढ़ाकर ग्रामीण युवाओं को बेरोजगारी से लड़ने में उल्लेखनीय सहायता प्रदान की और इस दिशा में महत्वपूर्ण योगदान दिया। महिलाओं के सशक्तीकरण और लिंग संबंधी मुद्दों को मुख्य धारा में जोड़ने के लिए संस्थान ने अनेक कार्यक्रम चलाए।

संस्थान का 45वां दीक्षांत समारोह 9 फरवरी 2007 को आयोजित किया गया। कृषि अनुसंधान एवं शिक्षा विभाग के सचिव तथा भा.कृ.अ.प. के महानिदेशक डॉ. मंगला राय जो इस समारोह के मुख्य अतिथि थे, ने दीक्षांत भाषण दिया। इस दीक्षांत समारोह में एम.एससी. के 75 व पीएच.डी. के 73 छात्रों को उपाधियां प्रदान की गई। श्री पी.एन. शिवलिंगम (पादप रोगविज्ञान) और श्री मृदुल चक्रवर्ती (आनुवंशिकी) को क्रमशः पीएच.डी. व. एम.एससी. के 'वर्ष 2006 के सर्वश्रेष्ठ छात्र' पुरस्कार प्रदान किए गए। संस्थान में अनेक नियमित/अल्पावधि प्रशिक्षण पाठ्यक्रम आयोजित किए गए। कृषि सूचना विभाग व जैव–सूचना विज्ञान पर भी संस्थान ने प्राथमिकता के आधार पर ध्यान केन्द्रित रखा। संस्थान का पुस्तकालय छात्रों व वैज्ञानिक समुदाय को अपनी अमूल्य सेवाएं प्रदान करता रहा।

संस्थान द्वारा हिंदी व अंग्रेजी में अनेक नियमित व तदर्थ प्रकाशन निकाले गए, ताकि संस्थान के अधिदेशित क्रियाकलापों को व्यापक रूप से प्रचारित किया जा सके। संस्थान ने 5 पेटेंटों के लिए आवेदन दाखिल किए और 4 समझौता ज्ञापनों पर हस्ताक्षर किए। इसके अतिरिक्त संस्थान ने राष्ट्रीय अनुसंधान व विकास परिषद को व्यवसायीकरण हेतु पांच प्रौद्योगिकियां सौंपी।

संस्थान का अनेक राष्ट्रीय व अंतरराष्ट्रीय संस्थाओं के साथ सहयोग–सम्पर्क बना हुआ है।

EXECUTIVE SUMMARY

The Institute continued to contribute significantly in its mandated areas of agricultural research, education and extension during the year 2007-2008.

The crop improvement work continued to play a significant role, and many trials were conducted successfully in several crops.

In wheat, three varieties, namely, Pusa 111 (HD 2932), HI 1544 (Purna) and HI 8663 (Poshan) were released. The variety Pusa 111, recommended for cultivation under late sown irrigated conditions of Central Zone and Peninsular Zone, has a protein content of 12.5%, and registered an average grain yield of 4.2 t/ha in Central Zone, and 4.33 t/ha in Penninsular Zone. The varieties, HI 1544 and HI 8663 were released for cultivation under timely sown, high fertility, irrigated conditions of Central Zone, and Peninsular Zone, respectively. The variety HI 8663 has high nutritional value, and is suitable for *chapati* and fast food preparations.

In rice, improved Pusa Basmati 1 (Pusa 1460) was released. This variety imparts a high degree of resistance to bacterial blight and has recorded an average yield of 6.0 – 6.5 t/ha in farmers' fields. Another variety developed by the Institute, namely, Pusa 1121 continued to show increase in the area under cultivation. During *kharif* 2007, it occupied nearly 60% of the total *basmati* rice area. Suited for low input conditions, this variety can be used for organic farming.

In barley, BHS 380, a hulled genotype developed by the Institute, performed well under both grain as well as dual purposes trials.

In maize, four entries, namely, AH 31021, ANEP Comp. 04, AH 56191 and AH 5506 showed a productivity range of 4.0 t/ha to 8.0 t/ha in different zones.

In pearl millet, a high yielding composite population MP 443 (PPMP 579) was found to be promising with good resistance against downy mildew disease.

In forage sorghum, two single-cut entries, namely, PC 1002 and PC 1003 gave superior performance in All India Coordinated Research Programme.

In chickpea, a bold seeded *desi* variety BG 2065 gave superior performance in All India Coordinated Trials. In mungbean, field pea and lentil, a number of genotypes were entered in different trials across different zones in the country. In pigeonpea, several highly heterotic cross combinations were identified in hybrid trials.

In *Brassicas*, a single zero quality (low erucic acid) variety LES 1-27 (Pusa Mustard 21) of Indian mustard was released for Rajasthan, Punjab, Haryana, plains of Jammu and Kashmir, Delhi and western UP. The average yield of this variety is 2.1 t/ha. Another single zero quality (low erucic acid) variety of Indian mustard LET 18 (Pusa Mustard 24) was identified.

In cotton, a genotype Pusa 72-9-37 showed the highest seed cotton yield, tolerance to jassid and high ginning out-turn of 37%.

In vegetable crops, several successful trials were conducted involving cole crops, cucurbits, solanaceous crops, root and bulbous crops, a leguminous crop, and a malvaceous crop. In the mid-late group, a cauliflower variety, DC 76 was identified for release. Another variety DC 5 was found promising for December-January maturity, based on its compact white curds. Among early hybrids developed by using CMS line, DCH 3 (28.5 t/ha) and DCH 9 (29.1 t/ha) were found more promising than the check PES (25.0 t/ha). Similarly, 3 hybrids, viz., DCH 801 (49.0 t/ha), DCH 804 (45.0 t/ha) and DCH 814 (43.0 t/ha) were found to be superior to the check Pusa Sharad (37.5 t/ha). In bottle gourd, the earlier released variety Pusa Santushti (Sel P6) for NCR, Delhi was identified for commercial cultivation in Zones IV and VII. In carrot, two varieties IPC 122 (red) and IPC 126 (black) from IARI were recommended for release. The garden pea variety DGP 4 developed by IARI gave the highest yield of 87.73 t/ha of green pods.

In fruit crops, different indigenous mango varieties/ collections were evaluated for various different physico-chemical parameters. Among fifteen indigenous varieties, the maximum fruit weight was noted in Mallika followed by

Zardalu and Pusa Surya. The maximum TSS was recorded in Amrapali followed by Mallika. Among five exotic cultivars evaluated for fruit growth and quality parameters, the maximum fruit weight was observed in Tommy Atkins and the smallest fruits were produced by St. Alexandrina. Evaluation studies were also conducted on other fruit crops such as grape, citrus, *aonla, bael*, pomegranate, apple, apricot, kiwifruit, pear, strawberry, and walnut. Two apple hybrids were selected for release as apple cultivars, viz., Pusa Amartara Pride (red coloured) and Pusa Gold. Pusa Amartara Pride is early ripening (one week earlier), and large in size with high juice content and TSS values.

In ornamental crops, evaluation studies were conducted on rose, gladiolus, marigold, tuberose, lillium, and alstroemeria. Irradiation at 15 Gy induced radiomutants in three chrysanthemum cultivars, namely, Sadbhawana, Thai Chen Queen, and Ajay. Ajay and Sadhbhawana are photo- and thermo-insensitive cultivars which flower at least thrice in a year. Creation of variability in such cultivars, therefore, is significant for offering the unique advantage of year round production of chrysanthemum.

The Institute developed appropriate techniques for hybrid seed production of tomato and brinjal in northern India. Hybrid seed production was found to be more profitable in the net house (where the crop is vigorous, insect free, show longer stigma receptivity, pollen viability, higher fruit and seed yields and better seed quality) as compared to that in open field condition. In cauliflower, the problem of non-synchrony could be mitigated with the spray of GA_3 (250 ppm) and IAA (50 ppm) at different stages.

Brown spot of rice caused by *Bipolaris oryzae* is a major seed borne disease prevalent in all rice growing countries. Studies on the effect of 8 botanicals and bio-control agents on inhibition of the pathogen strains revealed that patchouli oil @ 1 per cent was most effective against four isolates, followed by citronella oil and lemongrass oil, respectively. Kalisena @ 4×10^8 cfu also resulted in effective control of *Bipolaris oryzae.*

The Institute also conducted studies on seed production technology of medicinal plants; seed quality testing and enhancement in medicinal plants; assessment of seed vigour; effect of seed priming on capsicum seedling emergence and vigour in nursery; effect of pre-sowing seed exposure to static magnetic field on growth of maize seedlings under soil moisture stress; and NMR relaxation studies during water imbibition in microwave treated seeds of fodder legume *Stylo seabrana*. At the Seed Production Unit of the Institute (Delhi) and the Institute's regional stations at Karnal, Pusa, Indore and Katrain, nucleus, breeder and IARI seeds of different varieties of cereals, pulses, oilseeds, vegetables and ornamental crops were produced under strict quality control. Apart from seed production, 28 rose saplings and 932 fruit plants were produced at the Seed Production Unit (Delhi). At the Regional Station, Karnal, about 4000 horticultural plants were produced.

Under the research on crop genetic resources, several genotypes of different crops were found to be suitable for disease resistance, quality and other economic traits. In wheat, two new resistance sources WBM 1587 (INGR No. 07009; IC 549931) and WBM 1591 (INGR No. 07010; IC 549932) developed by Tutikandi Centre of IARI Regional Station, Amartara Cottage, Shimla were registered with NBPGR as germplasm with diverse and new resistant source against stripe rust pathotype 46S119. In maize, one maize line (SC 7-2) for resistance source for maydis leaf blight (INGR 07025) was registered with NBPGR. Another line IC 549904 was deposited with NBPGR as a genetic stock for maydis leaf blight resistance.

In microbial genetic resources, forty-one new cyanobacterial isolates were added to the culture collections of the Institute.

In biosystematics and identification services, seven hundred sixteen (716) fungal specimens were accessioned in HCIO raising the total number of specimens to 47,335. Eight species of Hyphomycetes, viz., *Corynespora baliospermigena, C. clerodendri-viscose, C. nanospora, C. sapotacearum, C. xylosma-longifoliae, Cercospora prosopidicola, Cladosporium cycadacearum* and *Taeniolella sapindi* and 10 species of meliolaceous fungi, viz., *Amazonia elaeocarp, Irenopsis sidae, Meliola kanniyakumariana* var.*brahmgiriensis, M. palakkadensis, M. saliciicola, M. tabernaemontanae* var. *wrightiae, Asterina canthiigena, Asterostomella baliospermi, A. strombosiae* and *Sarcinella wrightiae* and two species of dematiaceous Hyphomycetes, viz., *Deightoniella mayeei* and *Dischloridium gangawanei* were proposed as new species. A new fungus, *Polyrostrata indica* gen.nov. was described from the stems of *Erianthus munja.*

The Indian Type Culture Collection (ITCC) was enriched by a new addition of 108 different fungal cultures.

Some noteworthy plant pathogens accessioned include *Fusarium fusarioides* from cumin, *Trichoderma citrinoviride* and *Metarrhizium anisopliae* from bamboo hopper, *Colletotrichum capsici* from turmeric, *Mucor hiemalis* from rice yellow stem borer, *Trichoderma fasiculatum* and *Fusarium equiseti* from brinjal, and *Sclerotium rolfsii* from saffron.

Four hundred twenty-nine (429) authentic fungal cultures belonging to different groups, viz., Zygomycetes (25), Hyphomycetes(156), Ascomycetes(17), Penicilli(46), Aspergilli (36), Coelomycetes(65) and Fusaria(84) were supplied.

Three hundred and thirty-five (335) cultures/specimens, mostly plant pathogens, post harvest pathogens, biocontrol agents and industrial fungi were identified. Some important fungi identified include *Phoma tropica* from *Dolichos lab lab, Stachybotrys atra* from cucumber seed, *Glomerella cingulata* and *Colletotrichum gloeosporoides* from castor, *Phoma glomerata* from *Ficus religiosa* and *Fusarium oxysporum* from cardamom.

Under the Insect Identification Service, 847 insect specimens were identified. *Camponotus sericeus* belonging to the *Camponotus (Orthonotomyrmex)* species group was found to possess the metapleural gland. This character is absent in most species of *Camponotus* worldwide, except for *C. gigas* from Indonesia and *C. thadeus* from Australia. Thus, it is the first report of the presence of metapleural gland in an Indian species of *Camponotus* and the third from the world. In Hemiptera, three type species, viz., *Tetroda histeroides*, *Ectomocoris quadriguttatus* and *Phalantus geniculatus* were redescribed with illustrations of their taxonomic characters.

Predominantly occurring plant parasitic nematodes from the rhizosphere of peach and apple in the northern hilly region were isolated. Detailed morphological studies led to the identification of three new species, one of the genus *Paratylenchus* from Uttarakhand and two of the genus *Xenocriconemella* from Himachal Pradesh, and Bhutan.

Three gene sequences of the ITS region of rDNA – one of indigenous entomopathogenic nematode species (Steinernema species Meghalaya strain Accession No. EF 219458) comprising 516 base pairs; and two of the bacteria (*Xenorhabdus indica* Accession No. DQ211718; and *Providencia vermicola* Accession No. EF192136) associated with *S. thermophilum* – were deposited with GenBank.

The National Nematode Collection of India (NNCI) was augmented with 22 type slides of newly described saprophagous nematode species (*Longidorella retenta, L. rotunda, L. rashidae, L. saadi, L. perplexa, L. pachyderma, L. papilloides* and *L. tunicata*) and 218 wet nematode suspensions, thus bringing its strength up to 2211 type accessions; and 3212 wet collections. After completing the database of type accessions, this year, a database of wet suspensions was designed, and 620 records entered.

One hundred fifteen (115) nematode specimens received from Uttarakhand, Uttar Pradesh, Jammu and Kashmir, Gujarat, West Bengal and Assam, were identified. The important species identified were: *Meloidogyne incognita, Rotylenchulus reniformis, Paratrichodorus christiei, Xiphinema elongatum, Pratylenchus thornei, Aphelenchus avenae, Aphelenchoides composticola, Steinernema carpocapsae, S. riobrave,* and *Heterorhabditis bacteriophora,* and some free living rhabditids *(Cephalobus persegnis, Mesorhabditis* sp.*).*

The Institute conducted several important studies on the effect of short-duration summer forage crops and phospho-gypsum-enriched urea (PGEU) on the productivity of succeeding aromatic rice; effect of organic and inorganic fertilizer management on the productivity of soybean-based cropping system; evaluation of quality *Brassica* genotypes under different sources and levels of nutrients and their residual effect on the succeeding cowpea; water economization in potato-based intercropping systems; performance of mustard as influenced by aqua-fertilization and fertility levels under rainfed conditions; performance of new wheat genotypes at normal and late sowing dates under irrigated condition; performance of new wheat genotypes at late and very late sowing dates under irrigated condition; comparative performance of irrigated, timely and late sown varieties under different sowing dates; performance of new wheat genotypes under irrigated saline and alkali conditions; evaluation of suitable wheat varieties under conventional tillage and zero tillage conditions; effect of seed treatment with *Azatobactor* and PSB culture on wheat; performance of wheat genotypes under different growing conditions; comparative evaluation of system of rice intensification (SRI) and conventional system under different agronomic factors for yield and quality of scented rice; and effect of transplanting date, nitrogen fertilizer, and spacing on seed yield of rice cv. Pusa 1460.

Under soil management, studies were conducted on long-term impact of rice-wheat and maize-wheat cropping systems on the stability of humus-carbon in the soil; sulphate sorption characteristics of acid soils of eastern India; stability of clay minerals in relation to pedogenic progression in different agro-ecosystems; ion exchange resin method for estimation of plant available soil phosphorus; soil biodiversity assessment for enhancing carbon sequestration and nitrogen cycling under different tillage systems and crop rotations; effect of mineral fertilizers and organic manure on the soil quality index and productivity under soybean-wheat cropping sequence; relative efficacy of soil and foliar application of iron in correcting iron deficiency under aerobically grown rice; effect of tillage, water and nutrient management practices on available micronutrient status of soil under rice-wheat and maize-wheat cropping sequences; influence of continuous irrigation with Yamuna water on soil chemical environment; screening of *Brassica* cultivars for their phyto-extracting ability; release of mineral nitrogen from sewage sludge and rice straw; effect of enriched paddy straw compost on nutrition of cowpea and soil health; effect of enriched composts on pearl millet; and dynamics of potassium release in soil fertilized with microbially treated waste mica and its uptake by Sudan grass.

Under water management, the Institute conducted meteorological studies on the application of CLIMGEN model in climate change investigations and development of drought indices for agricultural water management, besides studies on watershed, irrigation agronomy, pressurized irrigation, groundwater, aerobic rice cultivation, and water quality.

Under integrated nutrient management, studies were conducted on long-term effects of fertilizers and manures on crop productivity and soil fertility under maize-wheat sequence; integrated nutrient supply and management in pearl millet-mustard cropping system; characterization of rock phosphate-enriched pressmud compost and its effect on phosphorus use efficiency in pearl millet-mustard sequence; integrated nutrient management in pigeonpea-wheat system; development of basic data and soil test based fertilizer recommendations for pearl millet and mustard; integrated nutrient management in sweet corn; and effect of integrated N management in sole and intercropped cotton.

Under nutrient management, the studies covered the appraisal of multi-nutrient deficiencies in soils and their amelioration through site specific nutrient management; and nutrient management through organic sources in brinjal-based cropping systems.

Important studies were conducted on rice-wheat cropping system; orchard management practices; and protected cultivation technology.

Several farm related equipment, machinery and technology were developed or under development for optimizing crop production and reducing drudgery. A whole pulse grain polisher was developed for improving the appearance and physical quality of whole pulse grains. The Institute also developed a grain flaking machine to prepare flaked products from maize and *jowar*. An orange grading machine, which grades fruits on weight basis, is under development.

Under post harvest technology and management, an alternative method of regulation of ripening of mango by the use of methyl cyclopropane (1-MCP) was studied since it has unique capability of binding the ethylene that inhibits ripening. Other studies were on the role of 1-MCP on commercial CA storage of apples; effect of post-harvest treatment and packaging on the shelf life and quality of pointed gourd (*Trichosanthes dioica*), enhancing the shelf life of apples; use of black carrot anthocyanin as a potential colourant and functional ingredient; application of hydrocolloids in fruit juices for attaining cloud stability; preparation of GOG powder; dehydration of *methi* leaves; screening of new cultivars of carrot for dehydration; fruit cracking due to vivipary and its control; studies to reduce the spoilage caused by post-harvest diseases in apples; optimization of process parameters for the preparation of quick cook *dal*; correlation studies between various physical and physico-chemical characteristics of pigeonpea pulse; hydration characteristics of maize and sorghum; and physical properties of sorghum.

In microbiology, important studies were conducted on recycling of agricultural residues and their utilization in sustainable and organic agriculture; exploitation of microorganisms for crop production; molecular characterization of agriculturally important microorganisms; and exploration and exploitation of cyanobacterial genetic resource and *Azolla* for agriculture and industry.

The major studies concerned with environmental sciences were on developing weather-derivatives-based insurance products for adapting to climatic risks; global warming potential of agricultural soils; adaptation strategies to reduce GHG emissions from rice and wheat crops; establishment of research infrastructure for climate change studies; effect of high temperature on pollen germination of

wheat; effect of continuous increase in temperature on crop yield; effect of elevated CO_2 on crop yield; soil microbial community dynamics in response to temperature in different soil carbon scenarios; coping strategies of farmers against floods in rice-wheat ecosystem; establishment of *Jatropha* in degraded lands; economics of *Jatropha* cultivation under various conditions; utilization of *Jatropha* fruit and seed coat for bioremediation of lead, cadmium and chromium from aqueous solution; bio-ethanol from maize grain; physio-chemical characterization and alternative use of waste generated from ethanol production in agriculture; utilization of paper mill effluent in agriculture; impact of surface ozone on crop productivity; land-water resource degradation in two economically contrasting districts of NCR; assessment of decomposition of Bt cotton (MECH 162 +Bt) and its near isogenic line (MECH 162 -Bt) leaf residues and determination of persistence of Bt toxin in soil; and radiocesium desorption from soils as influenced by different extractants.

In crop protection, important findings were made by the Institute in plant pathology, entomology, nematology and agricultural chemicals.

In plant pathology, findings were made on fungal diseases affecting wheat, rice, maize, chickpea, urdbean, mungbean, pea, pigeonpea, rapeseed and mustard, vegetables, fruit crops, and large cardamom. Important studies conducted on bacterial diseases including legumes and vegetables. Research was also conducted on viral diseases leading to several important findings. The complete coat protein (CP) gene from 25 CTV isolates, and a 404-nucleotide (nt) fragment of 5 ORFIa variable region gene (positioned from 52 between 1074 and 1478 nt) were cloned and sequenced for determining genetic diversity. The complete genome of *Indian citrus ringspot virus* (ICRSV) infecting Kinnow mandarin of Hoshiarpur (Punjab)(ICRSV-H) and the complete genome of BSV from a banana (Poovan) isolate from Trichy were sequenced. 16S (1417 bp), 23S (247 bp) and 16S-23S intergenic spacer region (620 bp) of ribosomal DNA of greening bacterium {*Candidatus liberibacter asiaticus (Cla)*} in Kinnow mandarin (Ludhiana) were sequenced for the first time in India and showed maximum identity with the corresponding region of Cla sequenced from other countries. Genome organization and complete nucleotide sequence of the small (S) (AY871098) RNA segment of GBNV (mungbean isolate) were determined.

In entomology, insect pest management studies were conducted on cereals, pulses, oilseeds, soybean, cotton, and vegetables. Other studies covered biological control; insect physiology; and insect toxicology. In nematology, important studies were made on biodiversity, mechanism of resistance and nematode management. In agricultural chemicals, significant research was conducted on the development of natural and synthetic agrochemicals and their adjuvants; new synthetic products; risk assessment of pesticides, their environmental fate, and remedies; and improvement in safety and efficacy of pesticide formulations.

In weed management, studies were conducted on the effect of tillage and weed control practices on the performance of cotton; sequential application of metribuzin for weed management in soybean; integrated management of C*yperus rotundus* in soybean; evaluation and management of cross-resistance in *Phalaris minor* biotypes across Punjab and Haryana; integrated weed mangement practices in onion; and comparative efficacy of different herbicides on weed growth and productivity of direct-seeded rice.

Several significant findings were made by the Institute under basic and strategic research.

In plant biotechnology, studies were conducted on transgenic expression of a CMS associated gene inducing male sterility in *Arabidopsis thaliana*; Indian mustard (*Brassica juncea*) expressing β-farnesene synthase for repellence to mustard aphids (*Lipaphis erysimi*); isolation of a full length cDNA of mungbean lectin; transformation and regeneration of *Brassica juncea*; pigeonpea genomics; fine mapping of QTLs for salinity tolerance in rice variety CSR 27; pyramiding of additional bacterial blight resistance genes in *basmati* rice background; development of transgenic rice by the use of *AtDREB1A* gene; transgenic rice lines with blast resistance genes; molecular characterization of apple; and micro-propagation and improvement through tissue culture of fruit crops.

In biochemistry, the studies covered the isolation and characterization of *fad2-1* gene encoding ω-6 desaturase from soybean; expression of *DGAT* gene in *E. coli*; isolation and characterization of lysophosphatidic acid acyltransferase gene from *B. juncea*; isolation and characterization of differentially regulated genes under moisture stress in rice; and *in silico* analysis of a cDNA sequence encoding an antiviral protein (BBAP-II) from *Bougainvillea* x*buttiana* and its expression in *E. coli*.

In plant physiology, several important studies were made on the physiological constraints limiting productivity;

improvements in abiotic stress tolerance in crop plants through physiological approaches; post-harvest physiology of fruits, vegetables and flowers; characterization of crop responses to global climate change; *gamma* irradiation for altering plant responses, microbial growth and nutritional quality of agri-produce; effects of exposure of wheat seeds to *gamma* irradiation on the physiological and morphological traits; *gamma* irradiation effect on cotton fiber strength; and phytosiderophore as possible tool for biofortification of wheat with zinc and iron. The genetic studies conducted at the Institute covered the crops: wheat, rice, maize, pearl millet, chickpea, lentil and fieldpea, pigeonpea, *Brassicas*, cowpea, cotton, and soybean; and *Drosophila melanogaster*.

In agricultural physics, the studies covered soil physics; remote sensing and GIS; and agricultural meteorology.

Several important studies were conducted at the National Phytotron Facility of the Institute catering to the needs of the various divisions and other establishments of the Institute, and outside institutions.

In agricultural economics, the Institute conducted studies on the adoption and impact of resource conserving technologies on farm economy in Indo-Gangetic plains of India; labour migration and its impact on rural economy of Indo-Gangetic plains of India; marketing information system for horticultural commodities in India; impact of trade liberalization on Indian agriculture; study on peri-urban agriculture and its management in Delhi; food safety measures and their implications on India's horticultural exports; and co-integration of horticultural markets in India. In agricultural extension, studies were conducted on farming systems research and extension for sustainable development; assessment of socio-economic and environmental impact of agricultural technologies; enhancing the efficiency of extension organization; development of participatory extension methodology and intersectoral micro-plans; impact analysis of training programmes conducted under CAS in agricultural extension; evaluation capacity building in rural resource management; taking wheat cultivation technology to remote and tribal areas; and alleviating malnutrition through popularization of consumption of *durum* wheat. Under technology assessment and transfer, the Institute made several interventions to improve the productivity of crops in different agro-ecological regions, which also included several front-line demonstratons. The National Extension Programme in far off northern, southern, eastern and western parts of the country has been taken up by the Institute from *rabi* 2007-08 in collaboration with a few selected SAUs/ICAR institutes. The annual Pusa Krishi Vigyan Mela was conducted from February 24 to 26, 2007 on the theme "IARI – In the Service of Farmers". The *mela* was inaugurated by Shri Sharad Pawar, Hon'ble Union Minister of Agriculture, Consumer Affairs, Food and Public Distribution. The Institute also conducted several other extension related activities like off-campus exhibitions/field days, farmers' days, etc. The Institute's Agricultural Technology Information Centre (ATIC) continued to work as a 'Single Window Delivery System' for effectively providing products, services, technologies and information to different stakeholders.

The Institute's Krishi Vigyan Kendra at Shikohpur, Gurgaon continued to play a significant role in combating unemployment of rural youth through technological empowerment, and by improving the farmers' awareness and farm productivity through various TOT programmes. Several programmes were also undertaken by the Institute for empowerment of women and mainstreaming of gender issues.

The 45th convocation of the Institute was held on February 9, 2007. Dr. Mangala Rai, Secretary, Department of Agricultural Research & Education (DARE) and Director-General, Indian Council of Agricultural Research (ICAR), who was the chief guest, delivered the convocation address. On this convocation, 75 M.Sc. and 73 Ph.D. students were awarded degrees. Mr. P.N. Sivalingam (Plant Pathology) and Mr. Mridul Chakraborti (Genetics) were awarded the 'Best Student of the Year 2006' award for Ph.D. and M.Sc., respectively. The Institute also conducted several regular/short-term training courses. Agri-informatics and bio-informatics continued to receive the Institute's priority attention. The IARI Library continued to provide services to the students and the scientific community.

Several regular and *ad-hoc* publications were brought out by the Institute, both in English and Hindi, to disseminate information on the Institute's mandated activities. The Institute filed applications for 5 patents and signed 4 MoUs. The Institute also assigned 5 technologies to NRDC for commercialization.

Linkages and collaborations continued to exist with several national and international institutions.

1. CROP IMPROVEMENT

1.1 CEREALS

1.1.1 Wheat

1.1.1.1 Varieties released

Pusa 111 (HD 2932). A wheat variety Pusa 111 with wide adaptation was recommended for cultivation in late sown irrigated conditions of Central Zone and Peninsular Zone by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops. The variety having amber coloured, hard grain with high seed weight (43 g) and 12.5% protein content registered an average grain yield of 4.2 t/ha in Central Zone and 4.33 t/ha in Peninsular Zone. The variety possesses resistance against brown and black rusts (mainly due to minor genes), loose smut, powdery mildew and foot rot. It is early in maturity and possesses terminal heat tolerance.

HI 1544 (Purna). A bread wheat variety HI 1544 (Purna) was released during 2007 for cultivation under timely sown, high fertility, irrigated conditions of Central Zone. Despite being the earliest variety in heading and maturity compared to the checks, HI 1544 yielded 6.3 % higher than GW 190, and 7.9 % higher than Lok 1. It also gave equally good yield compared to GW 322 and GW 366. It saves irrigation water, a precious input in Central India, and helps in harvesting better yield even under limited irrigation availability. Its better grain appearance, high hectolitre weight, high protein and high sedimentation value, and medium bold grain (compared to that of checks) ensures good *chapati* making quality and better market price. In addition to very high field resistance to leaf and stem rusts, HI 1544 has seedling resistance to all the pathotypes of the two rusts, including the recently reported stem rust pathotype 58G13. Lok 1 and GW 322 have shown susceptibility to most of the pathotypes of leaf rust race 77-complex. HI 1544 will enrich genetic diversity under wheat cultivation and avoid build up of rust inoculum at secondary focus of infection.

HI 8663 (Poshan). A *durum* wheat variety HI 8663 (Poshan) was released during 2007 for cultivation under timely sown, high fertility irrigated conditions of Peninsular Zone. The *durum* wheat variety HI 8663 (Poshan) has high nutritional value. It can serve as a naturally bio-fortified health food and can be used for dual purpose**,** i.e., both for nutritive *chapati* and for fast food preparations for improving nutritional security, as it contains a high and stable β-carotene, high sedimentation value, high protein content and high levels of micronutrients, particularly iron and zinc. It is a novel genotype characterized by excellent grain quality with high and stable yield. It has high levels of field resistance to stem and leaf rusts and to Karnal bunt, compared to checks. It

A field view of wheat variety HI 1544 (Purna) and its seeds

A field view of wheat variety HI 8663 (Poshan) and its seeds

exhibited a high degree of adult plant resistance to two highly virulent stem rust pathotypes 40A and 117-6. In contrast, HI 8498 and Lok 1 showed susceptibility to stem rust pathotype 117-6, one of the most virulent stem rust pathotypes on *durum* wheats. HI 8663 is also resistant to 58G13, a new stem rust pathotype found in Karnataka with high virulence on *durum* wheats, ensuring protection to timely sown wheat cultivation in the Peninsular Zone. Moreover, HI 8663 has overall resistance to leaf rust as it is showing seedling resistance to all the leaf rust pathotypes including 12-5, one of the most virulent pathotypes on *durum* wheat. Its cultivation will ensure the production of high quality *durum* wheat for enriching nutritional security in the country.

1.1.1.2 Entries in pipeline

The following improved lines of wheat and triticale were under testing in coordinated trials:

Trials	Entry name/numbers
Advance Varietal Trials (AVTs)	HD 4717 (Final year, AVT II), AVT 1: HD 2969 (NWPZ), HD 2993, HD 2996 (SHZ), HD 2967 (NWPZ and NEPZ), HD 2978 (PZ and CZ), HD 2983(NEPZ), HD 2992 (SHZ), HD 2997 (Salinity), HD 2982, HD 2985, HD 2986, HD 2987, HD 2989, and HD 4719
National Initial Evaluation Trials (NIVTs)	HD 2999, HD 3000, HD 3001, HD 3005, HD 3008, HD 3011, HD 3015, HD 3018, HD 2997, HD 2998 (NIVT-1A), HD 3002, HD 3003, HD 3004, HD 3006 (NIVT-1B), HD 3012, HD 3017, HD 3020, HD 3021 (NIVT-3), HD 3010, HD 3013, HD 3014, HD 3016, and HD 3019, HD 4720, HD 4721, HD 3007, HD 3009, HD 3022
AVT Triticale	DT 173
NIVTs Triticale	DT 178, DT 179, DT 180, DT 181, DT 182, DT 183 and DT 184
Common Varietal Trials	96
Station Trials	567

The wheat lines HW 5204 and HW 5205 were in final year of testing under Southern Hills Zone. HW 5205 is likely to be proposed for identification in the ensuing wheat workshop on the basis of its performance. Other promising genotypes HW 5207, HW 5208 and HW 5209 were in AVT-II stage.

HW 1095, a dwarf *dicoccum* developed at Regional Station, Wellington using irradiation technique was in final stage of evaluation in Spl. trial on *dicoccum.*

A high yielding disease resistant wheat variety HW 5207-1 developed at IARI Regional Station, Wellington was promoted to NIVT 2 (All India) testing and being evaluated across India.

High yielding disease resistant dwarf *dicoccum* wheat varieties HW 1096 and HW 1097 were entered as new test entries in IVT spl. *dicoccum* trials.

Nearly 120 disease resistant high yielding wheat lines were being tested in Station trials at IARI, New Delhi; Indore; Shimla; RAU, Jaipur; ARS, Niphad, etc., under the shuttle breeding programme.

HS 490, a consistent performing genotype was promoted to the final year of testing under late sown and restricted irrigation conditions, while two facultative genotypes, HS 491 and HS 492 were promoted to the final year under early sown and rainfed conditions of Northern Hills Zone.

Two genotypes, HS 502 under late sown and restricted irrigation conditions and HS 490 under summer season of very high altitude were promoted to the second year of testing in Coordinated Trials of Northern Hills Zone. In addition to these, 11 genotypes, viz., HS 504, HS 505, HS 506, HS 507, HS 508, HS 509, HS 510, HS 511, HS 512, HS 513 and HS 502 were included in All India Coordinated Trials for further evaluation under different production conditions of Northern Hills Zone on the basis of high yield potential and high degree of rusts resistance.

Durum wheat variety HI 8671 has completed three years of testing under Coordinated Trials and is likely to be identified for cultivation under timely sown, high fertility and irrigated conditions of Central and Peninsular Zones.

The following wheat genotypes are being tested in various Advanced Varietal Trials:

Genotype	Zone	Cultivation conditions
Durums		
HI 8680	Peninsular	Timely sown, high fertility, irrigated
HI 8681	Peninsular	Timely sown, high fertility, irrigated
HI 8682	Peninsular	Timely sown, high fertility, irrigated
Bread wheats		
HI 1552	Central	Timely sown, high fertility, irrigated
HI 1556	Peninsular	Late sown, high fertility, irrigated

Ten *durum* genotypes, viz., HI 8690, HI 8691, HI 8692, HI 8693, HI 8694, HI 8695, HI 8696, HI 8697, HI 8698 and HI 8699; and eight bread wheat genotypes, viz., HI 1557, HI 1558, HI 1559, HI 1560, HI 1561, HI 1562, HI 1563 and HI

1564 were tested in various national initial varietal trials during 2007-08.

1.1.1.3 Breeding material

Different populations in varying states of genetic stability were raised for exercising selection as per the different objectives. A total of nearly 8000 segregating progenies (F_2-F_6) were handled for the purpose. Nearly a third of these were planted under artificial epiphytotic conditions of leaf rust for desirable plant type coupled with resistance during the crop season. Nearly 1500 fresh crosses and backcrosses involving identified donors/recurrent parents for various traits were effected. Summer nursery facilities at Lahaul and Wellington were also availed for advancing the segregating generations and screening for rusts.

The following breeding material after selection for desirable grain characteristics in the laboratory was evaluated in the field. This material was generated from straight crosses, three-way crosses and limited backcrosses involving bold earhead, plant type and diverse germplasm lines for yield components and disease resistance.

Generation	No. of families/crosses
F_5-F_7	877 families
F_4	256 families
F_3	216 families
F_2	37 crosses
F_1	160 crosses
● Crosses attempted (F_0)	146 crosses

1.1.1.4 Development of new varieties carrying specific rust resistance genes through back-cross programme

The following genes were taken for introgression: leaf rust genes *Lr35, Lr39, Lr40, Lr41, Lr42, Lr44* and *Lr45*; stem rust genes *Sr25, Sr26, Sr27, Sr36, Sr33, Sr39, Sr40, Sr41,* and *Sr44* to combat threat from the new pathotype Ug99 virulent on *Sr31*; and stripe rust genes *Yr10, Yr15, Yr16*.

The lines carrying *Secale cereale*-derived leaf rust gene *Lr45* and *Aegilops speltoides*-derived linked gene *Lr35+Sr39* in the background of C 306, HD 2329, HD 2285, HD 2402, HD 2687, HP1205, Lok 1, PBN 51, PBW 226, RAJ 3077, WH 147 and WH 542 were finally picked up at BC_3 F_2 stage during *rabi* 2007-08 and simultaneous molecular confirmation was also carried out. The BC_2 and BC_3 crosses for introgression of *Lr32, Lr41, Lr42* and *Lr39* were effected.

Pyramiding of *Sr24* and *Lr19+Sr25* with *Sr26* and *Sr27* was completed in more than 9 popular Indian bread wheat cultivars at BC_2 F_2 stage and simultaneous molecular confirmation carried out.

Pyramiding of *Yr10* and *Yr15* with lines carrying *Lr35, Lr39, Lr40, Lr41, Lr42, Lr44 and Lr45* was at BC_2 stage

To combat the threat from Ug 99 race virulent on *Sr31*, the introgression of effective stem rust genes *Sr25, Sr36, Sr26, Sr27, Sr38, Sr39* in the back ground of C 306, HD 2009, HD 2285, HD 2402, HD 2687, J 24, Kalyansona, Lok 1, MACS 2496, NI 5439, PBN 51, PBW 226, Raj 3077 UP 262, WH 147, and WH 542 was completed and the stock carrying *Sr36, Lr19, Sr25, Yr15* and *Pm6* constituted in the spring wheat background can be utilized as a genetic stock for the breeders.

1.1.1.5 Behaviour of quality traits in *durum* wheat

The β-carotene content in HI 8627, and V 21-23, an advance generation *durum* line, under early, timely and late sown conditions clearly indicates a linear relationship with temperature. β-carotene was the highest under late sown condition. The two varieties behaved differently for SDS value. In HI 8627, SDS improved linearly from early sown to late sown conditions whereas V 21-23 gave the best sedimentation values in early sown condition followed by timely and late sown condition. High protein content was observed in late sown condition showing a similar and parallel trend to β-carotene content.

(Note: The Central Institute of Agricultural Engineering, Bhopal is actively collaborating with the Institute in evolving widely adapted wheat varieties for central India and popularizing IARI wheat varieties by laying out field demonstrations).

1.1.2 Rice

1.1.2.1 Variety released

Improved Pusa Basmati 1 (Pusa 1460). Pusa Basmati 1, the most widely cultivated *basmati* rice variety for over a decade suffers badly from susceptibility to bacterial blight (BB). In collaboration with NRC on Plant Biotechnology, IARI, New Delhi, marker assisted pyramiding of BB resistance genes in Pusa Basmati 1 was undertaken integrating effectively

Improved Pusa Basmati 1

the marker assisted foreground for BB resistance genes *xa13* and *Xa21* and background selection for hastening the recovery of recurrent parent genome and compressing the breeding cycle. Improved Pusa Basmati 1 was released by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops in April 2007. Its important features are: (i) it carries genes *xa13* and *Xa21* imparting high degree of resistance to BB, (ii) it has recorded an average yield of 6.0-6.5 t/ha in farmers' fields with a market paddy price of Rs. 24,000/t, giving a gross return of Rs. 1,44,000/ ha, (iii) it has strong aroma and less than 5% chalky grains as compared to mild aroma and 15-20% chalky grains in its recurrent parent Pusa Basmati 1, and (iv) its cultivation will reduce the pesticide consumption and thus pesticide residue in grains, which is important considering the fact that *basmati* rice brings approximately Rs 3,000 crores of foreign exchange annually to the country, and keeping international standards of food safety for both domestic and export market is of paramount importance.

1.1.2.2 Promising entries in station trial

A station trial consisting of 15 entries, 13 newly developed NPT based *basmati* restorer lines and two checks, namely, Pusa Basmati 1and Pusa Sugandh 5 was conducted. Three entries (ADT- SPS 6, ADT- SPS 7 and DSPS 37) showed significantly higher yield (23.56-33.00%) compared to that of the best check Pusa Sugandh 5. In a non-*basmati* trial, out of 15 entries evaluated, three entries, ET 2-12, ET 2-13 and DSPS 99 were found promising, and superior to the check Pusa 44 (18.78- 21.73%).

Yield performance of non-*basmati* lines in station trial during *kharif* 2007

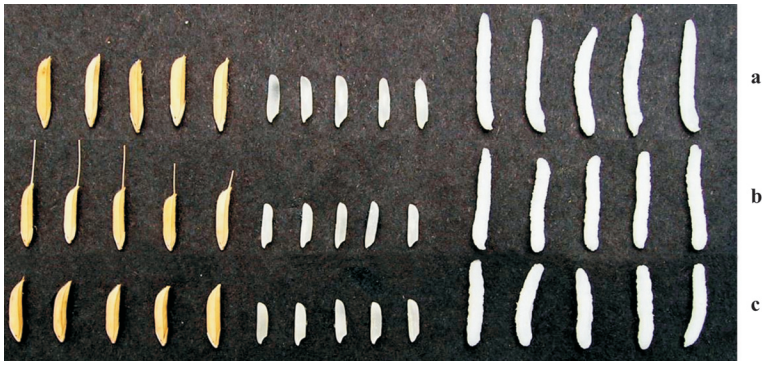
Genotype	Yield (kg/ha)	per cent superiority over check
ET 2-12	7000	21.73
ET 2-13	6950	20.86
DSPS 99	6830	18.78
Pusa 44	5750	-
CD	720	-

1.1.2.3 Advanced breeding lines

Approximately 1500 single plant selections (F_3-F_5) across 80 different cross combinations were made with a focus on improvement of quality and resistance to BB. All these single plant selections are under evaluation for quality parameters such as grain dimensions, L/B ratio, length and breadth after cooking, elongation ratio (ER) and ASV.

1.1.2.4 Spread of IARI developed *basmati* rice

Considering the consumer's preference for long grain *basmati* rice, efforts were intensified for developing varieties with increased kernel length. Adopting selective intermating approach in segregating populations and rigorous screening for grain and cooking quality characters, Pusa 1121 having extra long slender grains and exceptionally high kernel elongation ratio was developed and released in 2003 by the Delhi State. Since its release in 2003, the area under cultivation of Pusa 1121 has been on the increase. During *kharif* 2007, it occupied nearly 60% of the total *basmati* rice area. The variety has been adopted largely by the farmers of Punjab. Important features of this variety are: (i) very high elongation ratio (ER=2.5), cooked kernel length up to 20-25 mm, (ii) very high volume expansion (up to 4 times), (iii) matures in 140 days with an average yield of 5.0 t/ha with a paddy price of Rs. 22000/t, giving a gross return of Rs. 1,10,000/ha, (iv) fetches $100/t more than the traditional *basmati* rice in the export market; and



Rough, milled and cooked rice of Pusa 1121 (a) and Improved Pusa Basmati (b) as compared to Taraori Basamati (c)

(v) suited for low input conditions, a good candidate for organic farming.

1.1.3 Barley

BHS 380, a hulled genotype developed by the Tutikandi Centre of the Regional Station, Amartara Cottage, Shimla, performed well under both grain as well as dual purpose trials and was promoted to the second year of testing under both these conditions. Five genotypes, viz., BHS 382, BHS 383, BHS 384, BHS 385 and BHS 386 were included in All India Coordinated Barley Trials for further evaluation for both grain as well as dual purpose quality.

1.1.4 Maize

1.1.4.1 Entries in coordinated programme

During *kharif* 2007, four entries qualified for advancement to the next stage of testing - two (AH 31021 and ANEP Comp. 04) in AET 2nd year and the other two (AH 56191 and AH 5506) in AET 1st year. In general, the productivity of the new AH entries ranged from 4.0 t/ha to 8.0 t/ha in different zones despite belonging to early maturity. In IET, while AH 56191 was superior to both the checks across all the zones to the extent of over 60% (and 36 % overall), high performance of AH 5506 was more specific in the zones IV and V. In AET-I, the hybrid AH 31021 was superior to both the checks in zone I. On the other hand, new composite ANEP Comp.04 outyielded both the checks in Zones III and V, with a potentiality of 4.0-8.0 t/ha, despite maturing early.

1.2 MILLET

1.2.1 Pearl Millet

1.2.1.1 Hybrids and composites in coordinated trials

Hybrids. A hybrid Pusa 768 (MS 411 A x PPMI 69) was promoted from IHT II to AHT II A, and another hybrid Pusa 770 (MS 549 A x PPMI 295) was promoted from IHT II to AHT II B, for the 2nd year of testing during *kharif* 2007. Four new hybrids, MS 576 A x PPMI 964, MS 411 A x PPMI 964, MS 841 A x PPMI 493 and MS 411 A x PPMI 295 out yielded the best check Pusa 605 by 18-25% and were included in Initial Hybrid Trial (IHT II) conducted by AICPMIP for the first year of testing to be done during *kharif* 2007.

Composites. A high yielding composite population MP 443 (PPMP 579) that performed well in A_1 Zone in Advance Hybrid Population Trial completed 3 years of testing. MP 443 out yielded the popular checks CZP 9802, PUSA 266 and ICTP 8203 by 27.9%, 29.1% and 32.7%, respectively, and also showed good resistance against downy mildew disease. The identification proposal for release of this composite is being submitted in the coming workshop. Pusa Composite 612 (MP 480) performed well in initial population trials and was promoted to the second year of testing in three different trials conducted during *kharif* 2007 [AHPT A_1 (for Zone A_1), APT A (for Zone A) and APT B (for Zone B)]. A new population, viz., Pusa Composite 621 was included in the initial population trial (*kharif* 2007) of AICPMIP for the first year of testing.

A total of 219 new hybrids were generated and evaluated involving different sets of CMS and restorer lines for their preliminary evaluation and confirmation at the Delhi location in initial and advanced station trials. Similarly, six new OPV composites were also developed.

1.3 FORAGE CROP

1.3.1 Forage Sorghum

Two single-cut entries of forage sorghum, viz., PC 1002 and PC 1003 were promoted to the final year of testing based on their superior performance in the All India Coordinated Research Programme. Of the two genotypes, PC 1003 performed better. Based on the mean performance in both the zones of the country, PC 1003 was ranked first for green fodder yield (40.85 t/ha) as well as dry fodder yield (15.71 t/ha) in comparison to the checks HS 308 (GFY 38.66 and DFY 13.97 t/ha) and CSV 15 (GFY34.67 t/ha and *DFY* 13.62 t/ha). Its plant also exhibited good amount of protein (8.53%), protein yield (0.88 t/ha), *in vitro* dry matter digestability (IVDMD) value (47.6%) and HCN (77.6 ppm).

1.4 GRAIN LEGUMES

1.4.1 Chickpea

1.4.1.1 Varieties in pipeline

BG 5028, a *desi* bold seeded variety, and BG 5023, a bold seeded *Kabuli* variety, are under agronomic evaluation for their identification by IARI Variety Identification Committee for NCR region.

A bold seeded *desi* variety BG 2065 was promoted to AVT-II in CZ for late planting based on its superior performance in All India Coordinated Trials.

BGD 134 and BGD 135 developed at the Centre for Pulses Improvement, Dharwad are being evaluated in IVT (*Rainfed*) under AICRP on Chickpea.

1.4.1.2 Entries contributed for all India multi-location testing

A total of 18 promising entries, which were selected on the basis of their superior performance in advanced trials, were contributed for multi-location testing in all India trials during 2007-2008.

Chickpea entries in coordinated trials

Name of trials	Entries	Pedigree
IVT-*Desi*	BG 2073 BG 2074 BGM 561	(BGD 72 x BG 361) x BG 256 BG 1051 x PUSA 391
IVT- Bold	BG 2075 BG 2076 BG 2077	(SBD 377 x BG 1054) x (BG 391 x SBD 377) (SBD 377 x BG 1048) x BG 1032 (SBD 377 x Pusa 256) x Pusa 362
IVT- Late	BG 2078 BG 2079	(SBD 377 x Pusa 1053) x Pusa 256 (SBD 377 x Pusa 256) x (BG 1032 x SBD 377)
IVT-Rainfed	BG 2080 BG 2081 BGM 556 BGM 562	(SBD 377 x BG 1048) x (SBD 377 x Pusa 256) (Pusa 1053 x BG 1066) x SBD 377
IVT-Kabuli	BG 2082 BG 2083 BG 2084	BG 1073 x BG 1080 (BG 1048 x BG 1073) x (BG 1083 x BG 1090) BG 1048 x BG 1073
IVT- *Kabuli* Extra bold	BG 2085 BG 2086 BG 2087	(BG 1082 x BG 1048) x (BG 1090 x BG 1083) (BG 1082 x F_7 843) x (BG 1083 x BG 1091) (BG 1048 x BGD 70) x (BG 1082 x BG 1090)

1.4.1.3 Populations derived through mutation breeding

Three *desi* (ICC 6101, ICC 1581 and BG 362) and two *Kabuli* (BG 1053 and BG 1088) varieties of chickpea were treated with chemical mutagens (EMS, MMS, SA) and three *desi* (ICC 6101, ICC 1581 and BG 362) and two *Kabuli* (BG 1053 and FGK 97) varieties were irradiated with gamma-rays for mutant analyses in the field. One thousand one hundred fifty single plant progenies consisting of nine chickpea treated varietal selections (after evaluating yield and other traits) were sown as M_2 progenies during *rabi* 2007-08 along with nearly 2000 other single plants selections ranging from M_3 to M_5 mutant segregating generations.

1.4.2 Mungbean

1.4.2.1 Entries in pipeline

A number of promising mungbean genotypes were entered in different trials across different zones in the country.

Mungbean entries in pipeline

Season	Trial	Zone	Entry
Kharif	AVT I	NHZ	Pusa 0671, Pusa 0672
Kharif	AVT I	SZ	Pusa 0671, Pusa 0672
Spring Summer	AVT I	NEPZ	Pusa 0731
Spring Summer	AVT I	CZ	Pusa 0732
Spring Summer	IVT	All Zones	Pusa 0831, Pusa 0832

1.4.3 Fieldpea, and Lentil

1.4.3.1 Entries in pipeline

A number of promising fieldpea and lentil genotypes were entered in different trials across different zones in the country.

Promising fieldpea and lentil entries in pipeline

Fieldpea		
Trial	**Zone**	**Entries**
IVT Tall	All Zones	DMR 59, DMR 60
AVT I Dwarf	NWPZ	DDR 80
IVT Dwarf	All Zones	DDR 81, DDR 82, DDR 83, DDR 84
Lentil		
Trial	**Zone**	**Entry**
IVT Small seeded	All Zones	L 4582, L 4583
IVT Bold seeded	All Zones	L 4691, L 4692
IVT Extra early	All Zones	L 4695, L 4696
AVT I Extra early	Central Zone	L 4688, L 4689

1.4.4 Pigeonpea

1.4.4.1 Variety in coordinated trial

Pusa 2007, a pigenonpea variety developed by reconstituting the released variety Pusa 855 (widely adapted for NWPZ), and having better agronomic traits as compared to those of Pusa 855, was entered in IET of all India coordinated trials.

1.4.4.2 Evaluation of segregating generations

F_2 generation of 9 crosses, F_3 generation of 11 crosses and F_4 generation of 4 crosses of early group,

and F_3 generation of 20 crosses and F_4 generation of 7 crosses of long duration genotypes were evaluated. One thousand and sixty F_5 and 125 F_6 generation progenies of inter-specific cross *C. scarabaeoides* x Pusa 33 were also evaluated to identify superior genotypes with respect to development of superior high yielding restorer genotypes. One thousand single plant progenies were selected.

1.4.4.3 Hybrid trials

Fifty-nine hybrids along with their respective parents were evaluated in two trials in order to identify heterotic cross combinations for seed yield and its components. Highly heterotic cross combinations, viz., 07-2 x 07-7, 07-2 x 07-10A, 07-3 x 07-4, 07-6 x 07-7, 07-6 x 07-10 and 06-1 x 06-2, were identified.

1.5 OILSEED CROPS

1.5.1 *Brassicas*

1.5.1.1 Variety released

LES 1-27 (Pusa Mustard 21). A single zero (low erucic acid) quality variety of Indian mustard was released and notified by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops for Zone-II of India comprising Rajasthan, Punjab, Haryana, plains of Jammu and Kashmir, Delhi and western UP. The average seed yield of this variety is 2.1 t/ ha.

LES 1-27 (Pusa Mustard 21)

1.5.1.2 Variety identified

LET 18 (Pusa Mustard 24). A single zero (low erucic acid) quality variety of Indian mustard LET 18 (Pusa mustard 24) was identified for Zone-II by the Varietal Identification Committee.

1.5.1.3 Entries in pipeline

A number of promising mustard genotypes were entered in different trails.

Advanced mustard entries in pipeline

S. No. Name of trial	Entry
Brassica juncea	
AVT- I toria/early mustard	NPJ 112, EJ 17
IVT-toria/early mustard	NPJ 117, EJ 19
IVT-timely sown irrigated mustard	NPJ 116, HYT 1
AVT - I late sown mustard	NPJ 113
IVT - late sown mustard	NPJ 118
IVT quality mustard	LET 5, LET 14-1
Brassica carinata	
IVT-Karan Rai	BCS 3, BCS 4
National disease nursery for stem rot	BCS 3, BCS 4, NPC 12, NPC 16, NPC 17
Promising lines for aphid resistance	DLSC 1

1.5.1.4 Pre-breeding

Four Indian mustard entries for resistance to *Alternaria* blight, five for resistance to white rust and two for stem rot resistance in the respective nurseries including two entries in nursery for aphid tolerance and seven lines for abiotic stresses tolerance were contributed to AICRP on Rapeseed and Mustard Trials at national level. In addition, with an objective on prebreeding for genetic enhancement of stocks for traits like yield contributing characteristics, tolerance to early and late stage temperatures, combining ability for yield, quality oil, white rust resistance and *Alternaria* blight resistance, 239 crosses involving crosses from within and among the different species of oilseed *Brassicas* genera were attempted.

1.5.1.5 Breeding material

One hundred and twenty-four fresh crosses were attempted to supplement the breeding material comprising 1288 segregating and 127 fixed populations on which various

selection strategies were practised. Forty-nine F_3 and F_4 families were raised for low erucic acid traits and 28 F_2 and F_3 populations for double zero traits. Fifteen lines suited for early sowing in September and maturing before December (<100 days) were identified to replace low yielding *toria (B. rapa).* These will be tested and developed further. Amongst the timely sown breeding material, 58 F_5 derivatives from 28 crosses and 48 F_6 derivatives from 20 crosses showing a high degree of tolerance to high temperature on the basis of initial germination and seedling survival were shortlisted for further testing.

1.5.2 Soybean

1.5.2.1 Entries in the pipeline

Hybridization. Sixteen crosses were made in 4 combinations for charcoal rot resistance, yield and quality. Eleven new crosses were made for draught resistance.

Breeding material. The breeding material comprising 6 F_1's, 11 F_2's, 12 F_3's, 20 F_4's, 10 F_5's and 400 single plant progenies were evaluated. Six F_3 and F_4 single pod bulks were screened under rainfed conditions.

1.6 FIBRE CROP

1.6.1 Cotton

1.6.1.1 Entries in coordinated trials

Advanced varietal trial (Br 04a). Genotype Pusa 72-9-37 was promoted to AICCIP advance trial Br 04(a) for multi-location testing in Central Zone under irrigated conditions. It showed the highest seed cotton yield, tolerance to jassid and high ginning out-turn of 37%. It is also resistant to *Cotton leaf curl virus* disease.

Initial varietal trial (Br 02 a and b). Pusa 57-6 and P 21-15 were entered in AICCIP trials, Br 02 (a) and (b), respectively, for multi-location testing under irrigated and rainfed conditions, respectively. Both these genotypes have tolerance to jassid and high fibre strength.

Entries in technology mission on cotton (TMC) trials. Pusa 1752 and Pusa 1001 were entered in TMC trials to evaluate their suitability for mechanical harvesting.

1.6.1.2 Entries in station trials

A total of 17 promising strains, 22 high fibre strength lines, and 38 F_5 lines were evaluated in station trials.

1.6.1.3 Breeding material

Twenty crosses in F_2 generation and 15 in F_3 generation, besides 28 in F_3 generation supplied by CICR, Nagpur, were evaluated in large plots and single plant selections were made based on yield and important components.

1.6.1.4 Evaluation of cotton fibre quality

Cotton fibre quality was evaluated in promising breeding material using High Volume Instrument (HVI). Genotypes BS 66, F 2178, P 218-1, P 70-7-P1 and NH 630 were found promising for high yield and superior fibre quality. The genotype P 1102 gave the highest cotton (2.89 t/ha) and lint (0.99 t/ha) yields, high fibre length (30.9 mm) and high fibre strength of 27.9 g/tex with micronaire value of 4.5, while the highest fibre strength of 31.6 g/tex was observed in P 54-2. The overall quality of *desi* cotton was poor.

1.7 VEGETABLE CROPS

1.7.1 Cole Crops

1.7.1.1 Cauliflower

In the mid-late group, a cauliflower variety, DC 76 was identified for release through AICRP (VC) group meeting. Another variety DC 5 was found promising for December-January maturity, based on its compact white curds. Among early hybrids developed by using CMS line, DCH 3 (28.5 t/ha) and DCH 9 (29.1 t/ha) were found more promising than the check PES (25.0 t/ha). Similarly, 3 hybrids, viz., DCH 801 (49.0 t/ha), DCH 804 (45.0 t/ha) and DCH 814 (43.0 t/ha) were found to be superior to the check Pusa Sharad (37.5 t/ha). The other promising hybrid combinations in the group were CH 501, H 171, H 922, H 939, H 940, H 954 and H 971. For resistance breeding to downy mildew and black rot, 15 recombinant inbred lines (RILs) and 9 near isogenic lines (NILs) were advanced to third selfing stage for developing these as mapping populations.

Sterile cytoplasms from *Brassica canariance, Brassica tournefortii,* and *Brassica oxyrhina* were attempted by using embryo rescue technique in order to create diverse sterile cytoplasms in *Brassica oleracea* background for exploiting them in hybrid combinations.

In late (snowball) group of cauliflower, 50 new hybrid were developed using three CMS lines, Sera K I, Sera K 25 and Call B I. Consistent superiority for yield was found in four hybrids, viz., KTH 44 (24.2 t/ha), KTH 28 (24.0 t/ha),

KTH 40 (23.2 t/ha) and KTH 22 (22.7 t/ha) with 35%, 34%, 29% and 26% economic heterosis, respectively, besides showing superiority for other horticultural traits. Two new CMS based hybrid combinations KTH 50 (26.0 t/ha) and KTH 47 (25.2 t/ha) showed promise. Two entries, viz., KTH 1 (20.84 t/ha) and KTH 2 (22.83 t/ha) under AICRP (VC) in AVT-II trial gave 16% and 20% higher yield compared to that of the check. Back cross (BC_1) progenies were advanced to transfer CMS system into 10 promising genotypes after making selection for superior horticultural and reproductive traits. New cross combinations were made to transfer CMS in other 5 genotypes. Selections, namely, KT 16 (21. 8 t/ha) Sel 26 (21.5 t/ha), KT 22 (20 t/ha) and, KT 9 (19.3 t/ha) were found promising for yield contributing and horticultural traits. The lines, viz., KT 2, SR 05, KT 2587 and KT 187 developed through hybridization were found to be multi-resistant to black rot, *Sclerotinia* rot and downy mildew under artificial inoculated conditions at seedling stage. In mid maturity group of cauliflower, selection DC 76 (28. 6 t/ha), Himlata 1 (32.3 t/ha) and Pusa Sharad (33. 6 t/ha) and Hybrid 91 (34.8 t/ha) gave superior yields during summer rainy season in the hills. Seventy-six lines segregating generations/selections including CMS lines along with the respective maintainers were maintained after selection. Four new lines were collected and being maintained.

1.7.1.2 Cabbage

Evaluation of 24 SI based hybrids of cabbage revealed the superiority of KCH 19 (48.6 t/ha) followed by KCH 9204 (47.4 t/ha) and KCH 92 (44.8 t/ha) for yield over the standard check (41.9 t/ha). However, for reduced frame size, hybrid KCH 9836 was found to be promising. KCH 921 was found to be the earliest in maturity (58.5 days). Cabbage hybrid KCH 5 being tested in the AICRP (VC) was promoted to AVT-II. It gave a yield of 47.6 t/ha at IARI Regional Station, Katrain. Among the nine promising selections of cabbage evaluated, C 6 was found the most promising for higher yield and smaller frame size.

Improved source of Ogu CMS was transferred to ten promising lines/varieties of cabbage. Twelve F_2's, 4 varieties and 5 F_1's were subjected to artificial screening against DBM in polyhouse conditions. A total of 13 plants were selected in 8 F_2's (two plants each in crosses of C 8 x 204, GA x 204, C.No.8 x MR-1, MR-1 x C- 8 and 83-1 x MR-1 and one plant each in POA x 208, 83-6 x 204 and GA x MR-1).

1.7.1.3 Knol- khol

Knol-khol variety KS1 was entered in the AICRP (VC) trials for its multi-location testing. It yielded 43% higher than the standard check in the IET at IARI Regional Station, Katrain.

1.7.2 Cucurbitaceous Crops

1.7.2.1 Bottle gourd

In bottle gourd, the earlier released variety Pusa Santushti (Sel P 6) for NCR, Delhi was identified and recommended by XXVI AICRP (VC) Group meeting held at Bhubaneswar for commercial cultivation in Zone IV and Zone VII. It was also observed to be promising for setting fruits under low temperature (10-12 °C night temperature) as well as high temperature (35-40 °C night temperature). The variety was also superior in nutritional values.

1.7.2.2 Ash gourd

Two promising selections DAG 4 and DAG 6 developed earlier were evaluated under AVT-I and found to yield higher than the check both in summer and *kharif* seasons. They gave 44.5 tonnes and 47.0 tonnes yields/ha, respectively during *kharif* season. Both were earlier in maturity than IVAG 90 and PAG 71 (checks). Out of 36 F_1 hybrids tested under large scale yield trial, two promising hybrids DAGH 16 and DAGH 46 gave average yields of 57.50 t/ha and 52.00 t/ha, respectively, which were 38.0% and 30.5% higher than that of the check Pusa Ujwal, respectively. They were also earlier (2-3 weeks) in maturity than the check. The earlier released variety Pusa Ujwal for NCR, Delhi, performed best under AICRP trials and was identified by AICRP (VC) group meeting for cultivation in zone VIII.

A recently released improved variety of ash gourd Pusa Ujwal

1.7.2.3 Bitter gourd

A white fruited promising selection DBTG 1 was observed under large scale yield trial. It gave 16.0 t/ha yield which was 10.0% higher than that of the check Pusa Do Mausami. The best performing F_1 hybrids based on yield per plant were DBGY 201 × Priya (3.64 kg), DBGY 201 × DVBTG 5-5 (3.59 kg) and DBGY 201 × Pusa Do Mausami (3.07 kg). They showed 126.41%, 123.29% and 124.17% heterosis, respectively over that of the standard check Pusa Do Mousami.

The segregation for gynoecism in F_2 generation was observed to be in 3:1 (monoecious *vs.* gynoecious) ratio which indicated that gynoecious sex form in bitter gourd is controlled by a single recessive gene based on 4 F_1 hybrids.

Thirty-two genotypes of bitter gourd were screened artificially for salinity stress under 5 concentrations (1, 2, 4, 6 and 8 dsm^{-1}) of salts NaCl, Na_2CO_3 and K_2SO_4 (1:1:1). The genotypes WBBG 33, AK/VK 54, BGT 5-2, and MC84 were found moderately tolerant on the basis of different morphological traits studied.

1.7.2.4 Cucumber

Selections DC 54, DC 6 and DC 92 yielded 20.3 t/ha, 19.7 t/ha and 19.3 t/ha showing an increase of 19.5%, 15.8% and 13.5%, respectively, over that of the check Pusa Uday (17.0 t/ha). DC 6 was entered in AICRP (VC) trial. Monoecious F_1 hybrid DCH 6 and gynoecious F_1 hybrid DCHG 5 gave yields of 21.8 t/ha and 20.2 t/ha, respectively, which were 28.2% and 18.8% higher than that of the check Pusa Uday, respectively. (Some novel genotypes of cucumber, viz., gynoecious lines, carotene rich cucumber, *Cucumis histivus* and *Cucumis sativus* var. *Hardwickii* were collected, maintained and utilized in breeding programme).

1.7.2.5 Luffa

Sponge gourd Sel. DSG 43 gave a yield of 17.4 t/ha, which was 33.8% higher than that of the check Pusa Sneha. Sel. DSG 6 and DSG 7 gave yields of 16.8 t/ha and 15.7 t/ha, respectively, which were 29.2% and 20.7% higher than that of the check Pusa Sneha, and showed highly tolerant reaction to *Luffa leaf distortion mosaic virus* (Gemini virus) during rainy season. DSG 43 was entered in AICRP (VC) trial, while another entry DSG 5 was promoted to AVT-II trial on the basis of its superior performance. F_1 hybrids DSGH 9 and DSGH 3 gave yields of 19.2 t/ha and 18.0 t/ha, respectively, which were 47.6% and 38.4% higher than that of the check Pusa Sneha. Ridge gourd selection DRG 2 gave a yield of 14.2 t/ha, which was 57.7 % higher than that of the check Pusa Nasdar (9.0 t/ha). A unique plant with gynoecious behaviour was isolated from a segregating population of cross between ridge gourd and satputia.

1.7.3 Solanaceous Crops

1.7.3.1 Brinjal

One long fruited variety DBL 02 and one small round fruited hybrid DBHSR 66 were evaluated in AVT-I trials of AICRP (VC) and, on the basis of their performance, promoted to AVT-II trials. One long fruited hybrid DBHL 20 and two small round fruited varieties, viz., DBSR 52 and DBSR 195 were promoted from IET to AVT-I trials. Among long fruited varieties, Sel. DBL 02 gave the highest yield of 36.2 t/ha which was 28.8% higher than that of the national check Punjab Sadabahar (28.1 t/ha). In a small round fruited variety group trial, Sel. DBSR 52 yielded 31.9 t/ha and Sel. 195 (white brinjal) 30.1 t/ha which were 57.2% and 48.3%, respectively, higher than that of the national check Aruna (20.3 t/ha). In a long fruited hybrid trial, DBHL 20 (51.1 t/ha) and DBHL 150 (48.9 t/ha) were found promising with increases of 15.3% and 10.4%, respectively, over that of the check Pusa Hybrid 5 (44.3 t/ha). In round fruited group, DBHR 38 produced a yield of 50.0 t/ha with an increase of 15.5% over that of the national check Pusa Hybrid 6 (43.3 t/ha). In small round fruited group, hybrid DBHSR 66 was most promising with a yield of 34.7 t/ha, which was 18.4% higher than that of the national check ABH 1 (29.3 t/ha).

Sixty-five genotypes and thirty-two crosses were screened against Phomopsis blight. One hybrid DBHL 137 was found resistant while another hybrid DBHL 161 was found tolerant. Thirty-five genotypes and 32 crosses were screened against shoot and fruit borer under field conditions. Three hybrids DBHL 91, DBHL 150 and DBHSR 20 were found tolerant.

1.7.3.2 Tomato

Determinate tomato selection DT 2 gave a yield of 36.83 t/ha, which was 53.45% higher than that of the check CO 3 (24.0 t/ha). In a station hybrid trial, hybrid combinations DTH 5 (FEB x DT 10) and DTH 6 (3900 x Chikoo) gave a yield of 70.5 t/ha and 71.0 t/ha, respectively, which were 48.42% and 49.47% higher than that of the check Pusa Hybrid 2 (47.5 t/ha).In TLCV resistant varietal trial, lines N 5, N 1, H 86-1, 6-11-1, H 28-2-1, PH 348 and PH 348-4 were found resistant

against *Tomato leaf curl virus*. Genotypes FEB 2 and Megha were found resistant to early blight while CB 28 and Pusa 120 showed resistant reaction against root-knot nematode. Genotypes/varieties Pusa Sadabahar, Pusa Sheetal, Booster and their hybrid combinations Pusa Sheetal x Chikoo, N 5 x Pusa Sadabahar, Pusa Sheetal x Labonita, Pusa Sheetal x Pusa Sadabahar, Pusa Sadabahar x FEB 2 and Pusa Sheetal x Booster were found promising for setting fruits at low temperature ranging between 6 °C and 8 °C. Varieties Booster, Pusa Sadabahar, Pusa Sheetel and their hybrid combinations Pusa Sadabahar x Pusa Sheetal, Pusa Sadabahar x Booster, FEB 2 x H 24, FEB 2 x 39, Chikoo x N 1 and Pusa Sadabahar x Chikoo were found promising for setting fruits at high night temperature (approx. 28 °C) during May-June.

1.7.3.3 Capsicum

Capsicum hybrid KTCPH 7 was entered in the AICRP (VC) trial for its multi-location testing. Selection for fruit size, shape and number of fruits/plant was done in segregating material to develop lines with yellow, orange and red coloured fruits. Five crosses were attempted to transfer the male sterility from chilli into capsicum and paprika.

1.7.4 Root and Bulbous Crops

1.7.4.1 Carrot

Two carrot varieties IPC 122 (red) and IPC 126 (black) from IARI were recommended for release by the Delhi State Seed Sub-committee.

For spring summer crop of carrot, IPC 13, IPC 30, IPC 37, IPC 55, IPC 120, IPC 122, IPC 124, IPC 128, IPC 134 and IPC 135 genotypes were found promising. For July sown crop, IPC Ht_2, IPC Ht_1 and IPC 124 were adjudged as most promising compared to Pusa Kesar, whereas, for August sown crop, in addition to IPC Ht_2 and IPC Ht_1, IPC 11 and IPC 106 also showed desirable root formation. Fifty-five elite breeding lines with diverse characteristics were evaluated and their selected roots were planted for raising bud for further testing and utilization in hybridization programme. Cytoplasmic male sterility (CMS) was established in 25 most promising elite genetic backgrounds for evaluation in cross combinations to develop F_1 hybrids.

Fifty-nine experimental hybrids of temperate carrot developed by using nine CMS (A) and ten pollinator (c) lines were evaluated along with the standard check Pusa Yamdagni. Fifty-nine per cent hybrids surpassed Pusa Yamdagni for marketable root yield. Three high yielding hybrids, namely, KTCTH 7 (42.2 t/ha), KTCTH 8 (39.2 t/ha) and N-7 x 1060 (34.7 t/ha) exhibited economic heterosis percentage of 66.3, 55.5 and 36.5 for yield, respectively. On the basis of superior performance of KTCTH 7 in multiplicational trials at New Delhi, and Karnal, and in farmers' fields in different districts in H.P., its release proposal was submitted to IARI Variety Release Committee.

The β-carotene content per 100 g of fresh sample was found to be the highest in the hybrid Py-10 x Kt.Sel-17 (11.265 mg) followed by PY-10 x 1060 (10.766 mg) and Kt 1 A x 1060 (9.783 mg). In the germplasm, the highest β-carotene was found in Py-10 (9.845 mg) and Kt Sel 17 (9.003 mg). The hybrid KTCTH 7 also possessed an appreciable quantity of β-carotene (7.552 mg) in comparison to its parental lines and the check variety Pusa Yamdagni (4.010 mg).

1.7.4.2 Onion

Promising selection Sel 383 with 34.3 t/ha yield showed 13.6% increase over the check Pusa Red (30.2 t/ha) under AVT-II of AICRP (VC) trial. Two selections Sel 126 and Sel 153 with 31.7 t/ha and 36.4 t/ha yields were included in IET trial of AICRP (VC). Both are yellow skinned and have good storage traits. Hybrids H 18 and H 27 (developed by using CMS system) yielded 44.9 t/ha and 44.4 t/ha. They showed increases of 6.5%, and 5.2%, respectively, over that of the hybrid H 44 (42.2 t/ha) and 9.4% and 8.1%, respectively, over that of the commercial hybrid Matahari (41.1 t/ha). Seeds of cytoplasmic male sterile line and its maintainer line with stable performance were multiplied. Dark red coloured promising selections Sel 397, Sel 383 and I 40 were found superior for quercitin and flavanoids contents.

1.7.5 Leguminous Crop

1.7.5.1 Garden pea

Garden pea variety DGP 4 developed by IARI gave the highest yield of 87.73 t/ha of green pods with increases of 82.77%, 77.88% and 54.84% over that of the checks VL 3 (48.0 t/ha), VL 8 (49.32 t/ha) and NDVP 8 (56.66 t/ha), respectively. Promising genotypes/breeding lines were sown in the *Fusarium* sick plot for screening against *Fusarium* wilt resistance and suitability for earlier sowings. Of these, GP 471, GP 468, GP 447, GP 207 and GP 17 were found to possess moderate resistance against *Fusarium* wilt. A total of 130 cultures/genotypes were screened and evaluated for resistance to powdery mildew. Of these, 42 cultures showed field resistance, whereas 16 cultures turned out to be tolerant, the remaining ones were observed to be susceptible.

1.7.6 Malvaceous Crop

1.7.6.1 Okra

Selections 1-2-3, C 316, C 317 and C 36-1 gave extra early fruiting (42 - 45 days) during *kharif* 2007. Selections DOV 1 and DOV 2 were found promising at most of the testing centres under AICRP(VC). One hundred and sixty-three breeding material comprising breeding lines, segregating material, elite lines, germplasm and established varieties were subjected to evaluation for YVMV resistance, productivity, plant type and fruit type along with market acceptability. Selections C 289, C 328, A 9 and one selection from Kalna (WB) had shorter plants, and short (6-8 cm), dark green and less beaked fruits were found superior with regard to export characters.

1.8 FRUIT CROPS

1.8.1 Mango

1.8.1.1 Evaluation of mango varieties/collections

Different indigenous mango varieties/collections were evaluated for different physico-chemical parameters. Among fifteen indigenous varieties, the maximum fruit weight was noted in Mallika followed by Zardalu and Pusa Surya. The smallest fruits were produced in Bhadauran (78.2 g). The maximum TSS was recorded in Amrapali (22.5%) followed by Mallika (22.3%). The maximum acidity was observed in Bombay Green and Mallika (0.28%) whereas the minimum acidity was recorded in Amrapali (0.15%). The pulp β-carotene content was the maximum in Amrapali (16,210 µg/100 g pulp), followed by Pusa Arunima. Both Pusa Surya and Pusa Arunima showed better shelf-life (10.2 days) at room temperature.

Evaluation of indigenous mango cultivars

Cultivar	Fruit wt.(g)	TSS (%)	Acidity (%)	β-carotene (µg/100 g)	Vitamin C (mg/100g)	Shelf-life* (days)
Alphonso	129.2	17.2	0.20	11,423	35.12	5.6
Amrapali	156.5	22.5	0.15	16,210	31.55	5.0
Bangalora	170.3	14.2	0.20	7,669	38.29	5.0
Bhadauran	78.2	12.5	0.22	5,982	30.36	6.1
Bombay Green	204.1	18.0	0.28	9,056	42.65	5.0
Chausa	230.3	21.2	0.19	8,025	36.22	5.0
Dashehari	208.7	20.5	0.22	10,985	41.25	6.5
Himsagar	184.2	15.2	0.23	7,658	40.89	4.5
Husanara	133.4	17.0	0.22	9,982	30.68	4.5
Mallika	360.2	22.3	0.24	8,895	46.22	6.4
Neelum	110.3	16.5	0.18	8,256	46.98	4.0
Pusa Arunima	224.8	18.5	0.25	13,936	38.32	10.2
Pusa Surya	270.3	17.5	0.22	12,521	32.22	10.2
Ratna	140.6	16.0	0.22	12,654	37.54	6.8
Zardalu	310.8	15.0	0.20	7,881	35.99	4.0
*At room temperature						

Five exotic cultivars were evaluated for fruit growth and quality parameters. The maximum fruit weight was observed in Tommy Atkins and the smallest fruits were produced by St. Alexandrina. As evident from the data, all the exotic cultivars had moderate TSS ranging between 14.0 to 16.1°Brix. The highest TSS was registered in St. Alexandrina. The β-carotene content was in moderate range in all the five varieties. Sensation stored best (about 6.6 days) at room temperature followed by Rosari (6.2 days) and Edward (4.5 days).

Evaluation of some exotic mango cultivars at New Delhi

Variety	Fruit wt.(g)	TSS (%)	Acidity (%)	β-carotene (µg/100 g)	Vitamin C (mg/100g)	Shelf-life* (days)
Edward	380.2	15.0	0.20	9,689	35.5	4.5
Rosari	260.3	15.2	0.22	9,878	33.7	6.2
Sensation	225.2	14.6	0.32	9,956	34.0	6.6
St. Alexandrina	115.5	16.1	0.25	8,067	33.6	5.0
Tommy Atkins	410.3	14.0	0.22	8,806	32.5	6.0
*At room temperature						

1.8.1.2 Evaluation of mango hybrids

Sixteen mango hybrids were evaluated for fruit weight, pulp stone ratio and chemical qualities, viz., TSS, acidity and total carotenoids.

Fruit weight and chemical quality of some mango hybrids under evaluation

Hybrid	Fruit wt.(g)	Pulp: stone ratio	TSS (°Brix)	Acidity (%)	Total carotenoids (mg/100g)
H 1-1	177.25	3.66	19.2	0.11	10,965
H 1-3	180.35	3.60	18.5	0.16	11,698
H 1-4	120.4	3.82	19.0	0.18	8,339
H 1-6	210.64	3.59	20.8	0.15	8,456
H 2-4	128.65	2.03	17.1	0.15	8,029
H 2-6	200.68	4.09	19.5	0.23	11,564
H 2-10	140.60	2.59	18.3	0.19	8,555
H 3-2	210.85	3.88	18.0	0.20	8,901

contd.....

H 3-4	180.26	2.50	17.5	0.21	7,359
H 3-6	180.90	2.78	18.3	0.18	3,058
H 4-12	229.50	-	18.4	0.23	12,351
H 6-1	220.50	3.00	17.3	0.18	8,919
H 13-2	110.15	2.04	19.4	0.18	7,519
H 13-5	310.80	3.49	19.5	0.13	9,006
H 13-8	240.50	3.50	18.5	0.15	8,355
H 13-7	175.65	3.66	19.6	0.24	11,002

H 1-6 (Amrapali × Sensation)

H 2-6 (Amrapali × Lal Sundari)

1.8.1.3 Hybridization during March, 2007

Nine new crosses were made using Amrapali, Mallika, H 2-6 and IIHR 10 as female parent and Sensation, Lal Sundari and Pusa Arunima as male parent.

1.8.1.4 Characterization of polyembryonic mango genotypes

Sixteen polyembryonic mango genotypes were characterized by using plant vigour as index at nursery stage. Vigour index-I revealed that varieties, namely, Bappakai, Combodiana, Chandrakaran and Carabao have strong tendency of more vigour as compared to that of other varieties. However, Peach and Vellaikolamban showed lower vigour. The highest vigour index-II was recorded in Bappakai while the least was recorded in Peach followed by Vellaikolamban.

Polyembryony in Turpentine

Vigour indices of different polyembryonic mango genotypes

Genotype	Vigour index-I(cm)	Vigour index-II(g)
Bappakai	7067	547
Carabao	4455	451
Cecil	3631	212
Chandrakaran	4960	495
Combodiana	5073	500
Kerala-1	4119	353
Kerala-3	3376	153
Kerala-5	3555	196
Kurukkan	4849	256
Muvandan	3759	338
Mylepelian	4872	332
Olour	4076	330
Peach	1956	137
Sabre	4604	487
Turpentine	4727	493
Vellaikolamban	2212	153
C.D. at 5%	574	35

1.8.2 Grape

Nineteen grape cultivars were evaluated for yield performance on Head and Kniffen system of training. Out of

these, Tas-A-ganesh and Centenial seedless performed well again on Head and Kniffen system of training under yield trials.

Fifty-seven new grape hybrids were assessed and evaluated on different parameters for desirable characteristics. Selection 2005-6-17 and Selection 2006-12-1 exhibited earliness in ripening and produced good quality seedless berries. However, promising grape hybrids, viz., Banquei Abyad x Perlette 75-32 and Hur x Cardinal 76-1 were found to perform consistently well on Head and Bower systems of training this year too.

Physico-chemical attributes of grapefruit cultivars

Cultivar	Yield (kg/tree)	Fruit weight (g/fruit)	Fruit length (cm)	Fruit diameter (cm)	Juice (%)	Peel thickness (mm)	TSS (%)
Imperial	115.70	457.42	8.08	10.22	47.63	0.44	9.98
Foster	95.30	361.86	8.64	9.68	43.30	0.37	10.16
Walter	97.20	380.12	8.18	9.43	39.40	0.55	10.84
Triumph	50.80	324.24	8.32	8.26	40.10	0.48	10.96

Promising grape hybrids in pipeline

Hybrids	Ripening time	Average no. of bunches/vine		Average bunch weight (g)	Average berry weight(g)	TSS (%)	Remarks
		Head system	Bower system				
Banquei Abyad x Perlette 75-32	2nd week of June	20.00	46.00	550.00	2.00	17.00	Yellowish seedless berries suitable for table purpose
Hur x Cardinal-76-1	1st week of June	24.00	-	700.00	6.00	22.00	Yellowish bold berry, seeded, suitable for table and *munakka*-purposes

Potential grape hybrid selections

Hybrid	Ripening time	Average no. of bunches/ vine	Average bunch weight (g)	Average berry weight (g)	TSS (%)	Remarks
Selection 2005-5-1	Uniform 4th week of May	14.00	500.00	1.60	18.00	Yellowish green seedless
Selection 2005-6-17	-do-	15.00	400.00	1.80	20.00	Greenish yellow seedless
Selection 2006-11-8	-do-	18.00	450.00	1.90	20.00	Yellowish green seedless
Selection 2006-12-1	-do-	9.00	400.00	1.80	18.00	Yellowish green seedless

1.8.3 Citrus

1.8.3.1 Performance of grapefruit

Four cultivars of grapefruit, viz., Imperial, Foster, Walter and Triumph were evaluated for yield and quality attributes. Imperial produced the heaviest fruits (457.42 g each) and the highest yield (115.70 kg/tree), and yielded the highest amount of juice (47.63%). However, the lowest yield (50.80 kg/tree) was observed in Triumph and the least amount of juice was recovered in Walter. The highest TSS (10.96%) was recorded in Triumph followed by Walter and Foster.

1.8.4 *Aonla*

Cultivars Krishna, Chakaiya, Kanchan and NA 7 of *aonla* were evaluated for their suitability under Delhi conditions. The average fruit weight was recorded highest in cv Krishna (42.4 g) followed by NA 7 (36.5 g) while the minimum was recorded in Kanchan (31.2 g). Red peeled accession produced smaller fruits weighing 18.9 g on an average. The highest yield (68 kg/tree) was recorded in NA 7 followed by Kanchan (59 kg/tree). The highest seed weight was recorded in Krishna (2.20 g) followed by NA 7 (2.10 g). The maximum TSS (11%) and acidity (1.77%) were observed in Krishna while the maximum ascorbic acids (498.3 mg/ 100 g pulp) were recorded in NA 7.

1.8.5 *Bael*

The cultivars, namely, NB 4, NB 5, NB 7 and NB 9 of *bael* were evaluated under Delhi conditions for their performance. The maximum number of fruits per tree (74 fruits/tree) was recorded in Narendra Bael 5 (NB 5) closely followed by NB 9 (65 fruits/tree). The maximum yield was realized with cultivar NB 5(64.5 kg/tree) followed by NB 9 (60.8 kg/tree). The highest average weight of fruit was recorded in NB 7 (1380 g) followed by NB 9 (935 g). Skull weight was also found to be maximum in NB 7, while the

minimum was in NB 4. Physico-chemical parameters, namely, TSS, and ascorbic acid were higher in NB 5.

1.8.6 Pomegranate

Fifty-six cultivars of pomegranate were maintained in field. Performance of nine cultivars was evaluated under Delhi conditions for growth, flowering and fruit characteristics. Cultivar G 137 performed best in respect of growth and fruiting behaviour (yield 1.64 t/acre) followed by Jyoti (1.6 t/acre) and Ganesh (1.4 t/acre). Cultivar G 137 and Jyoti produced fruits of better aril colour, high juice and TSS content and low acidity followed by Ganesh. G 137, Jyoti and Ganesh were more susceptible to fruit cracking while other cultivars showed some tolerance to fruit cracking.

1.8.7 Temperate Fruits

1.8.7.1 Apple

The horticultural traits of 27 *Malus* species and their response to biotic factors, viz., woolly aphid (*Eriosoma lanigerum*), powdery mildew (*Podosphaera leucotricha*) and apple scab (*Venturia inaequalis*) were assessed. The horticultural traits evaluated were the propagation potential, vigour and chilling hour requirement. *M. baccata* (Shillong) and *M. purpuria* exhibited resistance to woolly aphid and powdery mildew. Resistance to apple scab was located in *M. baccata* (Shillong) and *M. prunifolia* var. Ringo Asami.

Two apple hybrids were selected for release as apple cultivars, viz., Pusa Amartara Pride (Red coloured) and Pusa Gold. Pusa Amartara Pride is early ripening (one week earlier), large in size, with high juice content and TSS values. Pusa Gold is very early ripening (three weeks earlier than the early ripening T.E.W.), bright golden with a bright red blush without stripes, and round and uniform in shape with TSS values in between those of the parents.

A high density apple plantation experiment is in progress with planting densities of 3402, 1736, 1111, 625 and 277 trees per hectare and Spur-Type-Red-Delicious as the test variety. The rootstock used was *M. baccata* (Shillong). Leaf nitrogen content and vegetative growth were maximum in the case of 1111 trees/ha. The average yields over a three year period of 12 - 14 year old plantation ranged from13.5 kg/tree to 26.64 kg/tree. This was equivalent to 45.93 t/ha for a planting density of 3402 trees/ha to 7.38 t/ha for the minimum planting density of 277 trees/ha.

1.8.7.2 Apricot

Eight cultivars of apricot fruited during the period under report. The cultivar Shakkarpara exhibited fruits with the highest fruit weight (88.20 g), largest fruits (78.48 cm^3) and the highest pulp:stone ratio(17.64) followed by the cultivar Kaisha Kinnaur with pulp: stone ratio of 16.40.

1.8.7.3 Kiwifruit

An easy and low cost technique for large scale multiplication of kiwifruit plants was developed. The technique was successfully evaluated by monitoring the performance of the propagation beds established by twenty orchardists. The overall rooting success obtained in different cultivars of kiwifruit varied from 55% in Toumri (male) to 80% in the cultivars Abbott and Bruno. Hayward, which is a good large fruited cultivar, exhibited 70% rooting. Packing of rooting hormone concentrate was standardized and made available to the growers on no-profit-no-loss basis.

1.8.7.4 Pear

Spraying of 2 ppm IBA at full bloom stage increases fruit setting in Bartlett pear. One of the *Pyrus* species, *Py. pashia* var. *Kumaonii* was found to be resistant to *Dematophora necatrix*.

1.8.7.5 Strawberry

The collection of strawberry cultivars was augmented to ninety-seven. These cultivars were evaluated for their various horticultural traits and incidence of leaf spot disease.

1.8.7.6 Walnut

A unique walnut clone, now christened as Pusa Khor, was collected in 2000. The clone has been regularly fruiting since 2002 and is being evaluated in comparison with seven other clones which had been collected along with the unique clone.

The rate of photosynthesis and transpiration was significantly higher in the unique clone compared to that in the other seven clones. A scrutiny of the bearing habit revealed that Pusa Khor bore 69.91% fruits laterally and 30.09% fruits terminally, while all the other three clones were borne terminally. The nut is thin shelled. Kernel colour is light cream yellow and good in taste. In organoleptic tests, its astringency was rated significantly lower than that of market samples. The oil per cent and shelling per cent were 55 and 50, respectively.

1.9 ORNAMENTAL CROPS

1.9.1 Rose

1.9.1.1 Evaluation of hybrids

During the year under report, several new hybrids multiplied on rootstock were assessed. Among the hybrids assessed, HT-B5-R2 and FL-B4-R6 belonging to Hybrid Tea and Floribunda group, respectively were found promising.

1.9.2 Gladiolus

Out of 18 gladiolus varieties evaluated, the varieties, namely, Pusa Suhagin, Australian Fair, Friendship, Pusa Gulaal, Pusa Shabnam, Rim-Jhim, Phule Neelrekha and No.86-17-6 were found to be superior in respect of spike length and rachis length. The varieties, Friendship and Rim-Jhim were superior in respect of number of florets per spike and floret size. Out of 72 hybrids evaluated 17 hybrids were found to be superior in flowering performance and floret colour.

Two hybrids, Salmon Queen Open and Little Fawn Open were proposed for release through IARI Variety Release Committee.

Salmon Queen Open (Veerangana) has soft yellow (13 D) florets with red purple (57 C) mid rib. Florets are produced all around the spike in such a way that the stem is not visible.

Little Fawn Open (Kataksh) floret colour is unique bright red (44 C). The spikes are straight and robust with 16 numbers of florets per spike. It is also a good multiplier.

1.9.3 Chrysanthemum

1.9.3.1 Induction of radiomutants in chrysanthemum

Irradiation at 15 Gy induced radiomutants in three cultivars, namely, Sadbhawana, Thai Chen Queen, and Ajay. Ajay and Sadbhawana are photo-and thermo-insensitive cultivars which flower at least thrice in a year. Creation of variability in such cultivars, therefore, is significant for offering the unique advantage of year round production of chrysanthemum for the farmers.

1.9.3.2 Management of chimeral tissue *in vitro*

The chimeral petals from induced mutants of chrysanthemum cvs. Thai Chen Queen, OHLU Red, Sadbhawana were successfully regenerated and are being propagated *in vitro*.

Promising radio-mutants evolved

Cultivar	Colour of the parent	Altered flower colour	Altered flower form
Ground cover cultivar			
Sadbhawana	Maroon	Yellow	NilIncurving
Standard cultivar			
Thai Chen Queen	Orange	Red yellow	NilIncurving
	Orange	Light pink	NilIncurving
	Orange	Orange pink	NilIncurving
	Orange	Pink	NilIncurving
	Orange	Light pink	Spoon shaped ray florets
	Orange	Bicoloured	Spoon shaped ray florets
	Orange	Lemon yellow	NilIncurving ray florets
Spray cultivar			
Ajay	Pink	Yellow	Incurving
	Pink	Light pink	Cup shaped ray florets

In order to purify the mutants obtained, attempts were made to regenerate the mutants by using the petals as explants. High frequency regeneration from petal explants of light pink, red yellow and orange pink mutants of cv. Thai Chen Queen was obtained on MS medium fortified with Kinetin 10 mg/l + 2.0 mg/l NAA.

1.9.3.3 Morphological characterization of promising mutants

The identified mutants were characterized morphologically for distinctness, uniformity and stability (DUS). The mutants were distinctly different from their parents.

1.9.3.4 New crosses

Five hundred crosses involving standard and spray types were attempted. The seed set was noticed only in single and semi double cultivars.

1.9.4 Marigold

1.9.4.1 New crosses

Inter-varietal F_1 hybrids in marigold were developed. For this purpose, promising varieties like Pusa Narangi Gainda, Pusa Basanti Gainda and selections numbered as Af / W-1, Af / W-2, Af / W- 4, Af / W-5, Af / W-7, Af / W-8, Af / W-11, Af / W-12, Af / W-14, Af / W-17, Af / W-18 and Af

/ W-19 were used as male parents while genetic male steriles lines, i. e., MS 5, MS 7 and MS 8 were used as female parents and crosses were made in all possible combinations.

In order to develop varieties/hybrids enriched with carotenoid contents, promising lines of African marigold containing higher carotenoids were involved in hybridization programme and crosses were made between these lines (male parents) and three male sterile lines (female parents) to develop F_1 hybrids with higher carotenoids.

1.9.4.2 Evaluation of selections

A number of selections belonging to French and African groups were evaluated in different seasons. Among the French marigold, the selections numbered as Fr/R-1 and Fr/R-2 performed very well and were found suitable for rainy season while a selection numbered as Fr/W-1 was found suitable for winter season for garden display. Fr/R- 2 was found suitable for June-July planting which flowered from mid October to mid December. Flowers were compact, medium in size and maroon in colour, suitable as loose flower for garland making. Another promising selection for rainy season, i.e., Fr/R-1 was found suitable for July-August planting and flowered from December to mid February producing compact, medium and orange coloured flowers which were also found suitable for garland making. Among the selections of African marigold evaluated, the selections numbered as Af/SR-1 , Af/SR-2 , Af/SR-3, Af/SR-4, Af/SR-5 and Af/SR-6 were found very promising for summer and rainy seasons, while during winter season, the selections numbered as Af/W-1, Af/W-2, Af/W-7, Af/W-11, AfW-12 and Af/W-19 gave better performance.

1.9.5 Antirrhinum

A new collection of antirrhinum suitable for cut flower and garden purpose was added to the existing germplasm. The promising selections made earlier were selfed for the production of inbred lines. New selections were made in rocket (suitable for cut flower purpose) and carpet (suitable for garden display) types. The germplasm exhibited wide variation for plant growth, flowering behaviour, yield, etc.

1.9.6 Tuberose

Eight varieties of single petalled tuberose, namely, Mexican Single, Calcutta Single, Hyderabad Single, Phule Rajani, Prajwal, Rajat Rekha, Sikkim Selection and Shringar were evaluated for various vegetative growth, floral and bulb production parameters. For majority of the parameters Shringar and Prajawal performed better than other varieties. March and April plantings produced better results in Prajawal and Vaibhav, respectively.

Efforts were made to induce earlier flowering in two varieties of tuberose, namely, Shringar and Mexican Single. In Shringar, first flowering was obtained during the last week of May under low plastic tunnels. Mexican Single did not respond to treatment under low plastic tunnel.

It was observed that in tuberose variety Hyderabad Single, plants can be uprooted after eight months of planting onwards to obtain higher yield of daughter bulbs.

1.9.7 Lilium

Ten Asiatic and five oriental hybrids of lilium were evaluated under polyhouse for various floral traits. In Asiatic hybrids, Harmony, Pollyanna and Prato were found to be the earliest in flowering, viz., 115.5 days, 120.2 days and 120.9 days, respectively. Inflorescence length (27.6 cm) was recorded maximum in Elite. The cultivar Brunello produced maximum (5.3) stem bulblets.

In oriental hybrids, the cultivar Siberia performed well for plant height (68.9 cm), flower diameter (23.1 cm) and leaf area (25.9 cm^2)

1.9.8 Alstroemeria

Six alstroemeria cultivars, namely, Amar Capri, Tiara, Rosita, Cindrella and Serena were collected and evaluated for various traits. The cultivar Serena performed well for plant height (96.4 cm), number of flowers (10.4) and duration of individual flowers (9.0 days). Earliest flowering (126.0 days) was observed in Tiara.

1.10 SEED SCIENCE AND TECHNOLOGY

1.10.1 Hybrid Seed Production in Vegetables

1.10.1.1 Tomato

Hybrid tomato seed production is primarily taken up in Ranebennur area of Karnataka. With more than hundred private companies taking up seed production, the competition for skilled labour has grown tremendously resulting in high labour cost. Moreover, with the same crops grown continuously for nearly last 25 years, there is increased pest and disease infestation. The cost of hybrid tomato seed being high, it can be a remunerative

business for small to medium level seed companies and rural entrepreneurs of northern India, who cannot afford to take up seed production in Ranebennur. However, owing to extreme cold and frost, seed production in open field conditions in northern India is not remunerative. Raising hybrid tomato seed crop under low cost poly-house was found to be highly economical and remunerative. The Division of Seed Science and Technology of the Institute developed a complete package of practices following which seed yield of 3.4 kg could be achieved in Pusa Hybrid 4 in a poly-house of 100 sq. m, which costs about Rs. 50,000/. This results in complete recovery of the cost of poly-house construction in the first year itself and also profits at a selling price of Rs. 20,000 per kg of hybrid seed. The profits accumulate in the subsequent years.

Comparative performance of tomato hybrids developed by IARI in temperature controlled poly-house

Hybrids	No. of fruits/plant	No. of seeds/fruit	100-seed weight (g)	Seed yield (kg)
Pusa Hybrid 1	34	121	0.349	1.86
Pusa Hybrid 2	29	139	0.372	1.94
Pusa Hybrid 4	44	146	0.407	3.40

This technology is doubly beneficial as it is remunerative to the seed producers, and popularizes public sector hybrids. Public sector hybrids can bring down the cost of tomato cultivation as the cost of hybrid seed from the public sector ranges from Rs. 20,000 to Rs. 25,000 per kg as compared to the cost of seeds of private sector hybrids which go as high as Rs. 80,000 per kg.

1.10.1.2 Brinjal

Hybrid seed production of brinjal can be undertaken successfully in northern India both under open and net house conditions. For hybrid seed production in *kharif* season, a nursery is sown on raised beds between 15th June and 20th June and transplanting is done after one month, i.e., between 15th July and 20th July, on flat beds maintaining a female to male row ratio of 4:1. For hybrid seed production, pollination should be initiated two months after transplanting on healthy, solitary, long styled flowers. Emasculation should be done in the evening followed by pollination on the next day between 8 A.M. and 9 A.M. as maximum fruit and seed set occurs when pollination is done on the same day of emasculation. Maximum fruit and seed setting is achieved in flowers crossed between 15th September and 15th October when temperature ranged between 26 ^{0}C and 30 ^{0}C, and RH between 55% and 70%. For achieving higher seed yield and quality, 5-6 fruits and 9-10 fruits, respectively, should be retained in round and long fruit types. Hybrid fruits should be harvested 65-75 days after pollination, and seed is extracted by cutting fruits in four halves and beating fruits with wooden block, followed by thorough washing and drying.

Hybrid seed production is more profitable in the net house (where the crop is vigorous, insect free, show longer stigma receptivity, pollen viability, higher fruit and seed yields and better seed quality) as compared to that in open field condition. An average hybrid seed yield of 2.0 kg can be achieved from an area of 100 sq. m.

1.10.1.3 Cauliflower

The parental lines, i.e., CC 14 (female) and 18-19 (male), of early group cauliflower hybrid, Pusa Kartik Shankar grown in optimum date of sowing showed non-synchrony in flowering in hybrid seed production. It was observed that the synchronization could be achieved with the application of GA_3@250 ppm to the female line plants at bud initiation (BI) stage, and IAA @50 ppm at curd maturity (CM), bolting and BI stages. Flowering duration (FD) increased by 5-7 days with the application of IAA and GA_3. The problem of non-synchrony can, therefore, be mitigated with the spray of GA_3 (250ppm) and IAA (50ppm) at different stages.

Effect of growth hormones on duration and days to flower in cauliflower parental lines

Treatment/stage of spray	Flowering duration (no.of days) in female plants				Control
	GA_3		IAA		
	(250 ppm)	(500 ppm)	(50 ppm)	(100 ppm)	
Bud initiation (BI)	22 (151-173)	28 (159-187)	27 (157-184)	29 (158-187)	Female-23 {161-184} Male-22 {149- 171}
Bolting +BI	26 (160-186)	26 (158-184)	23 (160-183)	24 (157-181)	
Curd maturity (CM)+bolting +BI	30 (152-182)	30 (147-177)	25 (149-174)	29 (148-177)	
Curd initiation+ CM+bolting +BI	29 (154-183)	24 (158-182)	25 (161-186)	24 (160-184)	

Note: Figures in parentheses indicate days to flower

1.10.2 Characterization of Isolates of *Bipolaris oryzae* and their Control

Brown spot of rice caused by *Bipolaris oryzae* is a major seed borne disease prevalent in all rice growing countries. Studies were conducted to evaluate rice varieties and different strains of the pathogen and also efficacy of botanicals and bio-control agents in controlling the pathogen in the laboratory test. Twelve isolates of the pathogen collected from different agro-ecological zones were characterized using RAPD markers. The isolates could be grouped into 5 distinct clusters based on 12 selected primers.

Studies on the effect of 8 botanicals and bio-control agents on inhibition of the pathogen strains revealed that patchouli oil @ 1 per cent was most effective against four isolates, followed by citronella oil and lemongrass oil, respectively. Kalisena @ 4 x 10^8 cfu also resulted in effective control of *Bipolaris oryzae*.

The study recommended the treatment of paddy seeds with patchouli oil @ 1 per cent for effective control of brown spot disease of rice.

1.10.3 Seed Production Technology of Medicinal Plants

An experiment was conducted to study the effect of three sowing dates and three nitrogen levels on seed yield and its quality in two varieties of isabgol (*Plantago ovata* L.), viz., GI 2 and Niharika. The crop was sown on November 2, November 17, and December 3, 2007 with three N levels (0, 45 and 90 kg N/ha) during *rabi* 2007-08. It was observed that delayed sowing adversely affected the seed yield as well as seed quality (as reflected by per cent germination and vigour). The mean highest seed yield of 706.1 kg/ha in GI 2 and 471.7 kg/ha in Niharika was obtained from the earliest sown crop.

Effect of different sowing dates and nitrogen levels on seed yield of two varieties of isabgol (*Plantago ovata*)

N level (kg/ha)	Sowing dates						Mean yield (kg/ha)
	November 2		November 17		December 3		
	GI 2	Niharika	GI 2	Niharika	GI 2	Niharika	
0	748.3	520.0	536.7	623.3	401.7	403.3	538.9
45	735.0	433.3	596.7	575.0	366.7	315.0	503.6
90	635.0	461.7	403.3	671.7	388.3	368.3	488.1
Mean	706.1	471.7	512.2	623.3	385.6	362.2	510.2
CD at 5 %: N = 44.87, Sowing dates = 69.87, Varieties = 36.64, N x dates = 77.27							

No significant differences in seed yield were observed as a result of different N levels. Seed quality parameters, viz., seed weight, per cent germination and seed vigour, were also adversely affected by late sowing.

1.10.4 Seed Quality Testing and Enhancement in Medicinal Plants

Seed testing protocols were formulated in senna (*Cassia angustifolia*), isabgol (*Plantago ovata*) and muskdana (*Abelmoschus moschatus*). Dormancy class and type were identified in order to determine the requirements of pre-treatments and additives.

Seed germination protocols for medicinal plants

Species	Substrate	Temperature °C	1st count	Final count	Pre-treatments / additives
Cassia angustifolia	BP	25 or 30	6th day	12th day	Pre-treatment with H_2SO_4 for 30 minutes or boiling water equal volume
Plantago ovata	TP	20	4th day	6th day	Pre-chill 24 - 48 h or GA_3 250 ppm co-applied
Abelmoschus moschatus	BP	25 or 30	7th day	13th day	Pre-treatment with H_2SO_4 for 5 minutes or hot water equal volume

In sarpgandha, majority of seeds are empty with no embryos leading to very low seed germination. Therefore, a sorting technique was identified for separating the filled seeds of sarpgandha (with viable embryos) from empty seeds (with no embryos or aborted embryos) by floating the seeds in water or solvents. Floating (empty) seeds (about 80% by number) could be removed from the submerged seeds (which are filled and possess embryos) for getting higher germination (> 80%) of the seed lot, which emphasizes the importance of seed processing after seed harvesting.

1.10.5 Assessment of Seed Vigour

Seeds of onion and soybean are inherently poor storer species as they rapidly lose vigour and viability under ambient conditions. While standard germination test is a good indicator of seed germinability under favourable conditions, assessment of vigour is considered more reliable for determining the planting value of the seed even under less favourable as well as favourable growing conditions.

A two-year study with a large number of varieties revealed that among different methods of vigour estimation,

viz., speed of germination, seedling dry weight, EC of seed leachates, germination after accelerated ageing (AA) and controlled deterioration tests, volatile aldehyde (VA) trapping test and a new vigour test (NVT) developed by the Institute, the highest significant correlation with field emergence was obtained with AA test (0.602**), followed by EC of seed leachate (-0.588**) and VA (-0.417**) tests in soybean. In onion, the highest significant correlation with field emergence was obtained with AA test (0.731**), closely followed by CD (0.685**), EC of seed leachate (-0.677**) and NVT (0.662**).

The new vigour test (NVT) is based on the ability of seed to germinate under low oxygen availability and high levels of volatile aldehydes accumulated in a closed container (capped conical flask). The loss of seed vigour being associated with higher production and release of volatile aldehydes, the seed lots having low vigour are exposed to higher levels of such gases, which in turn, inhibit germination and seedling growth. The test is also effective in soybean, but in this case, seed coat integrity and solute leakage play a greater role.

1.10.6 Effect of Seed Priming on Capsicum Seedling Emergence and Vigour in Nursery

Seeds of capsicum cv. Calfornia Wonder were primed using osmoticum, salt and water, and were sown in well prepared nursery beds. Osmopriming (73.5%) and solid matrix priming (SMP) (72.2%) treatments were more effective than other treatments including control in improving seedling emergence. Maximum seedling fresh weight (636 mg/ seedling) and dry weight (76.8 mg/ seedling) were recorded in SMP treatment. Solid matrix primed seed also improved seedling length. Results indicated that solid matrix priming can be successfully used to improve emergence and vigour of capsicum seed.

Effect of seed priming on capsicum seedling emergence and vigour

Treatment	Emergence (%)	Per seedling		
		Fresh wt. (mg)	Dry wt. (mg)	Length (cm)
Osmopriming	73.5a	545b	73.0ab	5.87b
Solid matrix priming	72.2a	636a	76.8a	6.96a
Halopriming	68.6b	552b	69.9b	6.64a
Hydropriming	66.2c	465c	51.6c	5.73b
Control	62.5d	320d	39.9d	4.64c

1.10.7 Effect of Pre-sowing Seed Exposure to Static Magnetic Field on Growth of Maize Seedlings under Soil Moisture Stress

Maize var. Ganga Safed 2 raised from seeds exposed to static magnetic fields of 1000 Gauss for 2h and 2000 Gauss for 1h and subjected to soil moisture potentials of -0.2 MPa and -0.4 MPa for one month showed enhanced root characteristics like total root length, root surface area and root volume. This enabled the plants to maintain greater plant water status than the untreated plants, which resulted in improved plant growth in terms of leaf area and total plant weight.

Enhanced shoot growth of one month old magnetically treated plants of maize var. Ganga Safed 2 under soil water stress

1.10.8 NMR Relaxation Studies during Water Imbibition in Microwave Treated Seeds of Fodder Legume *Stylo seabrana*

Hard seededness of *Stylo seabrana* seeds was reduced and germination percentage increased by treating them with 840-1260 watts/g seed of microwave energy. The improved germination of treated seeds was explained by NMR relaxation studies, which indicated early appearance of bound water (40 h prior to control) that helped in hydration of macromolecules needed for germination related activities.

1.10.9 Seed Production

At the Seed Production Unit of the Institute (Delhi) and at the Institute's regional stations at Karnal, Pusa, Indore and Katrain, nucleus, breeder and IARI seeds of different varieties of cereals, pulses, oilseeds, vegetables and ornamental crops were produced during the year under strict quality control. Apart from seed production, 28 rose saplings and 932 fruit plants were produced at the Seed Production Unit (Delhi).At the Regional Station, Karnal, about 4000 horticultural plants were produced.

Seed production (in tonnes)

Crop Seed Production Unit (Delhi)	Nucleus seed	Breeder seed	IARI seed	Total seed
Cereals	0.5	28.61	185.21 (Included the outreach programme seed)	214.32
Pulses	1.96	-	14.33(Included the outreach programme seed)	16.29
Oilseeds	-	1.16	3.52	4.68
Vegetable	4.3 (kg)	16.3 (kg)	1430 (kg)	1450.6 (kg)
Flowers	6 (kg)	-	63.7 (kg)	69.7 (kg)
Regional Station, Indore (Breeder seed produced under farmers' participatory programme)				
Cereals	-	203.00	-	203.00
Oilseed (Soybean)	-	4.00	-	4.00
Fruit (Papaya)	-	17 (kg)	-	17 (kg)
Regional Station, Wellington (Breeder seed produced under farmers' participatory programme)				
Cereal	-	10.00	-	10.00
Regional Station, Pusa				
Fruit (Papaya)	-	5.4 (kg)	-	5.4 (kg)
Regional Station, Katrain				
Vegetables	-	0.722	2.897	3.619
Regional Station, Karnal				
Cereals	3.39	101.48	244.90	349.77
Forage	0.12	2.10	1.97	4.19
Oilseeds	0.02	0.68	1.23	1.93
Pulses	0.09	4.00	7.43	11.52
Vegetables	0.39	4.41	0.72	5.52
Others	-	-	0.80	0.80

2. GENETIC RESOURCES

2.1 CROP GENETIC RESOURCES

2.1.1 Wheat

2.1.1.1 Novel genetic stocks

The synthetic wheat lines Syn.45 and Syn.46 were listed to possess novel single recessive gene while Syn.55 was characterized to possess a dominant gene for leaf rust resistance. Three *T. timopheevii* derivatives and two exotic lines were found highly resistant to 12 pathotypes of leaf rust. Eight interspecific derivatives obtained from IARI Regional Station, Wellington were found highly resistant to leaf and stem rusts. More than hundred derivatives of *Ae. markgrafii* and *Ae. speltoides* were evaluated for leaf rust resistance in glass house against race *Lr 77-5*.

2.1.1.2 New sources of resistance against rust

Two new resistance sources WBM 1587 (INGR No. 07009; IC 549931) and WBM 1591 (INGR No. 07010; IC 549932) developed by Tutikandi Centre of IARI Regional Station, Amartara Cottage, Shimla were registered with NBPGR as germplasm with diverse and new resistant source against stripe rust pathotype 46S119. Two new resistant sources, HS 424 and HS 431, were identified as new sources of resistance against all the pathotypes of stem and leaf rusts, and were in the process of being registered.

2.1.1.3 Germplasm evaluation

Fourteen genotypes as characterized for seedling resistance against 46S119 and 78S84 pathotypes of stripe rust were further tested for adult plant resistance in poly house. The wheat genotypes, viz., ES 73, HD 2402, Jing Dong 1, KVZ/3/TOB/LFN//88/4/Bollilos, Maris – Huntsman, Mega, VL 404, WBM 1587, WBM 1591, WBM 1858 and WBM 1963 showed adult plant resistance against 46S119 pathotype of stripe rust. Sixth HLWSN (high latitude wheat screening nursery) of CIMMYT comprising 332 lines were evaluated for grain yield and its associated traits. Twenty-one genotypes showed grain yield superiority over the check variety VL 738, and 24 had bold grains (≥ 50g/ thousand grain).

2.1.1.4 Maintenance and characterization of wild wheats

Out of the nearly three thousand accessions of wild species received (during 2003) from USDA (Small Grain Centre), only limited accessions were retrieved, maintained and utilized in the primary gene pool. Now, the entire remaining accessions from each of the gene pool have been retrieved, one by one, germinated and seed multiplications undertaken in order to save the material from loosing germination under cold storage. Simultaneous characterization has also been undertaken.

2.1.2 Rice

2.1.2.1 Improved bacterial blight and blast resistant *basmati* rice genotypes

Improved Pusa Basmati 1 with resistance to blast. Using marker assisted foreground and background selection, two blast resistance genes, namely, *Piz5* from C10151A and *PiKh* from Tetep were put in plants individually, and will be crossed to pyramid two genes together.

Pusa 1527-04-56 and Pusa 1526-04-25. Pusa 1527 - 04-56 and Pusa 1526-04-25 were developed to improve Pusa 2511 and Pusa 1121, respectively, through marker assisted backcross breeding to combine four bacterial blight resistance genes (*Xa4, xa5, xa13* and *Xa21).*

Development of genotypes with extra long kernel. Keeping in view the emerging trend for longer grain in the domestic and international market, the *basmati* breeding programme was reoriented giving focus on development of genotypes with extra long kernel. Three genotypes, namely, Pusa 1484-03-1-3-2-1, Pusa 1484-03-1-3-2-2 and Pusa 1554-06-6 with more than 10 mm long grains were developed.

2.1.3 Barley

2.1.3.1 New sources of resistance against rust

Two resistant sources BHS 369 and BHS 371 were identified as new sources of resistance against all the pathotypes of stripe rust in seedling stage, and immune to

stripe rust in adult stage. These sources were in the process of being registered.

2.1.3.2 Evaluation of local germplasm from north western Himalayas

Two hundred and ten accessions of barley collected from north western Himalayas were evaluated for qualitative and quantitative traits. Considerable variability was observed for growth habit, heading days, awning, ear shape, grain colour, 1000-grain weight and field resistance against stripe rust. Maximum accessions were found to possess semi-erect growth habit, long awns, medium heading days, and moderately susceptible response against stripe rust under field condition. The highest coefficient of variation was observed for grain yield/plant (41.6%) followed by spikelets/ear (18.9%) and 1000-grain weight (17.7%) indicating maximum contribution of these traits towards variability.

2.1.4 Maize

2.1.4.1 Registration of disease resistant germplasm

One maize line (SC 7-2) for resistance source for maydis leaf blight (INGR 07025) was registered with NBPGR. Another line IC 549904 was deposited with NBPGR as a genetic stock for maydis leaf blight resistance.

2.1.5 Pearl Millet

2.1.5.1 Diversification and genetic enhancement of CMS lines and restorers with high level of resistance to downy mildew, and desired maturity

One hundred and ten pairs A & B lines involving 11 new downy mildew resistant male sterile lines MS (298A, 351A, 379A, 411A, 419A, 431A, 436A, 549A, 589A, 540 A and 773A) were developed.

Two hundred and sixty-two inbred lines derived from African inbreds for resistance to moisture stress and downy mildew were developed and maintained to exploit heterosis.

2.1.6 Pigeonpea

2.1.6.1 Germplasm resources

One hundred and ninety germplasm lines (49 short duration and 141 long duration) were grown for maintenance, multiplication and use in crossing programme. Accessions of *C. acutifolius* (ICP 15603, and ICP 15607), *C. goensis(* ICP 15633), *C. mollis (* ICP 15653), *C. lineatus (*ICP 15643), *C. platycarpus (*ICP 15665 and ICP 15670) and *C. scarabaeoides (*ICP 15685, ICP 15692 and ICP 15707) were characterized for their grain protein content and other traits.

2.1.7 *Brassicas*

2.1.7.1 Germplasm and RILs maintenance

A total of 544 germplasm lines of *Brassica* (*juncea*, *napus*, *carinata*, *compestris*, *nigra*, *oleracea*, *tournifortii*, and *caudatus*), *Raphanus* (*sativa*, and *caudatus*), *S. alba*, *E. sativa, Crambe, Camellina, Lapidium and Diplotaxis* are being maintained as core set of germplasm. In addition, 192 recombinant lines including parents from a cross Varuna x BEC 144 were selfed and maintained in F_9 generation and the F_{10} generation in the field was again selfed for generation advancement for characterization of agronomic and morphological traits.

2.1.7.2 *Brassica carinata*

One hundred and sixty-nine germplasm lines including the somaclones of *Brassica carinata* having variability for morphological traits of agronomic importance are maintained and utilized in the breeding programme.

2.1.8 Cowpea

Variability for novel traits like high seed index, drought and heat tolerance and long-succulent pods was observed in cowpea land races collected from Deccan Plateau and West Coast of India.

Variability for novel traits observed in cowpea landraces collected from Deccan Plateau and West Coast of India.

Variabilitiy for novel traits observed in cowpea landraces

Species	Trait identified	Genotypes (local accession Nos.)
Vigna unguiculata cv-gr unguiculata	High seed index	DWDCC 001, DWDCC 006, DWDCC 008, DWDCC 015, DWDCC 016
	Drought and heat tolerance	DWDCC 001, DWDCC 006, DWDCC 015
	Long and succulent pods	DWDCC 017, DWDCC 023, DWDCC 024

2.1.9 Soybean

2.1.9.1 Maintenance of germplasm

One thousand and two hundred germplasm lines were scored for resistance for *yellow mosaic virus* (YMV), 11 genetic stocks for yield related traits, 20 lines for water use efficiency (WUE), and 40 lines were maintained for root traits.

2.1.10 Cotton

2.1.10.1 Germplasm lines evaluated

One hundred and twenty germplasm lines were evaluated and characterized for their utilization in breeding.

2.1.11 Vegetables

A total of 50 germplasm of cabbage including 6 SI lines and 10 CMS lines along with their maintainers are being maintained.

Ninety-one germplasm lines including nine CMS (A) lines of temperate carrot along with their respective maintainers (B lines) were maintained.

2.1.12 Fruits

IARI Regional station, Amartara has a wide collection of germplasm of temperate pome and stone fruits. During the year, 14 varieties/lines of pomegranate were introduced for conducting trials.

A new evaluation technique was developed for screening of new foreign apple introductions for resistance to *Sclerotium rolfsii* causing seedling blight. Grafting twigs (10cm) were placed in petriplates lined with moistened blotting paper and inoculated with 7mm disc of fresh (4 days old) and vigorously growing mycelial culture of the pathogen. Out of the twenty-six apple genotypes subjected to inoculation through this technique, M 7, MM 106, *Malus orientale*, *M. baccata* var. *mandschurica* and *M. robusta* showed minimum internal bark rotting.

Apple genotypes evaluated against foliar diseases showed severe attack of *Alternaria* leaf spot followed by *Marssonina* blotch, scab and powdery mildew diseases. *Malus baccata* Khrot, *M. baccata*, *M. pumill* mill, MEM Wilson and *M. maruba* were least susceptible. *Cydonia oblonga* which was reported to be resistant to root rot showed susceptibility. Among various indigenous *Pyrus* species, *Py. Pashia* var. *Kumaonii* were found to be resistant to white root rot.

Foliar leaf spot (*Mycosphaerella fragariae*) has been found to reduce the runner production in strawberry. The mother plants of 34 varieties/cultivars/genotypes were categorized into six severity grades (0-6) and the number of runners produced in each category was recorded. Higher the disease severity lesser the number of runners produced by the mother plant. No runner production was observed in genotypes, viz., Selva, Confutra, Brighton, NR Round Head, Fair Fox, Hayward and Catskill having maximum disease severity. Leaf spot (*Mycosphaerella fragariae*) progress was studied on strawberry varieties under natural epiphytotic conditions to establish its correlations with the environmental factors. The leaf spots wiped out the infected leaves within 9 weeks after the first infection of the leaf; however, it varied with the cultivars infected. The leaf spots also reduced runner production in almost all the cultivars studied.

Apricot germplasm comprising varieties/cultivars/new introductions such as Kaisha, Charmagz, New Castle, First Ambris, Shiply Early, Suffaida, Nugget, Nari, Cneff C&A Royal, Basti, EC 168342, Kaisha Kinnaur were screened for resistance to frosty mildew/Cercosporell leaf spot (*Cercosporella persica*) under field conditions. The disease severity varied from 20% to 80% in different genotypes. Almost all the twenty genotypes were susceptible to frost mildew; however, Royal, EC 168342, Kaisha Kinnaur and Basti had less severity as compared to other genotypes. The onslaught of the disease results in premature defoliation and weakening of plants. Genotype Royal showed delayed appearance of the disease as well as retained the foliage for longer duration. The disease progress with respect to leaf fall was also studied on different genotypes, and the genotypes showing moderate resistance developed infection slowly corresponding to the delayed leaf fall.

2.1.13 Flowers

In rose, twenty-five varieties belonging to Hybrid Tea and Floribunda groups were collected from various sources in the country and added to the existing germplasm, consisting of 900 varieties. Forty varieties are being multiplied. A new demonstration plot comprising 36 Hybrid Teas and 36 Floribunda varieties developed by IARI was maintained.

One hundred chrysanthemum cultivars were maintained. Twenty-one new cultivars collected from IIHR, Bangalore and Dr.Y.S.P.U. Horticulture and Forestry, Solan were added to the existing germplasm.

In order to enrich the germplasm, twelve new collections of French marigold were added to existing germplasm and evaluated. Several lines of African marigold including three male sterile lines were also maintained by selfing and crossing with respective maintainers.

Ten genotypes of lilium, 10 of narcissus, 8 of daffodils, 6 of iris, 14 of dahlia and 37 genotypes of gladiolus are being maintained and used in crop improvement programme at IARI Regional Station, Katrain.

2.2 MICROBIAL GENETIC RESOURCES

2.2.1 BGA Germplasm Collection

The centre for conservation and utilization of Blue Green Algae is an important repository and service centre for fresh water blue green algae, housing a large number of cynobacterial isolates maintained in unialgal condition. During the reported period, forty-one new cyanobacterial isolates were added to the culture collections of this Centre. Majority of these isolates were from low fertilizer organic soils of *basmati* rice. One strain of *Nostoc muscorum* added in collection was originally from Antartica.

The cyanobacterial isolates from Andhra Pradesh were characterized for nitrate reductase, nitrogenase and glutamine synthase activities. The isolates of *Nostoc ellipsosporum* exhibited the highest nitrogensae activity *in vitro*, whereas *in vivo*, the activity was the highest with *Phormidium foveolarum*. The glutamine synthatase activity was the highest with *Nostoc hatei*.

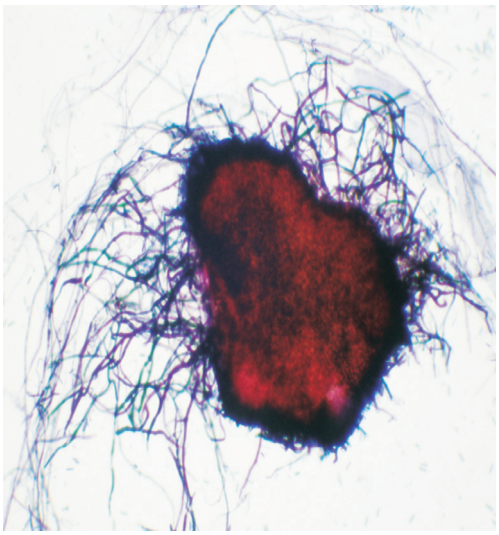
2.3 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

2.3.1 *Herbarium Cryptogamae Indiae Orientalis* (HCIO)

Enrichment of biodiversity. Seven hundred sixteen (716) fungal specimens were accessioned in HCIO raising the total number of specimens to 47,335.

New species proposed. Eight species of Hyphomycetes, viz., *Corynespora baliospermigena, C. clerodendri-viscose, C. nanospora, C. sapotacearum, C. xylosma-longifoliae, Cercospora prosopidicola, Cladosporium cycadacearum* and *Taeniolella sapindi* and 10 species of meliolaceous fungi, viz., *Amazonia elaeocarp, Irenopsis sidae, Meliola kanniyakumariana* var.*brahmgiriensis, M. palakkadensis, M. saliciicola, M. tabernaemontanae* var. *wrightiae, Asterina canthiigena, Asterostomella baliospermi A. strombosiae* and *Sarcinella wrightiae* and two species of dematiaceous Hyphomycetes viz., *Deightoniella mayeei* and *Dischloridium gangawanei* were proposed as new species.

New genera created. A new fungus, *Polyrostrata indica* gen.nov., was described from the stems of *Erianthus munja.*



***Polyrostrata indica* gen. nov. (Hairy pycnidia)**

2.3.2 Indian Type Culture Collection (ITCC)

Maintenance and preservation. About 3590 fungal cultures belonging to Mastigomycotina, Zygomycotina, Ascomycotina and Deuteromycotina were maintained by periodic transfer to suitable media. Of these, 200 cultures were preserved under mineral oil (liquid paraffin).

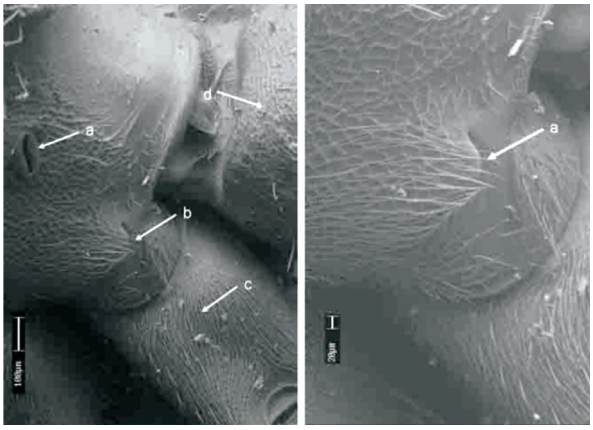
New additions. The culture collection was enriched by a new addition of 108 different fungal cultures. Some noteworthy plant pathogens accessioned include *Fusarium fusarioides* from cumin, *Trichoderma citrinoviride,* and *Metarrhizium anisopliae* from bamboo hopper, *Colletotrichum capsici* from turmeric, *Mucor hiemalis* from rice yellow stem borer, *Trichoderma fasiculatum* and *Fusarium equiseti* from brinjal, and *Sclerotium rolfsii* from saffron.

Culture supply. Four hundred twenty-nine (429) authentic fungal cultures belonging to different groups, viz., Zygomycetes (25), Hyphomycetes (156), Ascomycetes (17), Penicilli (46), Aspergilli (36), Coelomycetes (65) and Fusaria (84) were supplied.

Identification services. Three hundred and thirty-five (335) cultures/specimens, mostly plant pathogens, post harvest pathogens, biocontrol agents and industrial fungi were identified. Some important fungi identified include *Phoma tropica* from *Dolichos lab lab, Stachybotrys atra* from cucumber seed, *Glomerella cingulata* and *Colletotrichum gloeosporoides* from castor, *Phoma glomerata* from *Ficus religiosa* and *Fusarium oxysporum* from cardamom.

2.3.3 Insect Biosystematics

Under the insect identification service, 847 insect specimens were identified. Biological studies were conducted on cotton stem weevil *Pempherulus affinis* vis-à-vis its host plant relationship as a model. Speculative hypotheses on the concept of adaptive radiation and thereby towards faunistics were developed taking into account the results obtained through analysis of field biology and herbivory. With a view to facilitating the quarantine aspects towards confirmation of species identification of rice weevil *Sitophilus* spp., hitherto unexplored characters of rostrum and genitalia were worked out. RAPD PCR studies undertaken on the molecular aspects of intraspecific populations of *Bemisia tabaci* were further validated. Relationships worked out in terms of correlation coefficients towards cluster and discriminant functions of



(1) (2)

***Componotus sericeus:* 1. Lateral view of alitrunk showing propodeal spiracle (a); metapleural gland (b); metasoma (c); and node of periole (d) and 2. Enlarged view of metapleural gland (a)**

the taxonomic characters were analysed in the background of molecular variations in these intraspecific populations. *Camponotus sericeus* belonging to the *Camponotus (Orthonotomyrmex)* species group was found to possess the metapleural gland. This character is absent in most species of *Camponotus* worldwide, except for *C. gigas* from Indonesia and *C. thadeus* from Australia. Thus, it is the first report of the presence of metapleural gland in an Indian species of *Camponotus* and the third from the world. In Hemiptera, three type species, viz., *Tetroda histeroides*, *Ectomocoris quadriguttatus* and *Phalantus geniculatus* were redescribed with illustrations of their taxonomic characters.

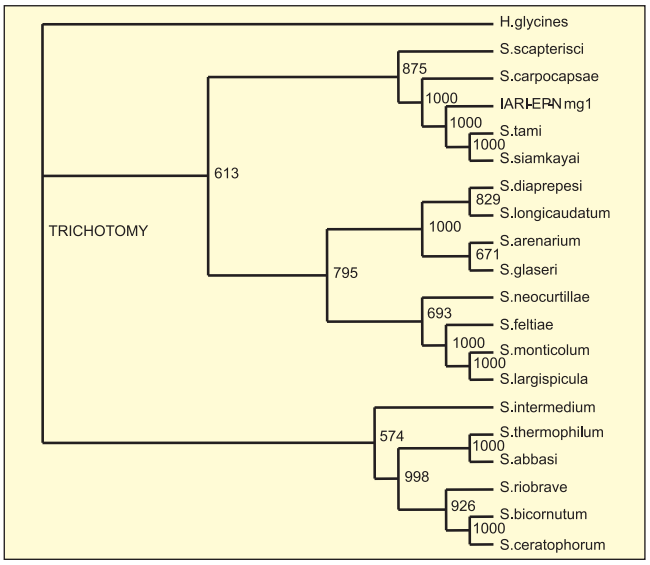
2.3.4 Nematode Biosystematics

2.3.4.1 New nematode species

Predominantly occurring plant parasitic nematodes from the rhizosphere of peach and apple in the northern hilly region were isolated. Detailed morphological studies led to the identification of three new species, one of the genus *Paratylenchus* from Uttarakhand and two of the genus *Xenocriconemella* from Himachal Pradesh, and Bhutan, which are being described and illustrated.

2.3.4.2 Molecular characterization of *Steinernema* species from Meghalaya

The complete ITS region of rDNA of the infective juveniles of *Steinernema* species was amplified and sequenced. A phylogenetic tree was obtained by maximum parsimony using default parameters of ClustalX. Tree evaluation was made using a heuristic search (simple stepwise addition, tree bisection reconnection branch swapping).Branch support was estimated by Bootstrap analysis (1000 replicates) using the same parameters as the original search. The phylogenetic relationships of Meghalaya strain (IARI-EPN-mg1) and *Steinernema thermophilum* with 18 other species, are presented in the following figure. The species were grouped in three main clusters, wherein the two Indian species – *S. thermophilum* and *Steinernema* species Meghalaya strain were located in different clusters, the former forming a clade in *bicornutum* group and the latter in *carpocapsae* group.



Phylogenetic relationships of Meghalaya strain of *Steinernema* with other 18 species of this genus based on bootstrap analysis of ITS regions of rDNA, with *Heterodera glycines* as an out group

2.3.4.3 NCBI GenBank depositions

Three gene sequences of the ITS region of rDNA – one of indigenous entomopathogenic nematode species (Steinernema species Meghalaya strain Accession No. EF 219458) comprising 516 base pairs; and two of the bacteria (*Xenorhabdus indica* Accession No. DQ 211718; and *Providencia vermicola* Accession No. EF 192136) associated with *S. thermophilum* – were deposited with GenBank.

2.3.4.4 National Nematode Collection of India (NNCI)

The NNCI was augmented with 22 type slides of newly described saprophagous nematode species (*Longidorella retenta, L. rotunda, L. rashidae, L. saadi, L. perplexa, L. pachyderma, L. papilloides* and *L. tunicata*) and 218 wet nematode suspensions, thus bringing its strength up to 2211 type accessions; and 3212 wet collections. After completing the database of type accessions, this year, a database of wet suspensions was designed, and 620 records entered.

2.3.4.5 Nematode identification service

One hundred fifteen nematode specimens received from Uttarakhand, Uttar Pradesh, Jammu and Kashmir, Gujarat, West Bengal and Assam, were identified. The important species identified were: *Meloidogyne incognita, Rotylenchulus reniformis, Paratrichodorus christiei, Xiphinema elongatum, Pratylenchus thornei, Aphelenchus avenae, Aphelenchoides composticola, Steinernema carpocapsae, S. riobrave,* and *Heterorhabditis bacteriophora,* and some free living rhabditids *(Cephalobus persegnis, Mesorhabditis* sp.*).*

3. CROP AND RESOURCE MANAGEMENT AND ENVIRONMENT

3.1 AGRONOMY

3.1.1 Effect of Short Duration Summer Forage Crops and Phospho-gypsum-Enriched Urea (PGEU) on Productivity of Succeeding Aromatic Rice

A field experiment was conducted during summer and rainy seasons of 2007 to study the effect of forage crops and phospho-gypsum-enriched urea on the productivity of aromatic rice cv. Pusa Sugandh 4. The forage crops, viz., pearlmillet cv. PCB 169, cowpea cv. V 585 and pearlmillet + cowpea were grown in summer, after which five treatments of phospho-gypsum enriched urea, viz., no N (absolute control), recommended dose of N alone, 2.5%, 5.0%, and 7.5% phospho-gypsum enriched urea were applied to the succeeding rice crop.

Maximum grain yield of rice (4.80 t/ha) was recorded after summer cowpea, which was significantly higher than the rice yields after pearlmillet (4.52 t/ha), and summer fallow (4.38 t/ha). Enrichment of urea with phospho-gypsum had significant effect on the grain yield of aromatic rice. The grain yields increased by 7.0%, 13.8%, and 21.1% because of the application of 2.5%, 5.0%, and 7.5% phospho-gypsum-enriched urea, respectively, over that of the recommended dose of urea alone.

3.1.2 Effect of Organic and Inorganic Fertilizer Management on Productivity of Soybean-Based Cropping System

A fixed plot experiment was carried out to study the effect of organic and inorganic fertilizers and their combination on the performance of soybean and their residual effects on the succeeding crops of chickpea and wheat.

In third cycle, 100% organic fertilizers management recorded higher growth and yield attributes culminating in significantly higher grain yield of soybean as compared to 100% inorganic fertilizers management and combination of 50% organic and 50% inorganic fertilizers management. A similar trend was observed in succeeding crops of chickpea and wheat. Soybean equivalent yield, net returns and BC ratio were significantly higher with 100% organic fertilizers management. Among the cropping systems, soybean-wheat system recorded higher soybean equivalent yield and net returns, while the soybean-chickpea systems recorded higher BC ratio.

Effect of nutrient management on productivity of soybean-wheat and soybean-chickpea cropping systems

Treatment	Seed yield of soybean (t/ha)	Seed yield of chickpea (t/ha)	Grain yield of wheat (t/ha)	Soybean seed equivalent (t/ha)	Net returns (Rs/ha)	B C ratio
Nutrient management						
Control	1.07	0.83	2.75	2.74	18954	1.36
100% org	1.92	1.46	4.06	4.60	39391	2.49
100% inorg	1.75	1.25	3.97	4.23	33558	1.95
50%+50%	1.84	1.35	4.13	4.45	36601	2.19
CD (P=0.05)	0.82	0.51	1.20	1.01	1217	0.07
Cropping system						
Soybean-wheat	1.65			4.13	32781	1.92
Soybean-chickpea	1.63			3.87	31470	2.07
CD (P=0.05)	NS			0.63	759	0.05

3.1.3 Evaluation of Quality *Brassica* Genotypes under Different Sources and Levels of Nutrients and their Residual Effect on Succeeding Cowpea

In a fixed plot experiment, one variety each of non-canola, semi-canola and canola rapeseed-mustard was evaluated under four levels of organic and inorganic sources of nutrients and two levels of sulphur. In second cycle, non-canola cv. Pusa Mahak and semi-canola cv. Pusa Karishma, being on a par, produced seed yield significantly higher than that of canola cv. GSC 3A. Semi-canola recorded lower oil content and harvest index compared to

those of non-canola and canola. Non-canola recorded markedly higher oil yield, net returns and benefit-cost ratio. Application of 80 kg N+ 17.5 kg P + 33.3 kg K/ha through inorganic source or recommended dose of N (RDN) through FYM being on a par, recorded significantly lower seed yield and oil yield compared to those obtained with integrated application of RDF through FYM (50% RDN) + 50% of recommended dose of NPK through inorganic sources. Integrated application of nutrients recorded the highest harvest index, net returns and benefit: cost ratio. Response to S application was the highest in traditional variety, followed by semi-canola and the lowest in canola. Cowpea recorded the highest green pod yield after cv. GSC 3A. Pod yields of cowpea due to residual effect of FYM and integrated application of nutrients were on a par but significantly superior to the residual effect of inorganic sources. System productivity in terms of mustard seed equivalent, net returns and benefit: cost ratio was the highest in Pusa Mahak- cowpea, followed by Pusa Karishma- cowpea system.

Productivity and economics of quality *Brassicas*-cowpea system as influenced by nutrient management

Treatment	Seed yield (t/ha)	Oil content (%)	Oil yield (kg/ha)	Cowpea green pods yield (t/ha)	Mustard seed equivalent yield (t/ha)	Net returns (Rs./ha)	Benefit: cost ratio
Genotype							
Pusa Mahak	2.17	38.54	0.84	108.0	4.20	46015	3.17
Pusa Krishma	2.06	33.67	0.69	108.3	4.09	44249	3.08
GSC 3A	1.47	39.75	0.58	114.9	3.62	36821	2.73
CD (P=0.05)	0.13	0.55	0.08	NS		-	-
Nutrient sources							
Control	1.37	37.25	0.51	82.0	2.91	27634	2.46
Rec. dose of NPK through fertilizer	2.02	36.40	0.74	106.5	4.01	43392	3.07
Rec. dose of N through FYM	1.95	37.92	0.74	129.6	4.38	47162	3.05
Half of rec. dose of N through FYM + half of rec. dose of NPK through fertilizer	2.26	37.41	0.85	123.4	4.57	51218	3.33
CD (P=0.05)	0.17	0.65	0.06	8.6		-	-
S levels (kg/ha)							
0	1.81	36.70	0.66	107.2	3.82	40085	2.90
40	1.98	37.94	0.75	113.5	4.11	44475	3.08
CD (P=0.05)	0.07	0.41	0.05	3.5		-	

3.1.4 Water Economization in Potato-Based Intercropping Systems

Three potato-based cropping systems, viz., sole potato, potato + *palak* and potato + radish, were tested under two methods of irrigation (regular furrow irrigation and alternate furrow irrigation), and three irrigation regimes, viz., (Irrigation at 0.8, 1.0 and 1.2 IW/CPE ratio. Sole potato produced the highest tuber yield (11.8 tonnes/ha), while potato equivalent yield (27.5 tonnes/ha) and water use efficiency (669.4 kg/ha-cm) were the highest with potato + radish cropping system. Regular furrow irrigation resulted in significantly higher yield of potato tuber (11.8 tonnes/ha), *palak* (22.8 tonnes/ha), radish (46.1 tonnes/ha) and potato equivalent yield (21.0 tonnes/ha) compared to the yields obtained with alternate furrow irrigation. Contrary to this, consumptive use of water was lower in alternate furrow irrigation, while water use efficiency based on potato equivalent yield was higher (536.2 kg/ha cm) in this treatment. Irrigation at 1.2 IW/CPE ratio recorded the highest tuber yield (12.1 tonnes/ha), *palak* yield (23.8 tonnes/ha), radish yield (45.8 tonnes/ha) and potato equivalent yield (21.3 tonnes/ha), while water use efficiency with respect to potato equivalent yield (545.26 kg/ha cm) was the highest with irrigation at 0.8 IW/CPE ratio.

3.1.5 Performance of Mustard as Influenced by Aqua-Fertilization and Fertility Levels under Rainfed Conditions

A field experiment was conducted during *rabi* season of 2006-07 to study the effect of date of sowing, aqua-fertilization and fertility levels on the performance of Indian mustard. Sowing on 25th October gave significantly higher seed yield, water use efficiency and net returns compared to those obtained in 5th November sowing. Aqua-fertilization with 15,000 litres of water/ha recorded significantly higher seed yield, water use efficiency and net returns compared to those obtained in dry sowing. Recommended dose of fertilizer (RDF) gave the highest seed yield, water use efficiency and net returns compared to those obtained in the control and 50% RDF.

Seed yield, water use and economics of mustard as influenced by date of sowing and aqua-fertilization in Indian mustard

Treatment	Seed yield (t/ha)	Consumptive use (mm)	WUE (kg/ha-mm)	Net returns (Rs/ha)
Date of sowing				
25th October	1.91	220.2	8.67	22500
5th November	1.65	212.1	7.78	18900
CD (P=0.05)	0.06			
Aquafertilization (water litres/ha)				
Normal sowing	1.66	207.3	8.07	19000
5000 litres	1.74	215.2	8.09	19840
10000 litres	1.79	221.2	8.10	20672
15000 litres	1.91	224.1	8.53	22520
CD (P=0.05)	0.08			
Fertility Levels				
Control	1.58	208.1	7.59	16300
50% RDF	1.79	219.2	8.17	20700
100% RDF	1.96	223.2	8.78	22360
CD (P=0.05)	0.09			

3.1.6 Performance of New Wheat Genotypes at Normal and Late Sowing Dates under Irrigated Condition

Four new wheat genotypes were tested against three established checks of normal sown and one check of late sown variety. All the four new genotypes tested, i.e., K 0402, NW 3069, DBW 22 and HI 1539 yielded better than three established checks, i.e., HD 2824, PBW 343 and DBW 14 under normal date of sowing, but only HI 1539 yielded better than the fourth check K 0307.

Under late sown condition, all the four new genotypes tested proved to be better than all the checks except K 0402 which yielded slightly less than K 0307.

3.1.7 Performance of New Wheat Genotypes at Late and Very Late Sowing Dates under Irrigated Condition

Four new genotypes of wheat, namely, PBW 579, WH 1022, HD 2932 and Raj 4101 were tested against three established varieties as checks. None of the new genotypes performed better than the checks in late or very late sown condition. However, the performance of WH 1022 was found to be consistently good.

3.1.8 Comparative Performance of Irrigated, Timely and Late Sown Varieties under Different Sowing Dates

Consecutive results for the second year revealed that the overall performance of normal sown varieties was superior to the overall performance of late sown varieties which confirms that under forced condition of late sowings one may prefer to go for the sowing of normal sown high yielding varieties of the area (Pusa Bihar), if seeds are available.

On the basis of mean over dates this year it was concluded that HUW 468 is the best variety of the area for sowing under different dates. In the order of preference for sowing under different dates, varieties HUW 468 (3334 kg/ha), NW 2036 (3271 kg/ha), HD 2733 (3154 kg/ha), PBW 343 (2996 kg/ha), DBW 14 (2972 kg/ha) and HD 2643 (2740 kg/ha) may be used by farmers.

3.1.9 Performance of New Wheat Genotypes under Irrigated Saline and Alkali Conditions

Two new genotypes, NW(S) 2-4 and KRL 119 were tested against established salinity tolerant varieties Kh 65 and KRL 19 in a saline patch of this location (Pusa Bihar) under different nitrogen levels. At a lower level of nitrogenous fertilizer application, these new genotypes could not perform better than the established check KRL 19 but at a higher level of nitrogenous fertilizer application, the genotype KRL 119 yielded better than the established check.

3.1.10 Evaluation of Suitable Wheat Varieties under Conventional Tillage and Zero Tillage Conditions

Results of this year's trial revealed that under conventional tillage condition, in the order of performance, K 9107 (3999 kg/ha) followed by HP 1731 (3810 kg/ha) and HP 1761 (3757 kg/ha) were on a par with each other and formed the higher yielding variety group while PBW 443 (3749 kg/ha), HUW 234, HD 2824 (3598 kg/ha) and HD 2733 (3552 kg/ha) formed the normal producing group.

Under zero tillage condition, HP 1761 (4044 kg/ha) followed by HUW 468 (3954 kg/ha) and HUW 234 (3908 kg/ha) formed the higher yielding varietal group while HP 1731 (3863 kg/ha), NW 2036 (3789 kg/ha) and HW 2045 (3719 kg/ha) formed the normal producing variety group.

3.1.11 Effect of Seed Treatment with *Azatobactor* and PSB Culture on Wheat

The results of this year's experimentation on seed treatment of wheat with P culture and *Azatobactor* were in conformity with the results of last year's experimentation. Seed treatment with bio-fertilizers (PSB culture and *Azatobactor*) in plots where half N and half phosphate of recommended dose were applied, yielded 3438 kg/ha as compared to 3582 kg/ha in plots where full recommended dose of N and P was applied. This clearly indicates that the application of these bio-fertilizers can compensate about 50% of recommended nitrogen as well as phosphatic chemical fertilizers, with only a marginal loss in yield but major gain in economy of zero tilled wheat production.

3.1.12 Performance of Wheat Genotypes under Different Growing Conditions

Under timely sown condition, wheat variety HI 1544 recorded the highest grain yield (6.55 t/ha) and biological yield (13.0 t/ha) and was significantly superior to HI 8663, GW 322, MP 4010 and HI 8498; and was on a par with GW 366, whereas, under late sown condition, it yielded significantly higher (4.87 t/ha) than the rest of the varieties, including GW 366.

Wheat variety HD 2932 yielded significantly higher to (5.4 t/ha) than HD 2930, DL 788-2 and MP 4010 under late sown condition, and was on a par with GW 322.

Under rainfed condition, *aestivums* yielded higher (1.66 t/ha) than *durums* (1.43 t/ha). Under restricted irrigation, the two wheat species recorded equal grain yield (2.83 t/ha), while *durums* yielded higher than *aestivums* under normal and late sown high fertility irrigated conditions.

3.1.13 Comparative Evaluation of System of Rice Intensification (SRI) and Conventional System under Different Agronomic Factors for Yield and Quality of Scented Rice

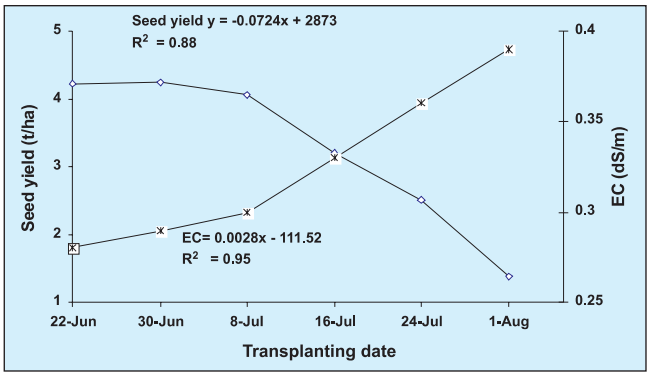
Seed yield remained on a par between different SRI treatments and conventional system. Among the fertility treatments, FYM + 75% RDF recorded significantly higher yield compared to that of the recommended dose of fertilizers. Seed quality of both the cultivars was not affected by SRI compared to that in conventional system. Preliminary study suggested that wider spacing can help in reducing the requirement of quality seed per unit area, and more area can be covered with the quality seed saved to enhance the national production. There was a saving of 3 to 4 irrigations in SRI compared to number of the irrigations given in conventional system.

Evaluation of SRI and conventional methods of seed production in scented rice

Spacing & fertilizer	Pusa Basmati 1 Seed yield (t/ha)	Pusa Sugandh 4 Seed yield (t/ha)
SRI 30cm x 30cm	4.55	3.90
SRI 25cm x 25cm	4.94	4.02
SRI 20cm x 20cm	5.09	4.30
Conventional 20cm x 15cm	4.98	4.42
CD at 5%	NS	NS
FYM + 75%RDF	5.15	4.47
Wellgro 300kg/ha+75%RDF	5.07	4.18
RD (NPK 100:50:25)	4.42	3.85
RDF +25%Extra N	4.93	4.14
CD at 5%	0.50	0.38

3.1.14 Effect of Transplanting Date on Seed Yield of Rice cv. Pusa 1460

The effect of transplanting dates on yield attributes, viz., panicles/hill, panicle length, and seed weight/panicle and seed yield, was significant in scented rice cv. Pusa 1460. There was considerable reduction in yield attributes and seed yield (24.1%, 40.6% and 67.1%) when transplanting was done on 16th July, 24th July and 31st July compared to 22nd June transplanting. Seed quality parameters like 1000- seed weight, germination percentage and electrical conductivity remained on a par up to 8th July whereas germination was not affected up to 16th July.



Effect of transplanting dates on seed yield and electrical conductivity of rice variety Pusa 1460

However, transplanting beyond 16th July (24th July and 1st August) resulted in significant reduction in all the parameters.

Effect of transplanting date on seed yield and quality of Pusa 1460

Trans-planting date	Panicles/ hill	Panicle length (cm)	Panicle weight (g)	Seed yield (t/ha)	1000-seed weight (g)	Germi-nation (%)	EC (dS/m)
22nd June	9.9	32.4	3.24	4.23	22.60	87.7	0.28
30th June	10.1	31.8	3.19	4.25	22.30	87.0	0.28
08th July	10.0	31.2	3.01	4.05	22.10	85.5	0.30
16th July	8.7	29.5	2.81	3.21	21.25	87.5	0.32
24th July	7.3	28.3	2.28	2.51	21.17	78.7	0.36
01st August	6.6	27.0	2.30	1.39	20.61	60.5	0.39
CD (P=0.05)	1.40	1.73	0.60	0.93	0.55	6.56	0.026

3.1.15 Effect of Nitrogen Fertilizer and Spacing on Seed Yield of Rice cv. Pusa 1460

Nitrogen levels had significant influence on the number of panicles/hill,1000- seed weight and seed yield of scented rice cv. Pusa 1460. The seed yield responded significantly up to 100 kgN/ha compared to that of the control and 50 kgN/ha. Further increase in nitrogen over 120 kgN/ha could not bring significant improvement in yield. Similar trend was noticed in straw yield. Among the different spacings maximum seed yield was obtained in closer spacing (20x15cm) which was significantly higher than that of 30x15cm spacing and on a par with that of 15x15cm and 25x15cm spacings. Spacing did not affect the straw yield.

Influence of nitrogen and spacing on the yield of scented rice cv. Pusa1460

Treatment	Panicles/ hill	1000-seed weight (g)	Seed yield (t/ha)	Straw yield (t/ha)
Nitrogen (kg/ha)				
0	7.3	21.34	2.63	6.03
50	9.8	21.55	3.96	7.07
100	11.6	21.90	4.47	8.41
150	12.0	22.16	4.80	9.04
CD (P=0.05)	1.26	0.35	0.45	1.42
Spacing (cm)				
15x15	8.5	21.80	4.18	8.1
20x15	9.6	21.76	4.31	7.6
25x15	10.7	21.83	3.95	7.9
30x15	11.8	21.65	3.43	6.9
CD (P=0.05)	1.26	NS	0.45	NS

3.2 SOIL MANAGEMENT

3.2.1 Long-term Impact of Rice-Wheat and Maize-Wheat Cropping Systems on the Stability of Humus-Carbon in the Soil

Kinetics of carbon release was studied on the naturally occurring clay-humus complexes extracted from the soils by sodium hydroxide - sodium pyrophosphate solution extraction. Results showed that the release of carbon (Q_t) at a given time from clay-humus complex followed very closely the Elovich reaction kinetics:

$$Q_t = (1/\beta)\ln(\alpha\ \beta) + (1/\beta)\ln t$$

with α and β coefficients signifying the initial rate of release and the coefficient of stability, respectively. The α and β values of clay-humus complex of different layers of two profiles from the contiguous area (one under rice–wheat and the other under maize–wheat for long time) were estimated. The average stability of the humus from the samples of rice–wheat cropping system was higher (β= 8.814) than that from maize–wheat cropping system ((β= 8.019). The average release of carbon from rice–wheat cropping system was lower (0.71%) than that from maize–wheat cropping system. In another set of experiments, the stability of carbon in the rhizosphere soil of wheat was lower, and carbon release coefficient was higher than that in the non-rhizosphere wheat soil. This is corroborated by the observations that the fraction of labile carbon was more in the rhizosphere than in the non-rhizosphere soil during wheat cropping.

3.2.2 Influence of Rice Cropping on the Clay Mineralogy of Two Divergent Soils

Clay fractions were isolated from soil samples collected from different depths of four profiles– two from BCKV farm, Mohanpur (WB) and two from PAU farm, Ludhiana (Punjab). Among the two nearby profiles collected from the contiguous places, one was under long-term continuous rice cultivation and the other from adjoining cultivated upland conditions. The X-ray diffraction studies confirmed the presence of pure phase mica (8.8 $^{o}2\theta$), vermiculite (6.1 $^{o}2\theta$), kaolinite (12.4 $^{o}2\theta$) and smectite (4.88 $^{o}2\theta$) (glycerol solvated). Other prominent peaks found were in the range of (11.2-11.3) $^{o}2\theta$, (9.2-9.3) $^{o}2\theta$ and (8.2-8.3) $^{o}2\theta$, which were ascribed to randomly interstratified kaolinite-mica, kaolinite smectite and mica-vermiculite, respectively. On an average, the Mohanpur soil exhibited more advanced stage of weathering compared

to the Ludhiana soil, and rice cultivation at the same site accelerated the weathering process.

3.2.3 Sulphate Sorption Characteristics of Acid Soils of Eastern India

A study was undertaken to relate sulphate (SO_4) sorption characteristics of five acid soils (two Alfisols, two Ultisols and one Inceptisol) with the soil properties. The pH of soils varied from 4.81 to 6.34. The organic carbon content ranged from 0.38 to 1.03%. The CEC was found to vary from 4.0 to 11.0 cmol(p^+) kg^{-1} and the clay content varied from 12.6 to 23.9%. The water extractable sulphate S and the phosphate extractable sulphate S ranged from 5.21 to 28.00 and 12.75 to 81.50 mg kg^{-1}, respectively.

The simple regressions showed that the Langmuir equation (r value, 0.94 – 0.99**) gave the best fit over Freundlich (r value, 0.84 – 0.97**) for all the soils. Sulphate sorption maximum (b) and constant related to bonding energy (K) calculated from Langmuir equation are presented in the following table. The sulphate sorption maximum value was found in the order: Alfisol > Ultisol > Inceptisol. The results indicated that SO_4 –S sorption maximum (b) had strong negative relationship with pH (– 0.892**). The sulphate sorption maximum was significantly related to clay (0.912**). There was a negative correlation between sulphate sorption maximum and organic carbon content (– 0.823**). The mechanism by which high organic carbon content inhibits the sulphate sorption on soil constituents involves the increase in dissolved organic carbon (DOC) concentration in soil solution. This increased DOC competes with sulphate ions for sorption sites and thereby decreases the sulphate sorption. Sulphate sorption maximum had a significant negative relation with water extractable sulphate S (– 0.972**) and a positive relation with phosphate extractable S (0.842**). The overall results indicate that the sulphate sorption capacity in moderate to strongly acid soils depended upon the soil pH, organic carbon, and native water and phosphate extractable sulphate pools.

Langmuir constants of S sorption in five acid soils

Soil /Location	Sulphate sorption maximum (b)	Bonding energy cons. (K) (L mg^{-1})	Max. buffering capacity (bXK) (L kg^{-1})	r-value
Alfisol (Dhanbad)	125.00	0.089	11.13	0.99**
Ultisol (Giridih)	110.23	0.912	10.05	0.97**
Ultisol (Hazaribagh)	115.38	0.950	10.96	0.97**
Inceptisol (Bhubaneswar)	84.83	0.104	8.82	0.99**
Alfisol (Ranchi)	120.23	0.078	9.38	0.94**

3.2.4 Stability of Clay Minerals in Relation to Pedogenic Progression in Different Agro-Ecosystems

Profile soil samples from one cultivated and two adjoining forest areas of Nagpur, Maharashtra, belonging to semi-arid eco-region in the Deccan Plateau, were collected. Semi–quantitative analysis of the clay minerals present in soils at different depths was done. The mineralogical studies revealed that, in general, in forest soils, there was more inter-stratification of mica-kaolinite and mica-smectite. This inter-stratification was less in the adjoining cultivated field. The more inter-stratification in forest soils might be due to more weathering caused by acid leaching of organic acids present in these soils. The conversion was more particularly in lower depth (60-100 cm) and on surface soils (0-15 cm). Computation of the weathering stage of the soil samples from the semi-quantitative clay-mineral analysis and Jackson's weathering sequences showed that in the surface soil the weathering stage was less advanced in the case of cultivated soils than that of the adjoining forest soils. Average weathering stage in surface soil of forest area indicated the sequence of transformation as mica .....▸ vermiculite .....▸ smectite. In the cultivated surface soils, the weathering was less advanced and followed the sequence mica .....▸ vermiculite.

3.2.5 Ion Exchange Resin Method for Estimation of Plant Available Soil Phosphorus

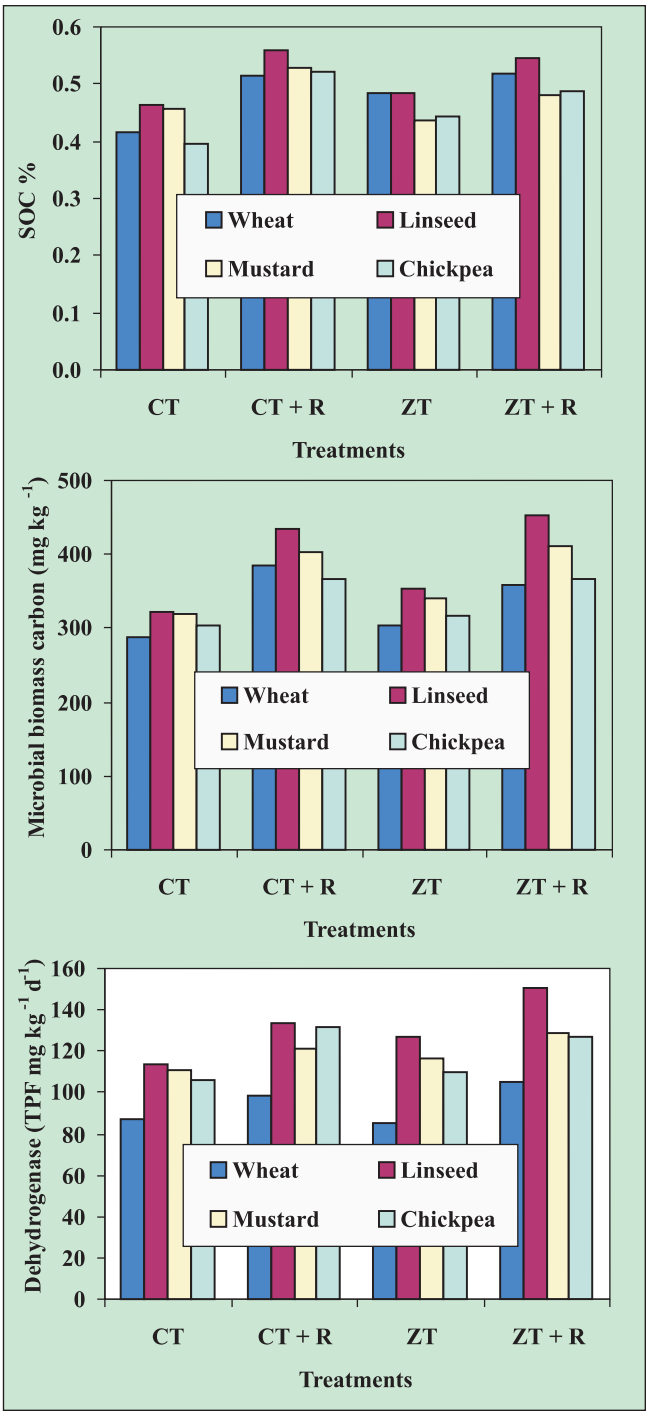
The hydroxide (OH^-)-saturated exchange resin bags with shaking period ranging from half-an-hour to 24 hours were evaluated on 27 soil samples for soybean crop against standard check of Olsen and $CaCl_2.2H_2O$ reagents as extractants for phosphorus. Pot experiment was conducted on soybean var. PK 1042 during *kharif* 2007 with two levels of phosphorus, viz. 0 (control) and 40 mg P_2O_5 kg^{-1} as KH_2PO_4. The dry matter yield (dried to a constant weight at 65°C) of the 45 days' old plants was recorded. Phosphorus content in the di-acid plant digests was determined. Data obtained showed that the phosphorus levels and soils significantly influenced dry matter yield, content and uptake of P by soybean. However, the interaction effect was non-significant. Soil P content extracted

by all the extractants gave highly significant positive correlation with most of the biological indices of soybean with the sole exception of OH^- resin bags with ½ hr shaking. The critical limits by promising extractants, viz., Olsen's, OH^- resin bags with 1 hr shaking, OH^- resin bags with 6 hours shaking and OH^- resin bags with 24 hours shaking were found to be 9.38, 4.60, 5.40 and 10.75 mg P kg^{-1} soil for soybean, respectively. The critical concentration of P in 45 days' old soybean plant tissues was found to be 0.26% on dry weight basis.

3.2.6 Soil Biodiversity Assessment for Enhancing Carbon Sequestration and Nitrogen Cycling under Different Tillage Systems and Crop Rotations

Soil samples from four different rotations, viz., maize–(wheat/linseed/mustard/chickpea)–greengram under conventional or no-tillage with or without residues treatments at the IARI research farm were studied in the *rabi* season of 3rd year of the experiment (2007-2008) for the assessment of C and N sequestration; and also for different biochemical and biodiversity indicators. The results revealed a range (0.39-0.54%) of soil organic C (SOC) in the samples. Incorporation of residues with conventional tillage (CT + R) or retention on the surface under zero tillage (ZT + R) had higher SOC than the conventional or zero tillage systems without residue. Growing linseed showed better C sequestration in soil than wheat, mustard or chickpea; and linseed under ZT + R had the highest SOC (0.54%) among the treatments. The average potential N mineralization (PNM) rate narrowly ranged from 1.4 mg kg^{-1} soil day^{-1} in ZT to 2.5 mg kg^{-1} soil day^{-1} in CT + R. The highest PNM of 2.6 mg kg^{-1} soil day^{-1} was exhibited in the system with chickpea under CT + R treatment.

The tillage and residue management practices had strong influence on the microbial biomass C (MBC), microbial quotient (ratio of MBC to SOC) and metabolic activity of microbial community (ratio of deydrogenase activity to MBC). These parameters invariably followed the order: ZT + R> CT+R> ZT> CT, and, as in the case of SOC, ZT + R under linseed had the highest MBC, dehydrogenase and MQ. The MBC was strongly associated (R^2=0.68**) with SOC, whereas deydrogenase had significantly higher correlation with MBC (R^2 = 0.60**) indicating that metabolic activity of the microbial communities was more strongly influenced by the pool of microbial biomass or metabolic quotient (R^2 = 0.45**) than the SOC (R^2 = 0.30*).



Soil organic C, microbial biomass C and dehydrogenase activity in soil as influenced by tillage and residues management practices in different maize-based cropping systems

With respect to microbial population, the average density of bacteria followed the order: CT + R> ZT + R> CT> ZT. In the case of fungi, the order was: ZT + R > CT + R > ZT > CT.

Proportionately higher fungal population under ZT + R indicates the higher contribution of fungi to residues decomposition and mineralization of nutrients.

3.2.7 Effect of Mineral Fertilizers and Organic Manure on the Soil Quality Index and Productivity under Soybean–Wheat Cropping Sequence

An attempt was made to monitor the soil quality and crop productivity under soybean-wheat cropping sequence as influenced by the application of organic manure and mineral fertilizers. The treatments consisted of three levels of N, viz., 0, 30 and 45 kg ha^{-1} for soybean and 0, 120 and 180 kg ha^{-1} for wheat. The entire amount of N was supplied to both the crops through urea and farmyard manure (FYM) alone or in combination of 1:1 ratio. Since the continuity of carbon supply depends on both the total pool size and lability, carbon management index (CMI) was computed. Results indicated that supplementation of N through FYM significantly improved the soil quality as evident from the carbon management index compared to that under integrated or inorganic sources after completion of five cropping cycles. Substantial improvement in the status of soil fertility parameters like available P and micronutrient cations was also discernible under organic and integrated inputs. However, FYM could not sustain the same yield level, particularly of wheat as that obtained with chemical fertilizers. Relatively higher amount of mineral N in soil and elevated N content in plant under chemical fertilizers compared to those under FYM at critical growth stages of wheat were responsible for higher crop yield. Hence, there is a need to integrate carbon–based soil quality index with the fluxes of mineral N in soil during the crop growth to have its true reflection on the productivity of the system.

3.2.8 Relative Efficacy of Soil and Foliar Application of Iron in Correcting Iron Deficiency under Aerobically Grown Rice

A field trial on diagnosis and amelioration of Fe deficiency under aerobically– grown rice was conducted using Pusa Sugandh 3, IR 64, IR 55419 and IR 55423 as test rice cultivars. Apart from control, Fe management treatments consisted of soil application of 150 kg $FeSO_4$/ha, and foliar application of 3% $FeSO_4$ solution. Results indicated that two foliar sprays of Fe (3% $FeSO_4$; 30 kg $FeSO_4$/ha) at 30 and 45 days after sowing (DAS) were more effective and economical in correcting Fe deficiency compared to soil application of 150 kg $FeSO_4$/ha. However, both the methods of Fe application were equally effective in maintaining Fe^{2+} in plants at 35 DAS. The Fe^{2+} content of $\geq$ 46 mg kg^{-1} in plants (on dry-weight basis) appeared to be adequate at 35 DAS for direct - seeded rice. Among the rice cultivars, Pusa Sugandh 3, IR 55419 and IR 55423 performed better under aerobic condition compared to IR 64.

3.2.9 Effect of Tillage, Water and Nutrient Management Practices on Available Micronutrient Status of Soil under Rice-Wheat and Maize-Wheat Cropping Sequences

Status of available micronutrient cations of surface soil (0-15 cm) as influenced by tillage-water-nutrient management practices was monitored after harvest of rice and maize under rice–wheat and maize–wheat cropping sequences, respectively, in the fifth cropping cycle. Results indicated that there was a substantial improvement in available iron (Fe) status in puddled soil (19.4 mg kg^{-1}) compared to that in unpuddled ones (10.6 mg kg^{-1}) after harvest of rice under rice–wheat cropping sequence. Among the water management treatments, continuous submergence and irrigation one day after drainage was equally effective in maintaining available Fe status in soil which was superior to irrigation after 3 days of drainage. Available Mn was depleted as a result of continuous submergence, particularly under unpuddled condition. These results clearly suggested that puddling coupled with intermittent drainage was not only a water-saving option but also an effective management practice in maintaining adequate fertility status of soil in respect of micronutrient cations, particularly Fe and Mn. Under maize–wheat cropping sequence, bed planting significantly improved the available Zn and Cu status of soil (1.25 mg kg^{-1}) as compared to that in conventional tillage (0.95 mg kg^{-1}). Two and three irrigations were equally effective in maintaining available Zn and Fe status of soil, which were significantly superior to irrigating maize crop once. However, on an average, available Fe (DTPA-Fe) content across the treatments was below the generalized critical limit of deficiency, i.e, 4.5 mg kg^{-1}. This suggests that there is a need for inclusion of Fe in fertilization schedule for maximizing the productivity under maize–wheat cropping sequence. Substitution of 25% of recommended dose of N by sewage sludge marginally increased the Zn, Cu and Fe status of soil.

3.2.10 Influence of Continuous Irrigation with Yamuna Water on Soil Chemical Environment

Soils irrigated with water from Yamuna river in Rainy Well near ITO, Delhi for more than two decades exhibited a significant build-up of total as well as DTPA-extractable Fe, Cu, Pb and Ni contents compared to those irrigated with tube well water. On the other hand in soils of Sarai Kale Khan (near Nizamuddin bridge, Delhi), an increase was observed only in total-Fe, -Zn, -Cd and DTPA- Fe, -Zn, -Pb contents. Though total Cu did not vary significantly in tube well and Yamuna water irrigated soils of Sarai Kale Khan, there was a significant decrease in the DTPA-Cu. The elevated heavy metals in both total and available pools in Yamuna water irrigated soils resulted in increased metal (Fe, Zn, Cu, Cd, Pb, Ni) concentration in guava fruit in Rainy Well, while Fe, Zn and Pb increased in tomato and Fe and Pb in wheat biomass in Sarai Kale Khan. Although long-term sewage irrigation contaminated the soils with heavy metals, it improved the soil fertility through a significant increase in the available P (35%), available K (28%), and available S (617%) contents in soils of Rainy Well.

Metal contents in different crops irrigated with tube well water and Yamuna water

Soils	Metal content in crops (mg kg^{-1})						
	Fe	Mn	Zn	Cu	Cd	Pb	Ni
Rainy Well Soil, Guava fruit							
Tube well water	343.5	35.5	23.2	21.8	1.77	13.1	22.4
Yamuna water	338.5*	37.8^{ns}	35.8*	25.3*	2.08*	18.5*	26.2*
Sarai Kale Khan Soil, Tomato fruit							
Tube well water	28.9	28.9	58.2	31.5	1.02	11.2	14.0
Yamuna water	32.5^{ns}	32.5^{ns}	62.6*	23.0^{ns}	0.88^{ns}	16.6*	12.0^{ns}
Sarai Kale Khan Soil, Wheat biomass							
Tube well water	29.3	38.7	28.7	15.1	0.39	5.65	9.5
Yamuna water	86.3*	25.6^{ns}	26.8^{ns}	7.9*	0.40^{ns}	7.75*	8.0^{ns}

^{ns} – not significant, *t test showing significant difference at 5% level

3.2.11 Screening of *Brassica* Cultivars for their Phyto-extracting Ability

In a net house experiment, 28 cultivars belonging to three *Brassica* species, namely, *Brassica carinata*, *B. napus* and *B. juncea* were tested for screening efficient phytoextractor for Cd, Pb and Zn. The cultivars Pusa Jaikisan, Pusa Bold, Rohini and Basanti of *B. juncea* and Pusa Swarnima of *B. carinata* emerged as promising accumulators of Cd. Basanti showed the highest yield in the Cd-spiked soil, while Pusa Bold showed the highest content of Cd. In the case of Pb, the cultivars RH 8113, GM 2, PBR 97 of B. *juncea*, GSL 1 of *B. napus* and Pusa Gaurav belonging to *B. carinata* were found to be promising. Among these, the cultivar RH 8113 showed the highest yield as well as contents of Pb. The cultivars belonging to *B. juncea,* RLM 619, Krishna, Basanti, Kranti and GM 2 were better accumulators of Zn than others. Among these, Kranti showed the highest yield, while Krishna showed the highest content of Zn. These screened species would be a valuable research material for choosing further efficient cultivars for the purpose of phytoremediation of heavy metal contaminated soils.

3.2.12 Release of Mineral Nitrogen from Sewage Sludge and Rice Straw

Laboratory incubation studies revealed that the soil amended with rice straw recorded the lowest content of mineral N up to 30 days of incubation; the mineral-N content, however, increased over control at 45 and 60 days but remained lowest among the amendments tried. Application of sewage sludge recorded the highest content of mineral inorganic N (NH_4 + NO_3- N). Sewage sludge and rice straw in a ratio of 1:3 recorded the highest content of mineral N. From this study, it can be concluded that application of these materials in soil requires a minimum of 15-30 days' time for release of mineral N in sewage sludge alone and mixed with rice straw, and 60 days in rice straw direct incorporation; otherwise, the crop sown immediately after these treatments may suffer from nitrogen deficiency.

3.2.13 Effect of Enriched Paddy Straw Compost on Nutrition of Cowpea and Soil Health

Five composts were prepared from paddy straw alone and by mixing 2% N, 2% N + 2% P, 2% N + 2% K and 2% N + 2% P + 2% K with paddy straw. The sources of N, P and K used for enrichment were urea, rock phosphate and mica, respectively. These composts were evaluated for their effect on yield, and nutrient uptake by cowpea cv. Pusa Komal, and soil fertility and biological health. Nitrogen dose of 60 mg N/kg soil was supplied either through compost alone or 75% N through compost + 25% N through urea or 50% N through compost + 50% N through urea under various treatments. Results showed that dry matter yield was significantly higher than that of control in all enriched compost treated pots. Maximum dry matter yield (40.67 g/ pot) was observed in the treatment where N had been applied

in the ratio of 50:50 through NPK-enriched compost and urea. Application of NPK-enriched compost in conjunction with urea N (25% N or 50% N) was associated with significant increase in total N uptake by cowpea over that of control. Application of N through NPK-enriched compost alone or in conjunction with urea (25% and 50% N) gave maximum uptake of P. Similar trend was observed in the K uptake by cowpea. The NPK-enriched compost in conjunction with 50% N through urea recorded maximum uptake of Zn, Cu, Mn and Fe. Application of enriched compost was associated with enhanced availability of major as well as micronutrients in the soil. Enriched compost treated soil samples showed a significant increase in organic C content and microbial biomass C (MBC) over those of control. Maximum increase in organic C (0.63%) and MBC (249 mg/kg) was observed where N had been applied in the ratio 50:50 by the NPK-enriched compost and urea. Significant increase in the dehydrogenase activity was also observed in the enriched composts.

3.2.13.1 Mineralization of C and N from cowpea decomposition

Above-ground portion of cowpea plant of 30 days (5 g fresh weight, 1.5 g dry weight) and 60 days (5 g fresh weight, 2 g dry weight) was decomposed in 200 g soil. Besides this, rice straw (2%) plus cowpea was kept for comparison. Initially organic C recorded higher values in the amended soil which, however, got stabilized at the end of the experiment. An appreciable increase in microbial biomass carbon (MBC) was found in the cowpea-amended soil followed by soil with cowpea and rice straw treatment.

3.2.14 Effect of Enriched Composts on Pearl Millet

Four enriched composts, viz., (i) ordinary rice straw (RS) compost (100% RS); (ii) enriched compost (100% RS) + rock phosphate (RP @ 4% P) + waste mica (@ 4% K) + phosphorus solubilizing micro-organisms (PSM); (iii) enriched compost (75% RS + 25% mungbean straw, MS) + RP (@ 4% P) + waste mica (@ 4% K) + PSM; and (iv) enriched compost (50% RS + 50% MS) + RP (@ 4% P) + waste mica (@ 4% K) + PSM along with one control and 100% recommended dose of NPK fertilizer (RDF) were evaluated in a field experiment on pearl millet. Application of different enriched composts and inorganic fertilizers recorded significantly higher grain, straw and total biomass yield of pearl millet. The highest grain yield (2.79 t ha^{-1}) was observed in treatment where 50% RDF was applied through inorganic fertilizers along with application of 5 t ha^{-1} of enriched compost prepared using 50% rice straw + 50% mungbean straw + RP @ 4% P + mica @ 4% K + PSM. Under this treatment, maximum uptake of N, P and K was observed. Higher yield and nutrient uptake in the soil receiving enriched compost prepared with 50% rice straw + 50% mungbean straw + RP @ 4% P + waste mica @ 4% K + *Aspergillus awamori* along with 50% recommended dose of fertilizer may be attributed to the overall improvement in the biological, physical and chemical properties of the soil, which favorably influenced the crop growth.

3.2.15 Dynamics of Potassium Release in Soil Fertilized with Microbially Treated Waste Mica and its Uptake by Sudan Grass

Greenhouse experiments were conducted to study the dynamics of K release from waste mica treated with microbial cultures, viz., *Bacillus mucilaginosus, Azotobacter chroococcum* and *Rhizobium* spp., and evaluate its effectiveness on yield and uptake by Sudan grass (*Sorghum vulgare* var *Sudanensis*) on two Alfisols, one each from Bhubaneswar and Hazaribagh. The crop was harvested five times at one-month interval. Biomass yield was recorded and the K content in Sudan grass was assessed. Soil samples were drawn after each cutting and analyzed for different pools of K. Results revealed that introduction of microbial cultures along with mica recorded higher yield and K uptake by Sudan grass in both the soils compared to those in mica alone. Treatment receiving *Bacillus mucilaginosus* proved to be effective in increasing the yield, uptake and recovery of K by Sudan grass. Treatment receiving mica along with *Bacillus mucilaginosus* also resulted in significantly higher water soluble and exchangeable K but lower amount of non-exchangeable K in both the soils. Alfisol from Hazaribagh recorded higher amounts of water soluble, exchangeable, non-exchangeable and total K than Alfisol from Bhubaneswar. Results on release kinetics of K in Alfisol from Bhubaneswar showed significant release of K from mica treated with microbial culture (*Bacillus mucilaginosus*). The X-ray diffraction analysis revealed that mica treated with *Bacillus mucilaginosus* underwent the highest dissolution in both the soils. This bio-intervention of waste mica could be an alternative and viable technology to utilize waste mica as a cheaper source of K fertilizer.

3.3 WATER MANAGEMENT

3.3.1 Meteorological Studies

3.3.1.1 Application of CLIMGEN model in climate change investigations and development of drought indices for agricultural water management

Daily rainfall data from 1972 to 2007 (36 years) of the WTC observatory were digitized and processed as an input to CLIMGEN model. These data were analysed using Fourier's transformation, and the data bases of the years 2010, 2020, 2030, 2040 and 2050 were generated using the capability of CLIMGEN model to study the decadal changes in daily precipitation. The non-parametric statistical methods, viz., the Mann-Whitney-Pettitt (MWP) method and Mann-Kendall rank correlation (MK) method were employed to test the existence of climate change pattern in the daily rainfall data.

3.3.2 Watershed Based Studies

3.3.2.1 Modelling watershed hydrologic responses using soft computing tools

Multivariate Adaptive Regression Spline (MARS) concepts were used to model the surface runoff and sediment yield from rainfall events in the watersheds under DVC, Hazaribagh, Jharkhand. MARS uses a "divide and conquer" approach through generation of splines and knots to automatically classify the training data into several groups. In each group, a regression line or hyperplane is generated for a specific spline and knot value and represented by basic functions. Compared to other soft computing technologies, MARS is fast, flexible, and capable of determining the important inputs to the model. In this study, MARS models were developed for two watersheds, i.e., Banha (17.61 km^2) and Pokhariya (64 km^2) using the data of daily rainfall, runoff and sediment yields of 7 years period. The validation results of MARS were compared with those of the best-fit regression models obtained using the "LabFit" tool. It was revealed that the MARS models for runoff prediction for both the watersheds performed better ($0.75 \leq R^2 \leq 0.92$) than the regression models ($0.45 \leq R^2 \leq 0.68$). Also, the MARS model developed for prediction of sediment yield for Banha watershed performed better (R^2= 0.82) than that of the regression model (R^2=0.56). It can be concluded that MARS can be successfully used for the prediction of watershed runoff and sediment yield from daily precipitation events.

3.3.2.2 Water harvesting and irrigation methods plan for Moolbari micro-watershed in Shimla district of Himachal Pradesh

Hydrologic monitoring and subsequent analysis of rainfall and runoff hydrograph revealed that water availability for utilization within the watershed could be increased as substantial amount of infiltrated water flow as base flow for considerable period. Normally the topography of the watershed in hills may not permit for large surface storage structures within the micro-watershed, and if large water harvesting structure is created at some location in the downstream side of main stream, pumping and conveyance would be a problem and uneconomical for small cultivated area. Looking at the prospect of stream water harvesting, the construction of a few small check dams in the primary and secondary channels at appropriate location to harvest the sub-surface flow was suggested. Tanks constructed near stream can be connected to sub-surface reservoir created upstream of the sub-surface dam to collect the sub-surface flow. By adopting the suggested measures, water availability in the micro-watershed can be increased by 0.02 mcm. Harvested water can be utilized efficiently through drip and sprinkler irrigation systems. Even small diameter flexible pipe can also be used to irrigate the vegetable crops. The irrigation system could be operated under gravity as sufficient head would be available to operate this.

3.3.3 Irrigation Agronomy

3.3.3.1 Performance of pearl millet-based cropping system under irrigated condition and its residual effect on succeeding wheat

In this study, wheat was grown after the harvest of pearl millet under the same field layout to asses the residual effect of different treatments. The treatments for pearl millet were two irrigation levels, i.e., rainfed and 2 irrigations applied each at flowering and dough stages, and 3 cropping systems, i.e., sole pearl millet (var. Pusa 383), pearl millet intercropped with mungbean (var. Pusa Ratna) and cowpea (var. Pusa Sampda) in additive series of intercropping. The experiment was laid out in split plot design with 3 replications. The irrigation schedule was allotted in main plots and cropping system in sub-plots. It was observed that pearl millet grown either as sole crop or intercropped with cowpea or mungbean produced similar grain yield. Additional yields of intercrops were obtained without any adverse effect on the yield of main crop. But pearl millet equivalent yields were significantly

higher with intercropping compared to sole crop under both rainfed and irrigated conditions. Soil moisture contribution from deeper soil depths towards the total water use was more under rainfed compared to irrigated crop. Total water use was higher in irrigated crop but the crop water use efficiency was more under rainfed conditions.

3.3.3.2 Aqua-ferti-seed drill studies

Under rainfed conditions, sowing by aqua-fert-seed drill (AFSD) gave significantly higher grain yield of wheat (2.44 t/ha) compared to that given by conventional method (CS) of sowing (1.68 t/ha). Under AFSD, germination and growth were better than those under conventional method. Performance of wheat variety HD 2865 was maximum (2.86 t/ha) followed by HD 2285 and HD 2687 (2.05 t/ha and 2.03 t/ha). The least grain yield was recorded with HD 2329 (1.69 t/ha). Moisture use by wheat under AFSD (in respect of seasonal consumptive use, moisture use rate and crop water use efficiency) was higher compared to that under conventional method. On an average, three irrigation, resulted in maximum seed yield (1.96 t/ha), which was 12.69% higher than that of one irrigation (1.74 t/ha) and 9.76% more than that of two irrigations (1.91 t/ha). Similarly nitrogen applied @ 90 kg/ha produced 1.98 t/ha, followed by 60 kg N/ha (1.88 t/ha) and the least with 30 kg N/ha (1.76 t/ha). Application of 40 kg S/ha enhanced the seed yield of mustard by 40.8% in comparison with no S (1.55 t/ha) followed by 20 kg S/ha which registered 21.63% increase over no S application. Moisture use in terms of seasonal consumptive water use and moisture use rate was maximum with three irrigations.

3.3.4 Pressurized Irrigation Studies

3.3.4.1 Response of summer groundnut to drip irrigation in semi-arid region

A study was carried out in summer 2007 with 5 irrigation schedules, viz., daily irrigation (As per ETcrop), alternate day, 30% of management allowed deficit (MAD), 40% MAD and 50% MAD and methods of sowing, viz., normal flat bed, paired row flat bed and paired row raised bed. Effects of irrigation schedules remained consistent with yield and water use efficiency, irrespective of the sowing methods. Daily irrigation as per the ETcrop produced the maximum pod yield. This was comparable to the pod yields obtained from the plots irrigated alternate day and at 30% management allowed deficit. However, the pod yields were significantly less if irrigation events were scheduled at greater than 30% management allowed deficit.

3.3.4.2 Response of garlic to different crop geometry under the influence of micro-irrigation and its economics

An investigation was carried out to evaluate the performance of garlic under micro-irrigation. The treatments consisted of six geometries and two methods of micro-irrigation, namely, drip and micro sprinkler. Maximum yield of garlic was found under drip irrigation (8.07 t/ha) compared to that under micro-sprinkler (6.61 t/ha). Amongst the crop geometries, 15 x 10 cm spacing produced significantly higher yield (9.23 t/ha). However, the yields obtained under 10 x 15 cm, 5 x 30 cm and 25 x 10 cm were on a par. Crop water use efficiency and irrigation water use efficiency were higher with drip irrigation compared to those under micro-sprinkler. Economic analysis indicated that drip irrigation gave maximum net returns and benefit cost ratio as compared to micro- sprinkler. The crop geometry of 10 x 15 cm under drip irrigation was found to be most economical.

3.3.4.3 Effect of drip fertigation on garlic yield

A field experiment was conducted on garlic var. G 50 with 3 irrigation levels, viz., 60%, 80% and 100% of the crop evapotranspiration (ET); and 4 fertigation frequencies, viz., biweekly, weekly, fortnightly and monthly. Yield of garlic was not significantly affected by biweekly and weekly fertigations, though there was a trend of lower yields with monthly fertigation. The highest yield was recorded in biweekly fertigation (18.7 t ha^{-1}), followed by monthly fertigation (10.4 t ha^{-1}).

3.3.4.4 Effect of deficit irrigation and its frequency on yield and quality of potato

An experiment was conducted on potato var. Kufri Badsah during October to February to study the effect of different levels of irrigation water and its frequency on potato yield and quality. Drip tape was buried manually in the middle of ridge at a depth of 15 cm. Three irrigation levels of 60%, 80% and 100% of the crop evapotranspiration and four frequencies of irrigations (daily, alternate day, biweekly and weekly) were maintained in the crop. Optimal or 'no stress' irrigation was calculated as the net amount of irrigation required to refill the soil moisture deficit with daily application of irrigation water. The water requirement of the potato was estimated as 23.5 cm. Maximum potato yield (46.5 t/ha) was obtained in the alternate day irrigation with no water stress. Maximum specific gravity (1.09) was observed with alternate irrigation. Maximum starch content (15.98%), and dry matter

content (21.6%) were observed in daily irrigation with no water deficit. Yield reduction was less for cultivation of potato under deficit irrigation.

3.3.4.5 Effect of deficit irrigation during crop growth stages of onion

In this study, onion was irrigated with subsurface drip irrigation involving nine treatments, viz., one period stresses at second, third and fourth growth stages and continuous partial stresses of 60% ETc and 80% ETc of the irrigation requirements. Minimum yield (28.7 t/ha) occurred in the fully-stressed treatment at 60% ETc. While maximum yield (37.7 t/ha) was obtained in the full-irrigation treatment. It was observed that water deficit at fourth growth stages gave non-significantly different yields from that in the optimum application. However, in no case the yields were higher than that in the optimum (full) irrigation. If the water deficit was in the second and third growth stages, or during all stages as 60% ETc and 80%ETc water deficit, the yields were significantly different from that in the optimal irrigation.

3.3.4.6 Effects of shading nets on micro-climate

Twelve shade nets of dimensions, 3m x 4m x 5m, of different colours and shade factors were constructed in the month of September and October. Temperature, solar insolation, wind velocity, relative humidity and ultraviolet radiation were measured at 10 a.m., 12.0 noon, 2.0 p.m. and 4.0 p.m. inside and outside the shade nets during winter season. Observations recorded are given below:

- Maximum temperature of 28.5°C, 23.2°C and 21.6°C in the months of November, December and January (at 12 noon) was recorded in the shade net having shade factor of 35% (BxW), while minimum was recorded in black colour shade net having 75% shade factor.
- Maximum humidity and solar insolation were observed in the BxG shade net having 35 % shade factor in the months of November, December and January
- Shade net having shade factor of 90% (Green) had minimum light intensity, while maximum was recorded in the shade net having shade factor of 35% (BxW and BxG).
- The shade net having shade factor of 90% (Green) received minimum ultra-violet radiation, while maximum was recorded in the shade net having shade factor of 35% (BxW and BxG).
- Wind velocity was maximum, ranging from 0.5 -1.00 m/s in shade net having shade factor of 35% and the rest of the shade net with different shade factors had negligible wind velocity.
- Shading reduced mean solar insolation by more than 40%, and the screen transmissivity was varying with solar elevation angle. Wind speed inside the shade net was reduced by more than 60%. Wind speed inside the screen house was reduced and ultimately crop water requirements would be lower than those under open field condition.

3.3.5 Groundwater Studies

3.3.5.1 Performance evaluation of filtration unit of ground water recharge shaft

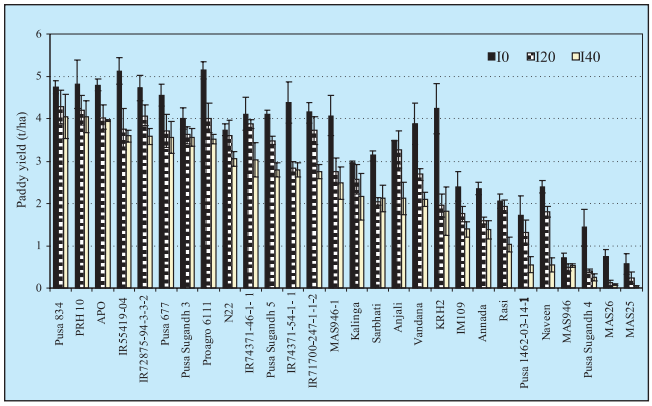
Recharge shaft models were fabricated using acrylic sheets and filled with filtration material, viz., coarse sand (CS), gravel (G) and pebbles (P) of varying depths to study the recharge rate and sediment concentration of the filtered water. The investigation was designed for five different thickness combinations of filtration materials, i.e., coarse sand (CS), gravel (G) and pebble (P) with varying depth ratios of 1:1.5:3, 1.5:1:3, 3:1:1.5, 3:1.5:1, 1:1:1 (CS: G: P). It was observed that higher depths of coarse sand in the filtration unit were very effective in reducing the recharge rate of the effluent. Also, the effect of change in the thickness combination of gravel and pebble layers with higher depth of coarse sand was observed to be minimal. Overall, the depth of the coarse sand layer in the filtration unit was responsible for controlling the recharge rate of the effluent. But, the rate of change in the outflow rate was not in proportion to the variations in the depths of the layers of coarse sand, gravel and pebble. The best thickness ratio of the filtration unit for obtaining the highest flow rate was observed to be 1:1:1 (CS:G: P). The combination of the filtration unit to perform the best filtration for all inflow sediment concentrations was 3:1.5:1 (CS: G: P). Analysis of the results of both the recharge rate and sediment concentration of the effluent revealed that the filtration layer thickness ratio of 1.5:1:3 (CS: G: P) would be the optimal design of the filtration unit of the recharge shaft for attaining higher recharge rate and better filtration of

the turbid water.

3.3.6 Aerobic Rice Cultivation

3.3.6.1 Aerobic rice system: A water-wise rice production system

Rice production under traditional puddle-transplanted lowland uses more than 50% of irrigation water used in agriculture. A change from traditional rice production system to aerobic rice system is imperative to increase water productivity of rice. Since no aerobic rice variety is released



Grain yield production of rice varieties in three levels of irrigation (Io, okPa; I_{20}, 20 kpa; I_{40}, 40 kpa) under aerobic production system at IARI during *kharif* 2007

for north Indian region, 28 rice genotypes were evaluated for their potential aerobic adaptation and high yield with three irrigation regimes, viz., irrigation at zero kPa, 20 kPa and 40 kPa soil moisture tension. Drought tolerant upland variety Nagina 22, aerobic rice varieties, namely, APO and MAS946-1 released by IRRI, Philippines and UAS, Bangalore, respectively, were used as checks. The total amount of water applied was 1345mm, 1045mm and 845 mm under the three irrigation regimes, respectively. Thus, aerobic rice method saved about 30-50% (~800 mm less water) as compared to 1800 mm water applied in transplanted rice. Pusa Rice Hybrid 10, Proagro 6111 (hybrid), Pusa 834, IR 55423-04, IR 72875-94-3-3-2 produced a grain yield similar to that of APO (4.8 t ha^{-1}) but higher than that of aerobic rice variety MAS946-1 (4.08 t ha^{-1}) under zero kPa. Pusa Rice Hybrid 10 and Pusa 834 showed a combination of aerobic adaptability similar to APO and better than Nagina 22 at 40 kPa, as they produced a grain yield of about 4 t ha^{-1}. The potential of aerobic rice in water saving was demonstrated in farmer's field in three villages of Bhulandshar district (U.P.).

3.3.7 Water Quality Studies

3.3.7.1 Spatio-temporal variability of groundwater quantity and quality parameters

Keeping in view the deteriorating ground water quantity and quality of National Capital Territory (NCT) of Delhi owing to higher population density and over-exploitation of ground water, efforts were made in this study to map the spatial and temporal variability of ground water depth and quality parameters using geostatistical concepts. The ground water depth and quality parameters were analyzed from the existing tubewells, and the spatial variability and probability maps were generated using geostatistical concepts. Ordinary kriging method was used to analyze the spatial variability of groundwater depths. Indictor kriging method was used to analyze the groundwater quality parameters such as chloride, electrical conductivity (EC), fluoride, magnesium and nitrate concentrations equal to or greater than that of the groundwater pollution threshold levels. It was revealed that the exponential semi-variogram model fitted well with coefficient of determination (R^2) equaled to 0.996 for water table depth, whereas the spherical semi-variogram model fitted well for the water quality parameter such as chloride (R^2 = 0.915), EC (R^2 = 0.897), fluoride (R^2 = 0.505), magnesium (R^2 = 0.920) and nitrate (R^2 = 0.656). The water quality parameters, viz., chloride and EC were inversely related with water table depth, whereas the magnesium concentration in groundwater was directly related to the depth of water table, and nitrate concentration had no correlation with the depth. The areas with potential salinization were in the northern part of NCT, whereas the chloride concentration was higher in the southern part and the nitrate pollution in the western part of NCT. The indicator kriging revealed that 50% of area within NCT was having polluted ground water resources.

3.3.7.2 Temporal variability of quantity and quality parameters of the waste water carrying channel in IARI farm and its use in agriculture

In continuation of the periodic reading of the flow depth and collection of water samples of the waste water-carrying channel at IARI farm, it was observed that for an average depth of 5 m from the culvert surface, the quantity of water flowing past the channel is about 48.5 million litres per day. By diverting about 50% of water from the channel and permitting the rest to flow past the channel to downstream regions, one can harvest about 24.25 million litres of water per day, which can meet the irrigation requirement to a large

extent. Further, to ascertain its use for agriculture, the water quality parameters were investigated by analyzing the collected samples from the channel at different times and days of the month throughout the year. It was observed that sodium absorption ratio (SAR) varied from 2.5 to 7.5 units, and was within safe limit for irrigation purposes. The residual sodium carbonate (RSC) value of less than 1.25 indicates that the water is safe for irrigation and a value more than 2.5 restricts its use for irrigation. It was observed that 20% of the collected waste water samples exceeded the safe limit (RSC > 2.5) for irrigation. The EC and pH of waste water were within the safe limit for irrigation purposes. Overall, the waste water was safe for irrigation with specific amendments to reduce the RSC or can be used safely in conjunction with fresh water. However, there is a need to estimate the content of heavy metals in the waste water and conduct long-term irrigation experiments to determine its impact on the soil and underlying ground water resources for sustainable agricultural production.

3.4 INTEGRATED NUTRIENT MANAGEMENT

3.4.1 Long-term Effects of Fertilizers and Manures on Crop Productivity and Soil Fertility under Maize-Wheat Sequence

The long-term experiment established in 1971-72 at IARI research farm under the aegis of All India Coordinated Research Project (AICRP) on Long-term Fertilizer Experiments (LTFE) was continued with maize-wheat cropping system. The experiment comprised sub-optimal (50% of recommended) to super-optimal (150% of recommended) NPK, NPK along with S, Zn, or FYM, unbalanced fertilizer use (NP or N alone), and an unfertilized control.

3.4.1.1 Crop productivity

Grain yield of maize and wheat under 150% NPK was significantly greater than that under optimal, i.e., 100% NPK. In fact, 150% NPK and NPK+FYM out-yielded all other treatments, and the yields under these two treatments were statistically on a par. A significant yield response to P and K was recorded in wheat. Comparison of mean yields (1993-94 to 2006-07) with the current yields confirmed an increase in response to P and a concomitant decrease in response to N with the passage of the time. Similarly, the yield differences between 150% NPK and NPK exhibited a widening gap over the years. The data trends underline the need for upward revision of fertilizer recommendations and also an increasing significance of balanced fertilization for sustaining high productivity levels.

Mean and current yields of maize and wheat under different nutrient supply options under long-term experiment

Treatment #	Mean grain yield (t ha^{-1}) (1993-94 to 2006-07)		Current grain yield (t ha^{-1})	
	Maize	Wheat	Maize	Wheat
50 % NPK	1.65	3.97	1.45	3.30
NPK	1.99	4.45	1.83	4.17
150 % NPK	2.29	4.81	2.25	4.69
NPK+ hand weeding	1.99	4.43	1.92	4.02
NPK+ Zn	2.12	4.54	2.01	4.27
NP	1.73	4.11	1.67	3.79
N	1.56	3.83	1.43	3.15
NPK+ FYM	2.34	4.88	2.18	4.58
NPK+ S	2.10	4.55	2.04	4.38
Unfertilized control	1.12	2.39	1.06	2.07
LSD (P=0.05)			0.15	0.36

#100% NPK for maize or wheat means 120-26-33 kg N-P-K ha^{-1}. FYM @ 15 t ha^{-1} was applied to maize, S @ 45 kg ha^{-1} to both crops, and zinc sulphate @ 10 kg ha^{-1} was applied to wheat.

3.4.1.2 Soil fertility status

The initial organic C content (0.44%) of the soil (0-15 cm depth) was either maintained or registered an increase in different treatments, except 50% NPK, N alone and control. The highest value of organic C (0.54%) was recorded under NPK+FYM. Available P content showed build-up in treatments receiving P through fertilizers or FYM, and the extent over the

Soil fertility status under long-term experiment after completion of 36 cropping cycles

Treatment	Organic C (%)	Available nutrients (kg ha^{-1})		
		P	K	S
50% NPK	0.39	20.4	229	22.0
NPK	0.44	29.5	259	20.5
150 % NPK	0.48	36.7	280	18.0
NPK + hand weeding	0.45	28.0	250	21.0
NPK + Zn	0.45	31.6	258	21.6
NP	0.43	29.7	183	23.5
N	0.38	18.1	211	24.8
NPK + FYM	0.54	38.5	272	30.7
NPK + S	0.47	32.2	230	39.3
Unfertilized control	0.34	17.9	188	21.9
LSD (P=0.05)	0.05	3.8	24	2.6

initial content was naturally higher in super-optimal NPK as well as NPK + FYM plots. Available K content of the soil also varied in accordance with annual input as well as crop productivity levels. Skipping of K in NP or N alone plots led to low soil K content compared with K-treated plots. Application of 45 kg S ha^{-1} to each crop in NPK+ S treatment resulted in significant increase in available S compared with the initial content (22.5 kg ha^{-1}). On the other hand, a significant depletion in available S content was recorded under super-optimal NPK, owing to greater annual removals.

3.4.1.3 Distribution of aggregates in relation to carbon

Data on physical properties revealed that rewetted aggregate size distributions were dominated by macro-aggregates (4-0.25 mm) in all the treatments at all the soil depths. Significant differences due to fertilizers and manures were observed in both micro - and macro aggregates. Percentage of macro-aggregates increased, whereas micro-aggregates (0.25-0.1 mm) decreased significantly in the plots with 100% NPK + FYM over those with no FYM (100% NPK) in 0-15 cm soil layer, while at 15-30 cm, opposite trend was obtained. At 0-15 cm, the control treatment showed the highest and the lowest percentage of micro-aggregates and macro-aggregates, respectively. Application of balanced dose of NPK at 150% level showed significantly higher percentage of micro-aggregates compared to those at lower doses (50% NPK and 100% NPK) or unbalanced fertilization (100% NP and 100% N) in 0-15 cm layer. Total organic C concentration was greater in micro-aggregates than in macro-aggregates at all the soil depths, irrespective of the treatment. However, irrespective of the aggregate size class, the concentration of C was higher in the NPK + FYM treatment, followed by 150% NPK at 0-15 cm and 15-30 cm soil layers.

3.4.2 Integrated Nutrient Supply and Management in Pearl Millet–Mustard Cropping System

A field experiment initiated during 2004-05 at IARI research farm was monitored during 2006-07 for mustard and pearl millet crops. The results revealed that with the increase in the rates of N + P_2O_5 + K_2O from 75+30+30 to 150 +75 +75 kg ha^{-1}, there was significant increase in grain and stover yields and uptake of N, P and K by both the crops. Further, application of 20 t FYM and 10 t sulphitation pressmud (SPM) per hectare with recommended level of nutrients (100+50+50 kg ha^{-1}) to preceding pearl millet had residual effect on mustard equivalent to that of direct application of their half dose (10 t and 5 t ha^{-1}, respectively) to mustard in terms of grain yield, nutrient uptake, and N and P use efficiency. Contribution of directly applied FYM (10 t ha^{-1}) and SPM (5 t ha^{-1}) towards total N and P uptake in mustard was 14.49% and 6.57% for N, and 13.29% and 5.71% for P, respectively. Effect of conjoint application of 100 kg N +50 kg P_2O_5 + 50 kg K_2O ha^{-1} along with FYM (10 t ha^{-1}) was equivalent in effect to the application of the highest level of nutrients (150+75+75 kg ha^{-1}) through fertilizers in terms of grain yield and nutrient uptake (NPK). However, the former proved to be much better than the latter in relation to nutrient use efficiency (N and P) in pearl millet.

3.4.3 Characterization of Rock Phosphate-enriched Pressmud Compost and its Effect on Phosphorus Use Efficiency in Pearl Millet–Mustard Sequence

Rock phosphate-enriched pressmud compost (RPEPMC) was prepared by using a mixture of low-grade rock phosphate (RP) and fresh pressmud in the ratio of 1:20 with inoculation of composite microbial culture, and evaluated through a series of laboratory and field experiments. Field experiments were carried out to study the direct effect of levels and sources of RFEPMC and DAP, and their combinations in the ratios of 3:1, 1:1 and 1:3 on pearl millet and their residual effect on succeeding mustard. Results showed that C:N ratio of the compost material decreased significantly from 27.2 to 10.2, while total P_2O_5, citrate-soluble P and water-soluble P contents increased significantly with the progression in the period of composting up to 120 days. Their values in the final compost product were 5.67%, 2.19% and 0.49%, respectively.

Laboratory incubation experiment indicated that Olsen's P content in the P-treated soil (RP and RPEPMC) showed a gradual decrease after 75 to 150 days, while exchangeable Ca values exhibited an increasing trend with progression of incubation time from 15 up to 150 days. The mean Olsen's P as well as exchangeable Ca values were significantly higher with RPEPMC in comparison to RP at 30 mg P kg^{-1} level.

Field evaluation showed that among the three ratios of RPEPMC and DAP combinations (1:3, 1:1 and 3:1) tried at 80 kg P_2O_5 ha^{-1}, grain yield and total P uptake of pearl millet in 1:3 ratio (2.69 t ha^{-1} and 14.5 kg P ha^{-1}, respectively) and 1:1 ratio (2.65 t ha^{-1} and 14.1 kg P ha^{-1}) were comparable to each other but both were superior to 3:1 ratio (2.35 t ha^{-1} and 12.6 kg P ha^{-1}). The 1:3 RPEPMC:DAP combinations at

80 kg P_2O_5 ha^{-1} proved as effective as DAP alone in terms of grain yield, total P uptake, and per cent P utilization by pearl millet. The residual effect in terms of per cent relative grain yield and P uptake response in mustard was maximum with 3:1 ratio (66.4 and 65.9) of RPEPMC:DAP followed by 1:1 ratio (65 and 64.2) and 1:3 ratio (61.8 and 59.6). On the basis of per cent utilization, the three ratios of RPEPMC and DAP combinations were in descending order of 3:1, 1:1 and 1:3.

3.4.4 Integrated Nutrient Management in Pigeonpea-Wheat System

A field experiment on extra-short duration (ESD) pigeonpea-wheat cropping system established in 2004-05 was continued during the fourth consecutive year. In all, 15 treatments were evaluated in a randomized block design, which comprised fertilizer NPK and organic manures, i.e., FYM or sulphitation pressmud (SPM) alone or in combination induced defoliation (ID) in pigeonpea using a foliar spray of 10% urea solution at physiological maturity, and an unfertilized control.

Conjoint use of fertilizer NPK and manure (FYM or SPM) improved soil physical health as revealed by a significant decrease in soil bulk density (BD) and an increase in water holding capacity (WHC) *vis-à-vis* sole fertilizer treatments or control. Whereas BD decreased from 1.50 Mg m^{-3} in N, P and K to 1.39 Mg m^{-3} in NPK+SPM+ID plots, the WHC increased from 35.1% in NPK to 39.4% in NPK+FYM or NPK+SPM plots. Available N, P and K content also exhibited improvement. In general, the highest values of microbial biomass C (MBC) and microbial biomass N (MBN) were recorded in treatments that had received NPK + manure (FYM or SPM) with or without ID.

Physical and biological characteristics of soil (0-15 cm) under integrated nutrient management

Treatment	Bulk density (Mg m^{-3})	Water holding capacity (%)	MBC (mg kg^{-1})	MBN (mg kg^{-1})
Control	1.57	35.2	178	22.8
NPK	1.50	35.1	239	39.1
FYM alone	1.45	35.6	264	41.4
NPK+ FYM	1.42	39.3	378	60.3
SPM alone	1.48	34.5	245	38.5
NPK+ SPM	1.42	39.4	303	44.4
NPK+ ID	1.44	38.1	288	43.4
NPK+ FYM+ ID	1.40	38.5	373	65.8
NPK+ SPM+ ID	1.39	37.5	327	52.4
LSD (P=0.05)	0.09	3.5	33	5.9

Application of fertilizer NPK at soil-test based recommended rates produced 1.76 t ha^{-1} grain yield of pigeonpea, which was significantly greater than that of unfertilized control (0.88 t ha^{-1}) or treatments receiving manure alone (1.05-1.20 t ha^{-1}). The grain yield with NPK+ manure (FYM/SPM) was, on the other hand, significantly greater than that of sole NPK treatment. In wheat crop also, integrated use of NPK and FYM/SPM produced significantly greater grain yield (4.83 to 5.32 t ha^{-1}) than that of recommended NPK (4.05 t ha^{-1}). The performance of SPM was constantly superior to that of FYM. Application of manure @ 2.5 t ha^{-1} to pigeonpea and @ 7.5 t ha^{-1} to wheat appeared to be a better strategy than applying the entire quantity of manure to wheat. The use of SPM or FYM at 10 t ha^{-1} in the absence of fertilizers could produce a grain yield of 2.56 - 2.79 t ha^{-1} only, indicating clearly that the organics applied alone might not support high productivity levels.

Induced defoliation treatment imposed in pigeonpea led to an additional litter-fall of about 1.4 t ha^{-1}, through which 40 kg N ha^{-1} was recycled. The effect of ID on pigeonpea yield was not visible, but the same was very much apparent on the yield of succeeding wheat. The ID accounted for wheat grain yield increase of 0.15 - 0.50 t ha^{-1} in NPK or NPK + manure (FYM/SPM) treatments, owing to additional nutrient input (particularly N) and a marked improvement in soil health parameters.

3.4.5 Development of Basic Data and Soil Test-Based Fertilizer Recommendations for Pearl Millet and Mustard

From the soil test crop response correlation field experiments conducted on pearl millet cv. Nagina and mustard cv. Pusa Jagannath, the basic data were generated on nutrient requirement of crops and per cent utilization efficiency of soil, fertilizers and manure nutrients. The soil test-based fertilizer recommendations for targeted levels of yield production for pearl millet and mustard were developed.

From the follow-up experiments, it was observed that besides acting as the store house of nutrients, FYM also raised the efficiency of applied N, P and K fertilizers by 7.4%, 6.8% and 29.0% in pearl millet, and 11.2%, 6.5% and 25.8% in mustard over minus-FYM treatments. Because of these direct and indirect contributions of FYM, the fertilizer dose of N, P_2O_5 and K_2O could be reduced by 35, 30 and 25kg/ha; and 50, 35 and 30 kg/ha with 10 t FYM /ha in pearl millet and mustard, respectively.

Basic data and soil test-based fertilizer adjustment equations for pearl millet and mustard

Nutrient	NR*	% CS	% CF	% CFYM	Fertilizer adjustment equations
Pearlmillet (Nagina)					
Without FYM					
N	3.30	19.1	43.6	-	FN = 75.7 T – 0.44 SN
P_2O_5	13.5	46.0	19.7	-	FP_2O_5 = 68.5 T – 5.35 SP
K_2O	47.4	19.3	117.0	-	F K_2O = 40.5 T – 0.20 SK
With FYM					
N	3.30	19.1	51.0	23.0	FN = 64.7 T – 0.37 SN – 2.25 FYM
P_2O_5	13.5	46.0	26.5	9.0	FP_2O_5 = 50.9 T – 3.97 SP – 1.56 FYM
K_2O	47.4	19.3	146.0	52.0	F K_2O = 32.5 T – 0.16 SK – 1.50 FYM
Mustard (Pusa Jagannath)					
Without FYM					
N	46.2	21.5	43.4	-	FN = 106.4 T – 0.50 SN
P_2O_5	15.5	48.7	22.3	-	FP_2O_5 = 69.5 T – 5.00 SP
K_2O	52.6	32.3	82.5	-	F K_2O = 63.8 T – 0.47 SK
With FYM					
N	46.2	21.5	54.6	24.3	FN = 84.6 T – 0.39 SN – 2.23 FYM
P_2O_5	15.5	48.7	28.8	12.4	FP_2O_5 = 53.8 T – 3.87 SP – 1.97 FYM
K_2O	52.6	32.3	108.3	36.3	F K_2O = 48.6 T – 0.36 SK – 1.41

* NR is nutrient requirement in kg/t of grain production
% CS, % CF and % CFYM represents per cent contribution from soil available, fertilizer and FYM nutrients. S and F represent soil and fertilizer nutrients (kg/ha), FYM represents Farmyard Manure (t/ha), and T denotes yield target (t/ha)

3.4.6 Integrated Nutrient Management in Sweet Corn

In an experiment on sweet corn (Zea mays var. saccharata), three levels of fertilizers {recommended dose of NPK (RDNPK), 125% RDNPK, 150% of RDNPK} with (6 tonnes of FYM/ha) and without FYM were tested.

Effect of organic sources and fertility levels on green cobs yield (t/ha) of sweet corn

Treatment	RDNPK*	125% RDNPK	150% RDNPK	Mean
No FYM	8.9	9.8	10.6	9.8
FYM @ 6 t/ha	10.4	11.3	11.8	11.2
Mean	9.7	10.5	11.3	
CD (P=0.05) Organic manure = 0.53, Fertility levels = 0.65, Interaction = 0.81				

*Recommended dose 150kg N, 60kg P_2O_5, 40 kg K_2O/ha

Significant improvement in green cobs (14.3%) and fodder yield (12.7%) was recorded with the application of FYM over no FYM treatment. Similarly, increasing the levels of NPK to 125% and 150% of RDNPK significantly improved green cobs yield by 8.2% and 16.5%, and fodder yield by 8.6% and 21.8%, respectively. Interaction between organic manures and fertility levels indicated that combined application of 6 tonnes of FYM/ha with RDNPK and 125% RDNPK gave cob yields similar to those obtained with 125% and 150% RDNPK alone, respectively. Significant enhancement in net returns and benefit: cost ratio was noticed with FYM application and with increasing levels of fertility.

3.4.7 Effect of Integrated N Management in Sole and Intercropped Cotton

A field study was conducted during *kharif* 2007 on integrated N management in sole and intercropped Bt cotton. Intercropping of groundnut with cotton had no adverse effect on seed cotton yield as compared to sole cotton. An additional groundnut yield (0.46 t/ha) in intercropping enhanced the system productivity in terms of cotton equivalent yield by 38%. Groundnut as an intercrop in cotton produced 42% of the sole crop yield (1.08 t/ha).

Effect of integrated N management in sole and intercropped cotton

Treatment	Seed cotton yield (t/ha)	Groundnut pod yield (t/ha)	Cotton equivalent yield (t/ha)
Cropping system			
Sole cotton	2.24		2.24
Cotton + groundnut (1:3)	2.53	0.46	3.10
CD (P=0.05)	NS		0.12
N management (% inorganic N + % FYM-N)			
0+0	1.53	0.58	1.85
100+ 0	2.77	0.40	2.82
75 + 25	3.05	0.39	3.30
50 + 50	2.20	0.47	2.50
CD (P=0.05)	0.44	0.12	0.18

Sole groundnut yield: 1.08 t/ha
Minimum support price (Rs/t): Cotton: 20300; groundnut pods: 15500

Substitution of 25% N through FYM being on a par with 100% N through fertilizers recorded markedly higher seed cotton yield over 50% substitution of fertilizer N through FYM. Groundnut recorded significantly higher yield in unfertilized plots, which was similar to 50% N each supplied through fertilizer and FYM, but greater than 100% inorganic N, and 75% inorganic N +25% N through FYM. The system productivity was significantly more in treatment receiving 75% inorganic N+25% N through FYM.

3.5 NUTRIENT MANAGEMENT

3.5.1 Appraisal of Multi-Nutrient Deficiencies in Soils and their Amelioration through Site Specific Nutrient Management

In the on-going IARI-IPNI (earlier PPIC) India Programme collaborative research project on soil fertility appraisal was extended for a period of 3 years (2007-08 to 2009-10), expanding its scope to include field experiments on development of Site Specific Nutrient Management (SSNM) packages, in addition to the soil fertility, appraisal as mandated in the initial project. The present report includes fertility appraisal in the soils of 03 AESRs, and the results of SSNM experiments on pearl millet cv. Hybrid JKDH 676.

3.5.1.1 Soil fertility appraisal

Soils belonging to hot hyper-arid climate (Jodhpur) were mildly alkaline to alkali in reaction with an average pH of 8.6, whereas those from moist sub-humid climate (Ranchi and Nadia) generally exhibited mild to acute acidity. Deficiencies of 6 nutrients i.e. N, P, K, S, Zn and B were noticed in all the 3 AESRs, although the magnitude varied. More than 90% samples across the locations containing $\leq$ 0.75% organic C were categorised as responsive to fertilizer N. Equally widespread was the deficiency of P in Jodhpur and Ranchi, and that of K in Nadia soils. Among secondary nutrients, S-responsive category varied from 19% in Nadia to as many as 95% in Ranchi. Inadequacy of Ca (39%) in Ranchi and that of Mg (36%) in Jodhpur was also noticed. Of the micronutrients, deficiency of Zn ranged between 14% and 99% and that of B between 14% and 56% in different AESRs. Prominent multi-nutrient deficiency combinations included 4 to 7 nutrients in the case of Jodhpur and Ranchi, and 2 to 4 nutrients in Nadia district. Deficiency of N,P,K,Zn and N,P,K,S,Zn accounted for 25% of the samples from Jodhpur, whereas 33% samples from Ranchi exhibited simultaneous deficiency of N,P,K,S,Zn or N,P,K,S,Zn,B. In Nadia, N,K,B (35%) deficiency was predominant, followed by N, and K (21%).

3.5.1.2 On-farm experiments on SSNM

The soils of SSNM experimental sites (Lohtaki village) were loamy sand in texture, and contained very low organic C (0.19% to 0.35%). These soils suffered from N, K, P, S, Zn and B deficiencies of varying magnitude. All 14 sites contained N in responsive range, and 13 out of 14 sites were rated as K-responsive also. Thus SSNM treatment comprised 4 to 6 nutrients in different experiments. The grain yield of pearl millet under SSNM was the highest, which ranged between 3.75 t ha^{-1} and 4.58 t ha^{-1} with a mean of 4.09 t ha^{-1}. Averaged across the experiments, SSNM out-yielded the farmers' fertilizer practice (FFP) by 1.81 t ha^{-1} and state recommendations (SR) by 1.0 t ha^{-1}, accounting for a yield response of 79% and 32%, respectively. Fertilizer for target yield (FTY) and FTY + secondary and micronutrients were the other promising nutrient management options. Substantial yield gains under these treatments were attributed to the application of all deficient nutrients in adequate amount as against 60 kg N/ha alone in the FFP and a K-skipped fertilizer application in the SR. The promising treatments, viz., SSNM, FTY or FTY+ secondary and micronutrients resulted in additional net returns of Rs. 8900 to 9800 ha^{-1} over FFP. Application of K along with FFP or SR invariably increased the yield, but the magnitude of response was greater under SR. In fact, treatment differences in individual experiments depended largely on the available nutrient status of the soil, which were masked on explaining the averaged results across the experiments.

3.5.2 Nutrient Management through Organic Sources in Brinjal-based Cropping Systems

A field experiment consisting of three brinjal based cropping systems and six fertility levels was conducted during 2006-07. Brinjal grown after fenugreek–*Sesbania* yielded more than that grown after brinjal (ratoon) –*Sesbania* and tomato–*Sesbania*. Brinjal–fenugreek–*Sesbania* cropping system gave the highest productivity, being 48.6% and 33.0% more than those of brinjal-brinjal (ratoon) –S*esbania* and brinjal–tomato–*Sesbania* cropping systems, respectively. Application of FYM @ 5 t/ha + vermicompost @ 2.0 t/ha + biofertilizer gave the highest yield of brinjal and total brinjal equivalent yield. Application of FYM @ 10 t/ha alone was inferior to other combinations of nutrient sources in respect of brinjal yield and total brinjal equivalents.

Effect of organic sources on the productivity (t/ha) of brinjal- based cropping systems

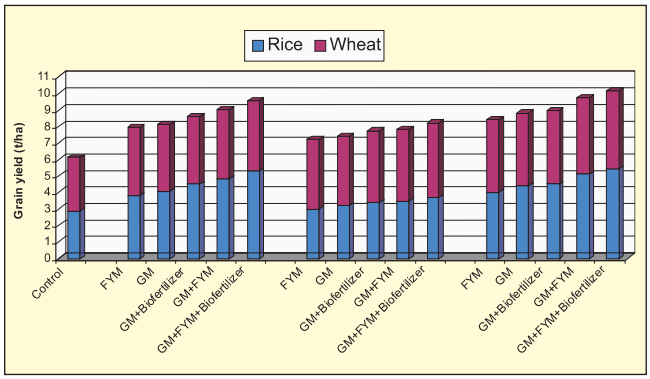
Treatment	Brinjal	Brinjal ratoon	Fenugreek	Tomato	Brinjal equivalent yield
Cropping system					
Brinjal-brinjal ratoon-*Sesbania*	30.2	26.2			56.4
Brinjal-fenugreek-*Sesbania*	33.6		2.01		83.8
Brinjal-tomato-*Sesbania*	31.6			15.7	63.0
CD (P=0.05)	NS				
Fertility level					
Control	20.0	17.5	1.51	10.4	45.3
FYM @ 10 t/ha	31.2	26.5	2.02	17.2	68.3
FYM @ 10 t/ha + biofertilizers	33.5	27.2	2.14	17.7	72.1
Vermicompost@ 4.0 t/ha	34.6	28.0	2.08	15.9	71.8
Vermicompost @ 4.0 t/ha + biofertilizers	35.9	28.9	2.18	16.3	74.5
FYM @ 5 t/ha + Vermicompost @ 2.0 t/ha + biofertilizers	35.7	29.7	2.13	16.9	74.6
CD (P=0.05)	2.4	4.7	0.37	2.9	

3.6 RICE-WHEAT CROPPING SYSTEM

3.6.1 Organic Farming of Rice-Wheat Cropping System

A field experiment was conducted on organic farming of rice-wheat cropping system to study the effect of different combinations of organic manures and biofertilizers on the productivity of the system. A set of five treatments was applied to rice only, to wheat only and to both the crops.

Application of FYM, green manure (GM), GM + biofertilizers, GM +FYM, and GM + FYM + biofertilizers to rice increased the productivity by 31%, 41%, 55%, 65% and 83%, respectively, in rice; and by 25%, 25%, 28%, 31% and 31%, respectively, in wheat over that of control. Similarly, application of FYM, GM, GM + biofertilizer, GM + FYM and GM + FYM + biofertilizers to wheat increased the productivity over that of control by 3%, 10%, 17%, 21% and 28%, respectively in rice, and 31%, 31%, 34%, 34% and 41%, respectively in wheat. However, the best results were obtained when these combinations were applied to both rice and wheat. Application of FYM, GM, GM + biofertilizers, GM + FYM and GM + FYM + biofertilizers to both rice and wheat increased the productivity over that of control by 38%, 52%, 55%, 76% and 86%, respectively, in rice and 37%, 37%, 38%, 44% and 47%, respectively in wheat. The present study, showed that productivity of 10 t/ha can be achieved in rice-wheat cropping system with a combination of FYM + GM + biofertilizers applied to both the crops.



Effect of different combinations of organic manures and biofertilizers on productivity of rice-wheat cropping system

3.6.2 Performance of Wheat under Organic Conditions in Rice-Wheat Rotation

Wheat variety HD 2643 was evaluated under different organic treatments and with recommended fertilizer treatment. The highest seed yield was obtained when FYM @ 10t/ha was used both in rice and wheat, and adding loose rice straw was not advantageous; rather it resulted in lower yield possibly because of immobilization. Residual effect of FYM in rice was evident in wheat; however, green manuring in rice was not found to be beneficial in wheat and resulted in significantly lower yield. Seed yield under FYM in both rice and wheat, and FYM only in rice resulted in seed yield on a par with that of the recommended fertilizers.

3.6.3 Nitrogen Use Efficiency in Rice in Conservation Tillage Practices

Under minimum tillage practice, consecutively for the fifth year, rice variety Pusa Sugandh 3 under transplanted unpuddled raised bed gave a yield of 6.38 Mg ha^{-1} compared to 5.23 Mg ha^{-1} under transplanted puddled flat-bed

Performance of wheat under organic conditions

Treatment	Plant height	Number of spikes/m. row	1000- seed weight	Seed yield (t/ha)
FYM in both rice and wheat	88.6	73.0	50.9	3.51
FYM in rice only	87.1	68.5	51.1	2.99
FYM in rice + rice straw in wheat	85.5	60.7	51.6	2.79
FYM in both rice and wheat+straw	89.5	78.0	51.3	3.48
GM in rice+FYM in wheat	79.2	60.7	50.7	2.66
GM in rice only	74.3	40.5	50.8	2.28
GM in rice+ rice straw in wheat	78.3	48.0	49.2	1.87
GM in rice+FYM in wheat+straw	82.0	66.5	50.1	2.33
Recommended fertilizers (NPK 120:60:30)	87.8	92.2	44.6	3.47
CD (P=0.05)	2.08	11.9	1.58	0.74

continuously flooded conditions in *kharif* 2007. The fertilizer N use efficiency was also higher in raised bed planting, 45.2% compared to 37.5% in flat bed. However, the system N use efficiency was 111% and 101%, respectively under the two planting conditions. Under bed-planting, the fertilizer-N nitrate leached below 60 cm soil depth to the extent 14 kg ha^{-1} and under flat bed (conventional), this value was 21 kg ha^{-1}.

3.6.4 Wheat and Rice Grain Yield and SPAD Index

The data on chlorophyll measurements using SPAD meter during wheat and rice growth showed that in uppermost leaf, the N content at GS-30 stage in wheat (tillering stage) and in rice in top-leaf at ear emergence had a linear relationship with SPAD (chlorophyll) value, and both had a linear relationship with grain yield at final harvest. These sensor-based parameters are a useful index for fertilizer N application to these crops.

3.7 ORCHARD MANAGEMENT PRACTICES

3.7.1 Performance of Sweet Orange cv. Mosambi on Different Rootstocks

The performance of sweet orange cv. Mosambi budded on five different rootstocks was evaluated under Delhi conditions. Plant height, canopy spread, fruit weight, yield and juice recovery were noted maximum on Mosambi plants raised on Karna Khatta rootstock while plant height and canopy spread were observed minimum on Cleopatra Mandarin. Rootstocks also influenced fruit quality of Mosambi. The maximum T.S.S. and ascorbic acid contents with lowest acidity were noted on Cleopatara Mandarin rootstock. Data also revealed that Karna Khatta rootstock had maximum potassium, zinc and iron contents in the leaves followed by Soh Sarkar while these were minimum on Cleopatra Mandarin rootstock. Observations on initiation of flowering in Mosambi budded on different rootstocks clearly indicated early flower initiation on Soh Sarkar roostock. However, late flowering was noticed in Cleopatra Mandarin rootstock.

Growth, yield and quality parameters of 'Mosambi' sweet orange on different rootstocks

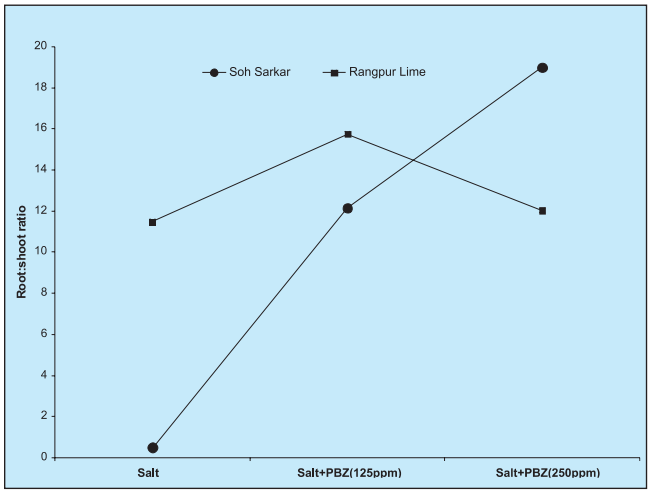
Rootstock	Plant height (m)	Spread (m)		Fruit yield (number/ plant)	Fruit weight (g)	Juice yield (%)	T.S.S. (%)	Acidity (%)	Ascorbic acid (mg/ 100 ml juice)
		E-W	N-S						
Soh Sarkar	2.98	3.45	3.40	64.16	186.33	46.25	10.20	1.03	42.87
Jambhiri	2.73	3.62	3.45	52.50	182.25	43.25	10.10	1.09	41.55
Mosambi	2.86	3.33	3.10	73.20	183.16	44.89	10.10	1.04	43.08
Karna Khatta	3.57	3.66	3.84	86.20	193.16	48.46	10.20	1.04	43.56
Cleopatra Mandarin	2.55	3.16	3.25	68.25	180.25	47.37	10.25	1.02	44.49

3.7.2 Salt Tolerance Studies in Citrus

Six genotypes of citrus, namely, Jatti Khatti, RLC 1, RLC 2, RLC 5, RLC 7 and Attain 1 were screened against different levels of NaCl stress. Results revealed that among six genotypes, Attani 1, RLC 1 and RLC 7 withstood salinity up to 1.95 dS/m and other genotypes failed to survive even at low level of salinity (0.98dS/m). Among three salt tolerant genotypes, minimum reduction in plant height (50.61%), root length (5.07%), dry weight of shoot (70.72%), roots (70.75%) and RWC (9.30%) was recorded in Attani 1 at higher salinity level suggesting that Attani 1 was more tolerant than RLC 1 and RLC 7 to salinity stress.

3.7.3 Effect of Paclobutrazol on Citrus Rootstocks under Salt Stress

Analysis of data showed that NaCl with paclobutrazol (PBZ) treatment affected growth parameters. All growth parameters decreased in NaCl stressed plants of the rootstocks Soh Sarkar and Rangpur Lime. However; the rate of reduction was different. Application of PBZ at 250 ppm was found to be effective in mitigating the salinity stress in salt susceptible rootstock Soh Sarkar. However, paclobutrazol when applied at 125 ppm improved the stress tolerance in salt tolerant Rangpur Lime. All growth variables increased with the application of PBZ in both the rootstocks. Application of 250 ppm PBZ increased the height by 34.47% in Soh Sarkar and 14.98% in Rangpur Lime. However, per cent increase in leaves/plant was higher (170.61%) in Soh Sarkar salt stressed plants treated with 250 ppm PBZ than in plants from salt stress without PBZ. Root length also varied significantly in different treatments. In Soh Sarkar, maximum increase in root length (51.18%) was recorded when salt stressed plants were treated with 250 ppm PBZ, while in Rangpur Lime maximum increase in root length (68.40%) was found with the application of 125 ppm PBZ under salt stress. Root to shoot ratio increased with the application of PBZ, and maximum increase (35.30%) was recorded with the treatment of 250 ppm PBZ in Soh Sarkar, whereas in Rangpur Lime, maximum increase (24.32%) was measured with 125 ppm paclobutrazol. Membrane injury index (MII) reduced with the increasing concentration of paclobutrazol, and lower MII was recorded with the application of 250 ppm PBZ in Soh Sarkar (0.253) and in Rangpur Lime (0.131) as compared to that in salinized plants (0.317 in Soh Sarkar and 0.272 in Rangpur Lime) without PBZ treatment.



Effect of salt and paclobutrazol on root:shoot ratio of citrus species

3.7.4 Studies on Mango Malformation

3.7.4.1 Antifungal activity of datura, calotropis and neem

To isolate the biologically active part of plant, different aerial parts (leaf, stem, flower, fruit and seed) of *datura*, calotropis and *neem* were air dried, powdered and then extracted in methanol using Soxhlet apparatus for 72 hours. *In vitro* culture of the malformed tissues in MS media along with different plant extracts revealed differential capacity to suppress the growth of *Fusarium mangiferae*.

In treatment where methanol and chloroform extracts of *datura* (leaves and seeds) and calotropis (leaves) were mixed and used, the mycelial growth was restricted to the surface of the explant only, and no fungal growth was observed in the media when compared with all other treatments.

3.7.4.2 Field trial with brewed tea spray

A slurry was prepared by mixing 100 g of well-rotted cow manure and fresh parts of *datura* (100 g leaves, 100g seeds) and calotropis (100 g leaves) in 15 liters of water. The slurry was allowed to brew for 15 days under continuous aeration by using an air pump, and then filtered by using a muslin cloth. The filtrate, which was richly-coloured and odorless, was used immediately for spraying without further dilution.

Since *Fusarium mangiferae* infects the sprouting buds, to induce the symptoms of malformation, the brewed tea was sprayed on the mango trees at flower bud sprouting stage, at fruit set stage, and in June-July on the newly emerged malformed panicles to see its effect on malformation. The results were compared with foliar spray with bavistin (1%, 2% and 10%). The control of malformation was found best (100%) in trees sprayed with brewed tea when compared with bavistin (1%, 2% and 10%).

3.7.4.3 Modelling epidemiology of *Fusarium mangiferae* in relation to mango malformation

Data related to intensity of mango malformation, number of colonies of *Fusarium mangiferae* per gram fresh weight of mango bud, and weather variables at selected malformation

prone and free areas in India were collected. They were analyzed for their relation and for developing and validation of Multiple Linear Regression prediction models. The results were confirmed with logistic regression model by using SPSS and GIS tools for two different states, namely, Andhra Pradesh and Uttar Pradesh, which differed significantly in malformation intensity. The relationship was verified between independent and dependent variables by multiple correlation analysis.

- Mango malformation showed positive correlation with the number of colonies of *Fusarium mangiferae* g^{-1} fresh weight of mango bud
- Among the weather variables, wind speed and RH2 showed the highest degree of positive association with the number of colonies of *Fusarium mangiferae* g^{-1} fresh weight of mango bud
- Out of five weather variables, maximum temperature and RH were found to be the determining factors for occurrence of mango malformation
- Weather in the initial month of flowering period (i.e., November in AP and February in UP) were found to be most responsible for mango malformation incidence
- The developed model correctly predicted the differential occurrence of malformation in UP and AP. The conditions for the development of *Fusarium* were found to be favourable only in certain pockets of north western AP, particularly in the districts of Medak, Rangareddy, Hyderabad and (part of) Adilabad. The remaining districts of AP are relatively free from the disease
- The weather conditions for the development of *Fusarium* were found favourable in the entire state of UP.
- GIS tool was found to be very useful for the prediction of spatial distribution of mango malformation at regional scale by using geo-statistical, multiple criteria analysis and logistic regression approach, which otherwise could have been impossible.

3.7.5 Organic and Biofertilizer Studies in Mango

An experiment was conducted to examine the effect of FYM, vermicompost, *Azotobacter*, *Azospirillum* and mixed strain of AM fungi (nutrilink), and phosphate solublising bacteria (Microphos) on plant growth, assimilate partitioning, leaf nutrient status, fruit yield and quality in mango cv. Amrapali. The experiment was laid out in a randomized block design comprising 13 treatments with four replications. Treatments given were T0 : Control (no compost or fertilizer), T1 : Farm Yard Manure alone (FYM), T2 : vermicompost alone (VC), T3 : FYM + VC, T4 : FYM + VC + *Azotobacter* (AZR), T5 : FYM + VC + phosphate solublising bacteria (PSB), T6 : FYM + VC + AM fungi, T7 : FYM + VC + AM fungi + AZR, T8 : FYM + VC + PSB + AZR, T9 : FYM + VC + AM fungi + AZR + *Azospirillum*(AZM), T10 : FYM + VC + PSB + AZM + AZR, T11 : FYM + VC + AM + PSB + AZR + AZM, T12 : 20 kg FYM + NPK. Treatments were given on the basis of total nitrogen requirement (500 g/plant/year) of the plants, i.e., FYM- 100 kg to T1 and 50 kg/plant to all treatments except T0, T2 and T12, and vermicompost -33 kg to T2 and 16.5 kg per plant to all treatments except T0, T1 and T12. Two kilogram neem cake was uniformly applied to each treatment. All biofertilizers were applied @ 10 g per plant, while AM fungi @ 20 g per plant was applied during August- end and the last week of February. For analytical procedure and observations on growth parameters, assimilate partitioning, leaf nutrient status, fruit yield and quality, standard procedures were adopted. Among various growth parameters observed, the increase in plant height and canopy volume was found significant, whereas the increase in trunk girth and plant spread (East- West and North- South) was found non-significant. Maximum increase in plant height was observed in T9 (9.1 per cent), which was closely followed by T8, T10 and T11. Application of biofertilizers along with FYM and vermicompost showed better results as compared to control, FYM and vermicompost alone. Assimilate partitioning and other physiological parameters such as photosynthesis rate and leaf nutrient status were significantly higher as compared to control, and full dose of N application. Leaf nutrient status was found significant for N, P, Ca, Mg, Fe, Cu and Zn as compared to control. The treatment comprising FYM (50 kg), vermicompost (16.5 kg), *Azotobacter* (10g) and PSB (10g) per plant gave the best results for maximum average numbers of fruits (181.2) per plant, yield (33.4 kg per plant), TSS (23.0 %), β-carotene (15,867 µg/100g) and ascorbic acid (37.5 mg/100g pulp) content.

3.7.6 Nutritional and Physiological Studies in Citrus

In *Kinnow mandarin*, foliar spray of micronutrients, i.e., manganese, zinc, copper and iron each at 0.4% along with soil application of biofertilisers alone and in combined doses were tried. A common fertilization dose and biofertilisers,

namely, *Azotobacter* (10 g/plant) + PSB (10 g/plant) were applied uniformly to all treatments. The treatment comprising combined spray of Fe, Cu, B and Zn at 0.4% each was found superior for growth and yield (105 fruits /tree) parameters as compared to control (71.0 fruits/tree) and other treatments. The maximum juice recovery (55.9 %) and TSS: Acid ratio (14:1) was also recorded in the above treatment.

3.7.7 Nutritional Studies in Sweet Orange cv. Mosambi

In sweet orange cv. Mosambi, various combinations of fertilizers along with biofertilisers and micronutrients (0.4% foliar sprays) were applied to assess the effect on fruit yield and quality parameters. Out of the various treatments, application of ¾th N (300 g) + ¾th P (250 g) + mixed strain of VAM (50g) + *Azospirillum* (5g) along with spray of 0.4% micronutrients (Cu + Fe + B + Zn) gave the maximum number of fruits (128.6 fruit per plant), higher yield (20.9 kg/ plant) higher juice content (49.3 %) and TSS: acid ratio (11.1:1).

3.7.8 Agronomic Studies on Papaya

In organic cultivation studies on plant growth of papaya, the height at flowering was significantly higher in treatment combinations receiving conventional fertilizers compared to those under organic cultivation. The number of days required for flowering (50% and 100%) were significantly low in the plants receiving conventional nutrients compared to those receiving nutrients from organic sources only.

A comparison of traditional methods of papaya cultivation revealed that plant height at flowering was significantly higher in treatment where plants were transplanted on bunds compared to those transplanted after pit digging. The time required for flowering (50% and 100%) was less in plants raised on bunds compared to those raised on refilled pits.

3.8 PROTECTED CULTIVATION TECHNOLOGY

3.8.1 Performance of Cherry Tomato Varieties under Greenhouse Conditions

Cherry tomato variety Selection 1 was superior to all other varieties grown in semi-climate controlled greenhouse over a period of 10 months in terms of plant height (10.80 m), total number of truss per plant (19.5), number of fruits per truss (29.0), fruit yield per plant (3.3 kg), and total fruit yield (58.5 t/ha). Quality of fruits with respect to optimum fruit weight, acidity and ascorbic acid content was also most superior in the case of var. Selection 1.

Qualitative performance of cherry tomato varieties under greenhouse

Variety	Fruit wt. (g)	Fruit quality lycopens (mg/100g)	Brix	Acidity	Ascorbic acid content (mg/100g)
Selection 1	13.0	5.4	10.4	0.43	20.7
N.S. cherry 1	18.0	5.6	10.01	0.38	18.6
N.S. cherry 2	15.0	5.2	11.2	0.43	17.2
T 56	23.0	4.8	7.8	0.26	21.5
BR 124	22.0	4.9	8.5	0.33	20.2

3.8.2 Effect of Plant Spacing on Growth and Fruit Yield of Greenhouse Tomato

In greenhouse grown slicing tomato var.GS 600, closest spacing between plants (30 cm) increased the plant height but decreased the number of fruits per truss, number of fruits per plant, and fruit yield per plant but the total fruit yield was on a par with the 45 cm spacing between plants. Although maximum number of fruits per truss (80.5), number of truss per plant (18.5) and the highest fruit yield per plant (8.694 kg) were recorded at the widest spacing (60 cm) between plants, the highest total fruit yield (22.65 t/1000 m^2) was obtained with 45 cm spacing.

3.8.3 Effect of Plastic Mulch on Growth, Yield and Crop Advancement in Winter Tomato

Mulching with transparent plastic films in open field tomato during winter season protected the crop from frost, advanced fruiting by 10 days, increased fruit yield per plant and gave maximum total fruit yield (35.40 t/ha) in comparison to those obtained with non-mulched crop. Transparent mulch increased the average temperature of the soil by 3.7°C at 2.5 cm soil depth and 2.5°C at 5 cm soil depth during winter season.

3.8.4 Effect of Shading on Damping Off Incidence and Seedling Quality in Early Season Cauliflower

In early season cauliflower var. Pusa Katki, covering of nursery beds with 40% and 50% black colour shade nets

significantly reduced the incidence of damping off. The incidence of damping off was 65% in control, whereas it was only 15% and 13% in 40% and 50% shade nets, respectively. The fresh weight and the quality of seedlings were also higher under 40% and 50% shading compared to those of control during peak summer months (May and June). Seedlings of 40% and 50% shade net covered beds were ready for transplanting 3 - 4 days earlier compared to the control.

3.8.5 Effect of Shading on Growth and Yield of Early Season Cauliflower

In early season cauliflower var. Pusa Katki, shading of the field with 40% and 50% black colour shade nets reduced the post-transplanting mortality significantly in comparison to that in the control (without shading). Shading of the crop with 40% and 50% black shade nets delayed the first harvest by 6 and 7 days, respectively, in comparison to that in the control, but it significantly increased the fresh weight of the whole plant. Maximum weight of curd (0.630 kg/curd) and total yield (18.7 t/ha) and the highest quality of curd were recorded with 50% shade net, followed by 40% shade net covered crop.

3.8.6 Standardization and Validation of IPM Strategies for Soil-borne Fungus and Nematodes in Greenhouse Cucumber

In greenhouse parthenocarpic cucumber cultivation during summer season, soil sterilization with formaldehyde significantly reduced the post-transplanting mortality compared to all other treatments. But the highest yield of fruit per plant (2.6 kg/plant) and total fruit yield (54.86 t/ha) were obtained with the application of neem cake @ 1.0 t/ha + carbofuran @ 20 kg/ha. Application of neem cake + carbofuron also helped in the reduction of nematode incidence significantly.

3.8.7 Development of Fertigation Scheduling Model for Onion Crop

Field experiments were conducted to study the effect of potassium on the yield of onion cv. Pusa Red using drip fertigation. Based on the study, a mathematical model of the form: $Y = 0.31\ X^{0.986}$ (R^2=0.96) was developed ,where Y is the yield of onion in t/ha and X is the amount of potassium (kg/ha) applied. Maximum yield of 30 t/ha was obtained with 100 kg/ha of potassium and 30 cm depth of irrigation water applied through drip irrigation system at an evapotranspiration rate of 80% ET_c.

3.8.8 Effect of Leaching on Fruit Yield and Quality of Greenhouse Tomato

Monthly leaching of drip irrigated tomato grown inside greenhouse resulted in increase in fruit yield up to 8% and increase in TSS up to 6%. The amount of leaching varied from 8 -10 m^3 per 1000 m^2 in the months of October-December. The EC and pH of the wetting front periphery soil decreased by 8-10% and 4-5%, respectively.

3.8.9 Studies on Growth Response in Greenhouse Chrysanthemum

Growth parameters of four varieties of chrysanthemum showed significant reduction in low ambient temperature.

Growth parameters of chrysanthemum varieties in winter

Variety	Plant height (cm)	Stem diameter (cm)	Stem length (cm)	Flower diameter (cm)
Leman's	10.2	0.63	8.3	5.2
Snowdon White	75.6	1.02	63.5	10.6
Yellow Bouquet	70.5	0.75	56.2	6.7
Thai Chen Queen	68.4	0.82	75.3	9.6

Low temperature (<10 ^{0}C) for two weeks was detrimental to the growth of chrysanthemum. The varieties, Snowdon White and Yellow Bouquet were more tolerant to low temperature, while var. Thai Chen Queen flowered with deformed stems. The var. Leman's remained unflowered and stunted.

3.8.10 Time and Motion Study of Manual Seeding of Plug Tray in Nurseries for Enhanced Output

Existing practice of seeding the plug trays in the nurseries is manual which is very slow and laborious, requiring about 8 man-hours to prepare and sow trays for 9800 seedlings. Time and motion study of different unit operations involved in plug tray seeding was carried out.

Existing practice and modified method of plug tray seeding

Treatment	Description
T_0 (Control)	Traditional method : single cell indenting, + manual sowing using hand palm as seed tray
T_1	Row indenting + manual sowing using cushioned seed tray
T_2	Row indenting + manual sowing with slider seed tray

Two modified methods were developed to enhance the manual output.

Based on the results and ergonomic considerations, a sowing table with seeding tray (T_2) for manual operation was developed and tested. It was found that by simple improvisations, output capacity of one person could be increased by more than 25% as compared to the traditional method of tray sowing.

Observations in different unit operations of plug tray seeding

Item	Average time required (min)		
	T_0	T_1	T_2
Making indents in tray cells	1.05	0.24	0.24
Placing seeds in tray cells	7.78	6.94	6.16
Unproductive time	1.93	1.5	1.6
Total time	10.76	8.68	8.0
Saving in time		2.08	2.76
Increase in output (%)		19.3	25.6

3.9 AGRICULTURAL ENGINEERING

3.9.1 Modified Vegetable Seed Extractor

The modified vegetable seed extractor was evaluated for extraction of bottle gourd and brinjal (round) seeds. Bottle gourd fruit was chopped into 5-7.5 cm long pieces and fed to machine. With the introduction of blades onto the cylinder of the modified extractor, a substantial improvement in throughput capacity was observed. A throughput capacity of 120 kg/h was achieved as against 30-40 kg/h in the earlier model. The recovery of seed was 4.37% and germination of these seeds was 82%. In the case of brinjal, when fed as whole fruit in batches of 5 kg, the throughput capacity was observed to be around 100 kg/h and seed extraction about 3%. It was observed that there is a need to modify the feeding hopper to achieve higher feeding rate. A motorized operation is necessary for continuous operation, and to achieve 100-120 rpm of cylinder, a gear box needs to be incorporated.

Vegetable seed extractor

3.9.2 Ergonomic Evaluation of Manual Rotary Power Generation

Manual energy is extensively used to operate various hand tools and devices in agricultural production system. The human energy can be converted into rotational power through simple mechanical devices. The conversion efficiency and power output in these modes vary significantly with respect to duration, load and group of muscles involved. To find out the best possible human posture to facilitate optimum combination of muscles to generate rotational power, an experimental device, Postural Dynamometer, was developed and modified with loading facilities.

3.9.2.1 Objective and subjective evaluation of manual rotary power generation

Experiments were conducted on three modes, viz., handle, pedal and rocking at mechanical power output of no external load, 0.05 HP and 0.1 HP. The objective evaluation in terms of heart rate and oxygen consumption was done. The mean heart rate values varied from 105 to 160 beats min^{-1} in different modes. Similarly, oxygen consumption values varied from 0.6 to 1.5 lit/min. Oxygen consumption is one objective indicator of human effort. In all the three modes of rotary power generation, the pedal mode of operation had lower values of energy expenditure as compared to the rest of the two. Subjective evaluation in terms of Body Part Discomfort Score (BDPS) and Overall Discomfort Score (ODS) were the lowest in pedal operation mode at all the power outputs. The human efficiency, ratio of mechanical output to human efforts ranged from 10 to 18%. The human efficiency was also the highest in pedal

operation, which was in the vicinity of 15 to 18%, as an outcome of postural comfort as compared to other modes and low oxygen consumption.

3.9.3 Design and Development of Aqua-ferti-seed drill with Constant Head Gravity Feed Metering of Aqueous Fertilizer

A tractor-drawn aqua-ferti-seed drill with constant head gravity feed metering of aqueous fertilizer using rotary gear pump was developed. This is an improvement over the tractor-drawn aqua-ferti-seed drill based on peristaltic pumping system developed earlier. The heart of the machine is an aqueous fertilizer metering system using constant head gravity feed mechanism with variable nozzle sizes. The design of the machine consists of a main frame,

Field evaluation of gravity feed aqua-ferti-seed drill

a metering system for both seed and aqueous fertilizer, furrow openers, ground wheels and a power transmission system. The aqueous fertilizer metering was attained by designing a suitable pumping system to deliver a measured quantity of aqueous fertilizer. The constant head in the gravity feed tank at different combinations of head and nozzle opening was maintained by varying the speed of rotary pump suitably.

Keeping in view the viscous and corrosive nature of the aqueous fertilizer, a rotary gear pump with a discharge rate of 60 l/min and an rpm range of 1450 was found suitable for pumping aqueous fertilizer to the central tank for maintaining the desired constant head. A fluted roller type seed metering mechanism having flute of proper size and shape was considered for metering of wheat seed. The range of seed rate with the system was between 80 kg/ha and 125 kg/ha, which met the requirement of dryland areas. A furrow opener of size 438x40x6 mm was designed. Two mild steel tubes were welded to facilitate the application of seed and aqueous fertilizer separately at a distance of 5 cm to avoid direct fall of aqueous fertilizer over the seed. The ground wheel was designed as per RNAM test code, i.e., 360 mm diameter which lies in the specified range of 350-450 mm. Based on functional test evaluation, the actual field capacity and field efficiency of the machine were 0.36 ha/h and 67%, respectively. The machine gave uniform discharge from its different nozzles. The percentage increase in soil moisture due to aqueous fertilizer application at the rate of 8000 l, 6700 l and 6000 l/ha were 241%, 196% and 117%, respectively, as against 8% loss in the case of control plot just after sowing. For 8000 l/ha aqueous fertilizer rate, the increase in germination, number of shoot per plant, number of ear head, plant height, grain yield and straw yield were 51%, 48%, 38%, 11%, 38%, and 60%, respectively, in comparison to those for no aqueous fertilizer. The cost of the machine is estimated at Rs. 27,000 with break even point (BEP) 49% of annual utility of 200 hours and pay back period of 3 years. It could make possible the sowing of wheat in dryland areas where seeding is not possible in many instances.

3.9.4 Agricultural Mechanization –A Major Drift through Custom Hiring

A survey in Haryana and western U.P. revealed that custom hiring is picking up not only in combine harvesting but in tillage and sowing/planting operations also. A major drift from linearity in mechanization has been observed in crop harvesting operation through introduction of combine harvesters on custom hiring. The combine owners of this area send a team of four persons - foreman, driver and two helpers to adjoining states including Gujarat, Maharashtra, Madhya Pradesh, Uttar Pradesh (Agra region). The time and space of journey is arranged keeping the crop maturity in mind. A business of Rs. 3 lakh per visit was reported by the combine owners.

Custom hiring in tillage has brought change in western U.P. and machine ownership pattern has shifted from cultivator and harrow to rotavator. The reason behind this shift is time saving due to higher field capacity and better

performance of rotavator. This is advantageous to both customer and service supplier. Similarly, in sowing operation also, custom hiring is catching on. Farmers from western U.P. with tractor and potato planter system have gone up to Agra for performing custom-services. The average annual use of tractors was for 990 hours; of which 86% use was for custom hiring. The share of custom hiring use in agricultural operations was 73% of the total annual use. It was mainly in land preparation and wheat threshing (34% and 14%), and 2 to 6% in other farm operations as sowing, interculture, transport of inputs and produce.

3.9.5 Okra Planter Seed Box Hopper Bending Fixture

A fixture has been developed for bending the seed box hopper of okra planter. It consists of a base frame, a vertical frame, a pressing unit and a lead screw with guides. Base frame of the fixture has been fabricated by welding of two 400 mm lengths of m.s. channel of section of 80x35x35x5 mm and two 300 mm lengths of m.s. angle of size 40x40x5 mm. Vertical frame is welded on the base frame. It consists of two pillars of height of 415 mm each made from m.s. channel section of 80x35x5 mm. Horizontal distance between these pillars is 380 mm and the top portions of these are joined by welding another m.s. channel section, and lower portions of these pillars are welded to the base frame in the centre.

Pressing units has been fabricated in two parts, i.e., convex half and concave half. Convex half is closed one whereas concave half is hollow. Height and width of convex half is 140 mm and 80 mm with a radius of 125 mm. Top of convex half is made from 12 mm thick m.s. plate, and its length and breadth is 225 mm and 175 mm, respectively. Lower half of the pressing unit is hollow concave and is made from 3 mm thick m.s. sheet having 128 mm radius. Concave is welded to the base frame in the centre and is supported by two side plates and these are welded to vertical frame. Templates have been made for seed box hopper and its top. Mild sheet of 3 mm thickness is cut manually according to template and is placed at top of concave half of pressing unit. The lead screw moves the convex half of the pressing unit. It presses the m.s. sheet placed in between the convex and concave half till the sheet takes the shape of hopper. Afterward convex half is moved upward with the help of lead screw and handle. Top of hopper and the flap are then welded. The average time taken for cutting, bending and welding is 8 minutes as compared to 18 minutes of normal method, i.e., giving shape by hammer over anvil and channel, and thus there is a net saving of 55% time in fabrication. Beside this, it gives more uniform hopper as compared to normal fabrication method, and the flow of seed in hopper is uniform.

3.9.6 Drying Studies in Solar Cabinet Dryer and Open Sun

An experiment on drying studies on onion was conducted in solar cabinet dryer. Open sun drying was also done to compare the effect of solar cabinet dryer. One kg sample of onion and cabbage was used for drying in the cabinet dryer and open sun drying. The samples were blanched with 10% sodium meta-bisulphate (KMS) and heated for 10 minutes. The measurement of temperature of the dryer chamber was done with the help of a portable temperature indicator (least count 0.1^0C) at three central locations in the chamber. The moisture content of onion in solar cabinet dryer (SCD) was reduced from 87.69% to 5.38% in 8 h, while in open sun drying (OSD) it took double the time (16 h) to reduce to 5.38%. The moisture content of cabbage in SCD was reduced from 84.34% to 6.23% in 10 h while in OSD it took 16 h to reduce to 6.23%. The drying rate was higher at different moisture content in SCD than in OSD. The drying rate was faster at different time in the case of SCD than that of OSD in both the vegetables. The quality of produce dried in solar cabinet dryer was better than that dried in open sun. The average temperature increase of about 14^0C was achieved in solar cabinet dryer compared to that in the ambient temperature.

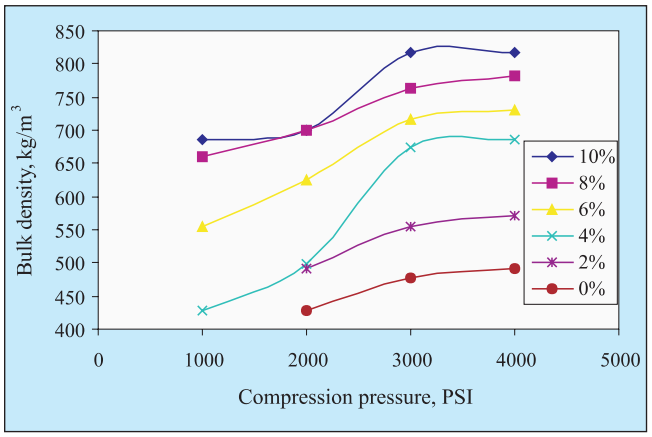
3.9.7 Mathematical Model of Green House

A mathematical model of a greenhouse to predict the performance of a particular greenhouse in terms of various design and climatic parameters was used to predict greenhouse air temperature at different times of the day in summer and winter. The inputs for the program are climatic parameters, such as ambient temperature, solar intensity (both averaged over one hour period), and design parameters of greenhouse design, viz., area of greenhouse, volume of greenhouse, transmissivity, etc. The output of the program provides hourly average temperature of the greenhouse enclosure. The greenhouse air temperatures have been predicted on an hourly basis for different seasons. As evident from the following graph, there is a fair agreement between the experimental and predicted values of the greenhouse air temperature. In order to design a greenhouse suitable for different climatic regions, data were

collected for maximum and minimum temperatures for different places in different regions for different months. The variation in yearly maximum and minimum temperatures for different regions was found between 25^{0}C and 40^{0}C, and 17^{0}C and 32^{0}C, respectively. In winter, the variation in maximum temperature and minimum temperature was found between 7^{0}C and 32^{0}C, and -3^{0}C and 5^{0}C, respectively. During summer, the variation in maximum temperature and minimum temperature was found between 27^{0}C and 42^{0}C, and 12^{0}C and 28^{0}C, respectively.

3.9.8 Compaction Characteristics of Barley Straws

Compaction characteristics of barley straw were evaluated. The blocks were tested to evaluate their bulk density, resiliency and compression ratio. Bulk density and compression ratio of the blocks decreased with the increase in moisture



Effect of compression pressure and molass content on bulk density of barley straws

content but increased with the increase in compression pressure, whereas resiliency increased with the increase in moisture content but decreased with the increase in compression pressure.Compression pressure of 3000 PSI was found to be appropriate for making blocks. The molass content of 6-8% was found suitable for block formation as higher molass content resulted in oozing of molass through air holes in compression chamber and subsequently choking of air holes.

3.9.9 Development of Whole Pulse Grain Polisher

Appearance of whole grains is an important parameter in reference to their commercial value in the market. With this view, a polisher consisting of rubber roller, concave, feed hopper and frame was developed for polishing whole pulse grains. The roller is made of MS pipe coated with rubber. The machine can be used for improving the appearance and physical quality of whole pulse grains, which would fetch better market price. This also enhances the storage life of the grain. The machine is run by an 2 HP electric motor.

Grain flaking machine

3.9.10 Development of Grain Flaking Machine

Flaking is an important unit operation in food processing. Therefore, a grain flaking machine was developed to prepare flaked products from maize and *jowar*. The machine consists of a frame, a hopper, double stainless steel a rollers, a roller gap adjusting mechanism, a roller-rotating mechanism, scrapers and a slanted product collection passage. The machine can be operated both manually and using an electric motor.

3.9.11 Evaluation of Grain Flaking Machine

Flaked grains are widely used as food products. With this in view, a grain flaking machine was developed and evaluated. The capacity of the machine varied from 15 to 30 kg per hour on manual operation. The machine was tested on greengram, wheat, maize and sorghum.

3.9.12 Development of Orange Grader

An orange grading machine, which grades fruits on weight basis, is under development. The grading machine consists of a main frame, a chain conveyor, fruit carrier cups, electronic weighing assembly, LDR laser beam pointer, fruit dropping and collecting mechanism, power transmission system and PCB with ICs. The plastic cups fitted on the chain and containing the orange fruits pass on to the dynamic load

Orange grader under fabrication in the workshop

cell assembly, which would weigh the fruits. The load cell output in the form of varying voltage with respect to time is provided to the IC AD 7730, which converts this into digital form. This digital voltage output for the single fruit is sampled into 10 equal samples and average voltage output is determined, which is proportional to the fruit weight. Once the fruit weight is determined, it is used by a microprocessor to decide which stepper motor is to be operated so that fruit will drop according to the predetermined 4 grades (100-150 g, 150-200 g, 200-250 g, <50 and >250 g). A light dependent resistor and a laser beam pointer have been used to determine the exact location of the fruit carrier cup so that stepper motor will be operated at the exact point of grading.

3.9.13 Farm Operation Services

3.9.13.1 Field operations

The Farm Operation Service Unit is catering to the needs of the divisions/project directorates/establishments, for conducting field experiments. The Unit has a large area under its control. In order to get uniform germination and stand of crops, the Unit has deployed laser leveler in areas of about 50 acres.

In order to break the hard pan of the soil due to continuous shallow cultivation, summer ploughing was done which improved the soil aeration, and killed some of the insect-pests and weed seeds. Because of summer ploughing, the beneficial microbial activity and fertility of the soil improved.

A massive programme of green manuring was undertaken during *kharif* to enrich the soil fertility of the Institute farm. During the year, a massive programme of cleanliness was also undertaken, and 80% roads and *nalas* were cleaned by using manual, chemical and power sources.

Very old imported machines, namely, Norvegion plot seed drill, space planter and Escort combine harvester, and plot thresher were repaired and put to use.

In recent years, a number of micro-experiments were being undertaken by the Institute. The needs of each experiment were unique and the Unit made efforts to satisfy the needs of each experiment.

One of the most important and critical operations is the harvesting of *rabi* crops. With the help of three very old plot combines, large areas (about 100 acres) under field experiments were harvested. The rest of the crops were harvested with the help of a class combine. The entire harvesting was completed before the onset of monsoon.

3.9.13.2 Irrigation distribution management

The Institute has a very efficient and effective underground irrigation system. The pipelines are 3 feet below the ground and have 105 outlets to irrigate different field plots. Against specific requisition, a particular outlet is opened to allow water flow and irrigate a specific field plot. Two reservoirs collect water from 18 tubewells during the night and supply it during the day through underground pipelines. During the process of pumping water, sands are pumped and get settled in the reservoir, which reduce the capacity of the reservoirs. Therefore, the cleaning of reservoir was done on top priority.

In order to supplement tubewell irrigation, canal irrigation water was drawn from Jamuna river and provided to paddy, orchard and agronomy fields.

3.10 POST HARVEST TECHNOLOGY AND MANAGEMENT

3.10.1 Post-harvest Handling and Regulation of Ripening of Mango

An alternative method of regulation of ripening of mango by the use of methyl cyclopropane (1-MCP) was studied since it has unique capability of binding the ethylene that inhibits ripening. In view of the difficulty experienced in its application as fumigant, the possibility of its use as aqueous

Control

MCP treated

Simple technique of MCP application

dip and in gaseous forms using simple techniques was explored**.** The MCP treatment as 1000 ppb gas exhibited a significant role in checking rotting of fruits up to 11 days after harvest. It also checked the progress of ripening as evident from lower carotenoid development, and starch to sugar conversion in treated fruits as compared to control.

3.10.2 Role of 1-MCP on Commercial CA Storage of Apples

Samples of apple cv. Royal Delicious fruits drawn from commercial CA stores of M/S FHEL (a wholly-owned subsidiary of CONCOR under the Ministry of Railways, Govt. of India) were treated with 1-MCP. Both the treated and untreated (control) fruits were stored at ambient condition for a period of three weeks. Treated fruits showed remarkable reduction in ethylene liberation on removal from CA store up to a period of 8 days, and thereafter, the rate of ethylene liberation showed a progressive increase. It also recorded lower value of respiratory rate throughout the period of storage at ambient condition compared to that exhibited by the untreated ones. Hence, MCP treatment could show promising results on post removal marketing of CA stored apples.

3.10.3 Effect of Post-harvest Treatment and Packaging on Shelf Life and Quality of Pointed Gourd (*Trichosanthes dioica*)

Effect of carnauba wax (plant origin edible wax) and KMS treatments on the shelf life of pointed gourd was investigated.

Control **Wax 1:10**

Wax 1:10+500 ppm KMS **500 ppm KMS**

Effect of carnauba wax and KMS treatments on the shelf life of pointed gourd

Treated fruits were stored at ambient and cold storage conditions. No detectable level of ethylene was found throughout the storage period, and therefore, pointed gourd was classified under non-climacteric group of vegetable. In general, 1:10 (wax **:** water) wax emulsion appeared to be the best treatment for maintaining the marketing quality and extending the shelf life of pointed gourd under both the storage conditions. Least physiological loss in weight (PLW), pectin methylesterase (PME) enzyme activity, carotenoids levels, total sugars content and chroma value (undesirable character) were recorded in fruits treated with 1:10 (wax: water) wax emulsion. For pointed gourd fruit packaging, zero perforated 200-gauge HDPE films may be used to get higher shelf life (up to 25 days) and better quality preferably during cold storage.

3.10.4 Studies to Enhance Shelf Life of Apples

Different experiments were conducted to enhance the shelf life of apples. Among different waxing treatments, lac-based formulation was found to be the best in maintaining the texture, fruit quality and shelflife of apples up to six weeks. Similarly, tray shrink-wrapped apples retained better firmness and shelf life for 35 days after harvest compared to unwrapped ones.

3.10.5 Black Carrot Anthocyanin – A Potential Colorant and Functional Ingredient

Black carrots were found to contain significantly high amounts of anthocyanins, high phenolics and high antioxidant activity. The anthocyanin content ranged from 145 to 245 mg/100 g cyani-din-3-glycoside and the antioxidant activity ranged from 13.43 to 15.43 µ mol Trolox/g. Black carrot anthocyanin juice obtained by enzymatic pressing significantly

Black carrot

increased juice yield and recovery of phenolic content in comparison to straight pressing.

In view of utilizing black carrots as a functional ingredient for fruit juices, the thermal stability of black carrot was evaluated at 100°C to simulate the harsh thermal conditions during processing. Black carrot anthocyanins showed superior thermal stability in terms of colour density, and polymeric index in comparison to black grapes anthocyanins. The stability of pigment was found to be significantly higher in plum juice and raw mango nectars. Black carrot anthocyanin juice seems to have great potential for colouring non-coloured beverages and improving their health promoting properties.

3.10.6 Application of Hydrocolloids in Fruit Juices for Attaining Cloud Stability

Different hydrocolloids, viz., gum acacia, carboxymethyl cellulose (CMC), pectin and *guar* gum were employed to attain cloud stability in citrus juice. They were used at various concentrations, viz., gum acacia - 0.2%, 0.4%, 0.6%, and 0.8%; CMC - 0.2%, 0.4%, 0.6% and, 0.8%; pectin- 0.1%, 0.2%, 0.3%, 0.4%; and *guar* gum - 0.2%, 0.4%, 0.6%, and 0.8%. Carboxymethyl cellulose was found to give the best organoleptic score followed by pectin. *Guar* gum and gum acacia were organoleptically unacceptable, and hence they were discontinued for use in further trials. Acceptable concentration of CMC was found to be 0.4-0.6% and that of pectin 0.2-0.3%. Juice with added hydrocolloids showed increase in viscosity during storage.

3.10.7 Preparation of GOG Powder

Ginger, onion and garlic (GOG) mix powder could be prepared from 5 mm thick dehydrated (GOG) slices, after mixing them in the ratio of 1:4:1 and treating with spray of 1% KMS solution @ 50 ml/kg of fresh material just to wet, and drying in a cabinet dryer at 60°C for 10 h, followed by grinding in a laboratory powder mill and sieving with 30 mesh sieve.

3.10.8 Dehydration of *Methi* Leaves

Dehydrated *methi* leaves which are relatively inexpensive, rich in nutrients and easy to prepare could be dehydrated after blanching for 2 min in boiling water containing 0.5% sodium meta-bisulphite, followed by drying in a cabinet dryer at a temperature of 58± 2°C. The dehydrated leaves could be stored at low temperature (7±2°C) after packing in 200 g high-density polyethylene (HDPE) pouches for off-season use.

3.10.9 Screening of New Cultivars of Carrot for Dehydration

Eleven new cultivars of carrot, viz., IPC 4, IPC 96, IPC 49, IPC 35, IPC 109, IPC 64, IPC 40, IPC 16, IPC 100, IPC 37 and IPC 98 evolved at IARI were screened for dehydration. On the basis of different drying characteristics like drying and rehydration ratio, nutrient content such as total carotenoids, β-carotene, lycopene as well as sensory score of colour, flavour, texture and overall quality, the cv. IPC 35 was found to be the best for dehydration purposes followed by IPC 4.

3.10.10 Fruit Cracking due to Vivipary and its Control

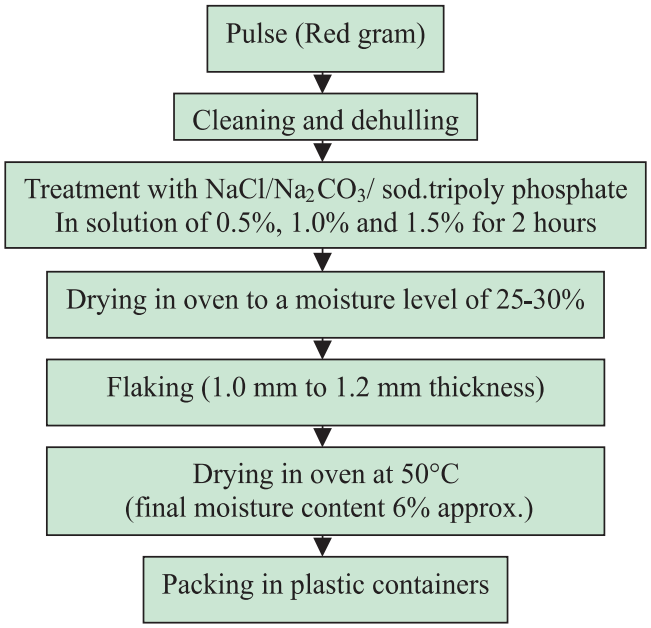
Due to prolonged retention of mango fruits on tree, fruit stone start germinating and subsequent cracking of fruits take place. Owing to cracking, 12.32 – 23.25% fruit loss was observed in Amrapali mango. The levels of TSS, total carotenoids, total sugars, acidity and ascorbic acid were also found to be lower in cracked fruits compared to healthy fruits. Pre-harvest foliar application of paclobutrazole (200 ppm) during the second week of July reduced the vivipary incidence during prolonged tree storage of the fruits and delayed harvesting up to 15th August. Foliar application of 1-MCP was not found effective in minimizing fruit cracking due to vivipary.

3.10.11 Studies to Reduce Spoilage Caused by Post-harvest Diseases in Apples

Various post-harvest diseases cause fruit decay in apples. To reduce the incidence of various post-harvest diseases, different experiments were conducted with the use of chemicals generally regarded as safe, viz., ethanol fumigation and injection, acetic acid fumigation and injection and use of antagonist organism, *Debarymyces hansenii*. Of the various treatments, combined treatment of *Debarymyces hansenii* + sodium carbonate (1%) was the best for reducing decay caused by post-harvest diseases. Similarly, ethanol injection was better than ethanol vapour, acetic acid vapour or injection in reducing post-harvest diseases of apples. Among different hot water treatments, hot water dip at 50°C for 1 min was found to be the best for reducing decay loss, and maintaining the fruit firmness, fruit quality and shelflife for 36 days at room temperature.

3.10.12 Optimization of Process Parameters for Preparation of Quick Cook *Dal*

Investigations were carried out to develop a process for preparation/production of quick cooking *dal* from the 3 selected pulse (red gram) varieties, viz., Pusa 2003-1, UPS 120 and Pusa 2004-1. The following flow chart shows the process sequence:



Flow chart of the developed process for quick cooking *dal*

Cooking trials revealed that the variety Pusa 2003-1 gave the best response when subjected to the developed process. It took just a little over 5 min to cook *dal* (ready to serve). The treatment combination of soaking in 1.0% NaCl solution (2 h), followed by drying to 30% moisture and flaking (1.0 to 1.2 mm thick) and again drying to a final moisture level of 6% gave the best results.

3.10.13 Correlation Studies Between Various Physical and Physico-chemical Characteristics of Pigeonpea Pulse

Different physical and physico-chemical parameters of pigeonpea pulse, viz., seed weight, seed volume, seed density, hydration capacity/seed, hydration index, swelling capacity/seed, swelling index and cooking time were studied. Correlation coefficients between seed weight and hydration capacity (0.77) and that of swelling capacity and swelling index (0.90) were significant at 1% level.

The correlation coefficients between seed volume and hydration capacity (0.54), seed density and swelling index (0.52), hydration capacity and swelling capacity (0.35) were good, although these were not significant. Cooking time was not found to be correlated with any of the parameters.

3.10.14 Hydration Characteristics of Maize and Sorghum

Hydration rate of majority of whole food grains is very slow leading to long cooking time requirement of these grains. There have been various efforts to remedy the long-term cooking requirements of raw grains, including pre-cooking the grains. With this in view, the hydration characteristics of Pusa varieties of maize, viz., PC 1, PC 2, PC 3, PC 4, Arun and NEP as well as some varieties of sorghum, viz., C 43, CSV 216R and SPV 813 were evaluated at temperatures varying from 70 to 100 °C. Efforts are going on to improve the hydration rate of these grains through chemical pre-treatments.

3.10.15 Physical Properties of Sorghum

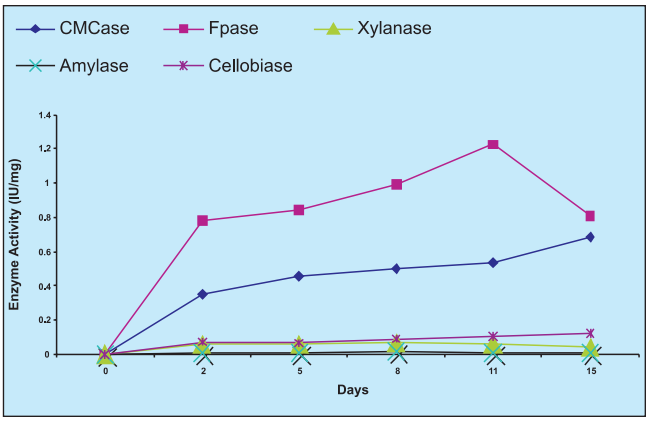
A study was conducted to determine the physical characteristics, viz., bulk density, true density, porosity, angle of repose, coefficient of friction and hardness of 3 varieties of sorghum, viz., C 43, CSV 216R and SPV 813 obtained from the National Research Centre on Sorghum, Hyderabad. These properties were useful parameters in designing various processing machines.

3.11 MICROBIOLOGY

3.11.1 Recycling of Agricultural Residues and their Utilization in Sustainable and Organic Agriculture

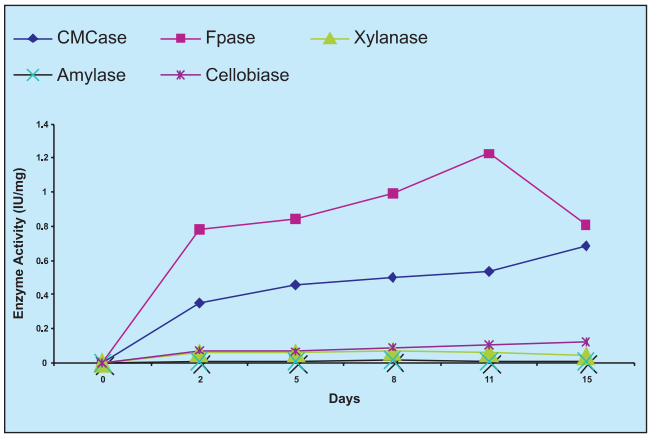
3.11.1.1 Development of composting technology

Screening of promising amylolytic and cellulolytic microorganisms for development of microbial consortium for composting. Microorganisms isolated from soil were



Extra-cellular enzyme activity of *Bacillus* sp. (SH- 4) on paddy straw

tested for their potential enzymatic activities on paddy straw as a substrate in minimal medium. *Bacillus sp.* (SH-4) and *Streptomyces sp*. (SA-5) were found to have higher amylolytic and cellulolytic activities on paddy straw. A constant increase in these activities was recorded with the period and the highest amylolytic and cellulolytic activities were found on the 15th day of incubation. These isolates were tested for composting of paddy straw under natural conditions.



Extra-cellular enzyme activity of *Streptomyces* sp. (SA-5) on paddy straw

Testing efficiency of a microbial consortium for composting. Paddy straw soaked in water for 48 h, amended with poultry manure (8:1) and rockphosphate (1%) was filled in pits of 1 m^3 size. This was mixed with a composite inoculum of fungi and bacteria @ 300 g/t. Adequate moisture (~75 %) was maintained in the substrate by mixing water during its turning at fortnightly intervals.

The compost prepared was found to be ready for use in 90 days. It was found completely free from phytotoxicity and matched prescribed standards of quality for compost.

Evaluation of different maturity parameters of paddy straw compost

Parameter	Paddy straw compost	Standard compost
pH	7.5	6.5-7.5
EC (ms cm^{-1})	2.9	≤4.0
C/N ratio	18.0	20:1
Humus (%)	10.4	-
Pathogens	Nil	Nil
Phytotoxicity(Germ. %)	80	60

Effect of integrated use of organic inputs and microbial inoculants on grain yield of wheat. To assess the effect of organic inputs on grain yield of wheat (HD 2687), vermicompost and enriched compost were applied @ 6 t/ha along with microbial inoculants (nitrogen fixing, and phosphate solubilizing and mobilizing organisms) in a field trial during *rabi*, 2007. The experiment was laid in a split-plot design with vermicompost and enriched compost in main-plots, and microbial inoculants in sub-plots. All treatments were replicated thrice in plots of 34 m^2 size.

Grain yield of wheat was maximum with vermicompost when inoculated with *Azospirillum* and *Azotobacter* in combination. Nevertheless, the grain yield recorded with phosphate solubilizing and mobilizing organisms was on a par with this treatment.

Effect of vermicompost and enriched compost on grain yield of wheat variety (HD 2687)

Treatment	Grain yield (t/ha)
VC	3.03
VC +Azs +Azt	3.18
VC+PSB +AM	3.02
VC+Azt+PSB+AM	3.69
VC+Azs+PSB+AM	2.77
EC	2.78
EC +Azs +Azt	2.67
EC+PSB +AM	2.72
EC+Azt+PSB+AM	2.42
EC+Azs+PSB+AM	2.78
CD (0.05%)	0.27

EC- enriched compost; VC – vermicompost; Azs- *Azospirillum*; *Azt-Azotobacter*; PSB- phosphate solubilizing bacteria; AM – Arbuscular mycorrhiza

Effect of organic amendments and microbial inoculants on soil health under wheat cultivation. Soils samples collected from various plots treated with different organic inputs and microbial inoculants at flowering and harvest time of the wheat (var. HD 2687) crop were subjected to analyses for organic C, nitrogen and dehydrogenase activity during the third year.

Soil with vermicompost was found to have higher dehydrogenase activity, organic C and total N as compared to that with enriched compost. Further improvement in dehydrogenase activity and the total N content of soil was observed with the combined application of nitrogen fixers–

Effect of organic matter amendments and microbial inoculants on organic C, total N, and dehydrogenase activity of soil under wheat cultivation

	Organic carbon (%)		Total N (%)		Dehydrogenase activity (µl H2↑ per day)	
	Time of sampling		Time of sampling		Time of sampling	
	Flowering (60 days)	Harvest (120days)	Flowering (60 days)	Harvest (120days)	Flowering (60 days)	Harvest (120days)
VC	0.505	0.87	0.05	0.07	433.0	859.0
VC+Azs+Azt	0.402	0.91	0.06	0.166	302.0	942.0
VC+PSB+AM	0.414	0.93	0.02	0.060	608.0	406.0
VC+Azt+PSB+AM	0.693	1.42	0.07	0.134	208.0	105.0
VC+Azs+PSB+AM	0.584	1.31	0.06	0.077	648.0	845.0
EC	0.488	0.80	0.021	0.042	186.2	902.0
EC+Azs+Azt	0.555	0.86	0.05	0.146	415.0	668.0
EC+PSB+AM	0.862	0.93	0.04	0.051	462.0	761.0
EC+Azt+PSB+AM	0.854	1.10	0.07	0.101	423.0	635.0
EC+Azs+PSB+AM	0.472	1.28	0.061	0.094	269.0	495.0

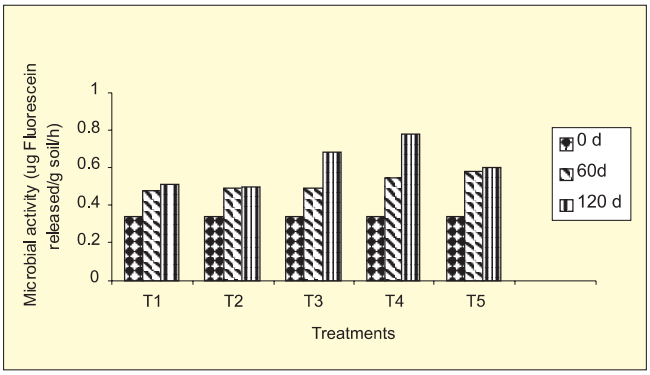
EC- enriched compost; VC – vermicompost; Azs- *Azospirillum*; *Azt- Azotobacter*; PSB- phosphate solubilizing bacteria; AM – Arbuscular mycorrhiza

Grain yield of rice was maximum when compost and inorganic fertilizers were applied in combination at half the rate of recommended N and P dose. This was followed by poultry manure alone @ 3 t/ha. Responses in grain yield with other treatments were on a par.

The variations in soil pH and EC were marginal. However, differences in organic C and available N contents of soil were significant at the harvest. Interestingly, microbial activity (FDA hydrolysis) of soil was found to corroborate with the grain yield of rice. Variation in soil dehydrogenase activity was marginal at flowering and harvest of rice.

Azotobacter and *Azospirillum*. Organic C of soil was maximum when nitrogen fixing, phosphate solubilizing and mobilizing organisms were used in combination.

Effect of organic amendments and inorganic fertilizers on soil health under rice cultivation. A field experiment was laid out in randomized block design to assess the effect of integrated use of organic and inorganic inputs on the grain yield and properties of soil under rice (var. Pusa 1121) cultivation. Compost was applied @ 3t and 6 t/ha, whereas poultry manure was applied @ 1.5t and 3 t/ha separately and in combination with full and half doses of 120 kg N and 60 kg P_2O_5/ha during the *kharif* 2007.



Changes in soil microbial activity as measured by FDA hydrolysis (µg fluorescein/g soil) activity during rice crop growth [T_1 - N_{120} P_{60} (full recommended dose); T_2 - compost @ 6t/ha; T_3 - poultry manure 3 t/ha; T_4 - N_{60} P_{30}+compost @ 3 t/ha; and T_5 - N_{60} P_{30}+poultry manure 1.5 t/ha]

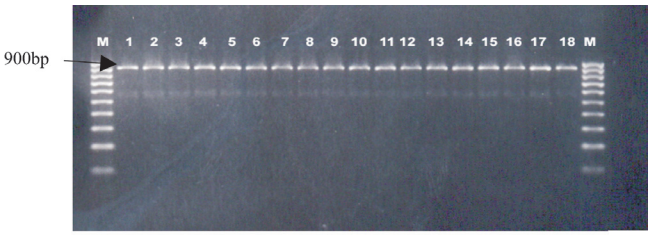
Effect of organic amendments on grain yield and soil properties under rice cultivation

Treatment	pH	EC (mS cm^{-1})	Organic C (%)	Available N (%)	Yield (kg/4.77 m^2)
Control	8.6	0.300	0.7	0.007	-
N_{120} P_{60} (Full recommended dose)	8.6	0.225	0.7	0.012	0.820
Compost @ 6 t/ha	8.6	0.225	1.0	0.012	0.800
Poultry manure 3 t/ha	8.3	0.225	1.1	0.010	1.270
N_{60} P_{30}+compost 3 t/ha	8.7	0.250	1.2	0.008	1.470
N_{60} P_{30}+poultry manure 1.5 t/ha	8.5	0.250	0.7	0.010	0.800
CD 5%	NS	NS	0.1	0.002	0.82

3.11.2 Exploitation of Microorganisms for Crop Production

3.11.2.1 Identification of efficient microorganisms for mass production of biofertilizer and their protocol development

Screening of released varieties of soybean for nodulation with native rhizobia under rainfed conditions. The nodulation status of the eight varieties of soybean (Pusa 16, Pusa 20, Pusa 22, Pusa 24, Pusa 37, Pusa 40, DS 9712



PCR amplification of RSα fragment in slow growing root nodulating isolates of soybean varieties. Lanes 1-4: Pusa 16; lanes 5-8: Pusa 20; lanes 9-12: Pusa 22; and lanes 13-18: Pusa 40

and DS 9814) released by the breeders under All India Coordinated Research Programme was examined. Seeds were sown on ridges, and 3 ridges per plot (4.0 m x 2.75 m) were maintained. The nodulation was observed at 50% flowering of each variety and the yield was taken at harvest.

On an average, 33-41 nodules per plant were observed. The number of nodules per plant was maximum with var. Pusa 20, while the dry weight of shoot was maximum with var. Pusa 37 (4.3 g/plant). The grain yield ranged from 767 to 1783 kg/ha. The maximum grain yield was observed with DS 9712 (1783 kg/ha) followed by DS 9814 (1493 kg/ha).

Screening of released varieties for nodulation with native homologous rhizobia

Variety	Nodules/plant	Dry weight of shoot/plant (g)	Yield (kg/ha)
Pusa 16	32.6	3.8	1183
Pusa 20	40.7	3.8	1200
Pusa 22	34.4	4.03	867
Pusa 24	37.0	3.4	950
Pusa 37	32.7	4.3	767
Pusa 40	40.2	3.9	867
DS 9712	37.0	2.95	1783
DS 9814	33.0	3.6	1493

Isolations of rhizobia were made from 20 individual nodules from six plants of each variety. A total of 46 rhizobial isolates (8, Pusa 16; 12, Pusa 20; 6, Pusa 22 and 20, Pusa 40) were purified and examined for colony morphology and growth on CRYEMA medium. Most of these isolates were found slow growers, with round and smooth colony morphologies. All isolates were found ketolactose negative. The PCR amplification of genes indicated the presence of RS α molecular marker fragment in 20 out of 25 isolates of rhizobia. This conserved sequence of ~900 bp was found in all soybean root nodulating bradyrhizobia.

Integrated use of micronutrients and B. japonicum inoculation for nodulation and yield of soybean. A field experiment was carried out to assess the effect of integrated use of micronutrients (B, Zn andMo) and inoculation with *Bradyrhizobium* on nodulation and yield of soybean (DS 9814). The observations on number of nodules, dry weight of nodule and shoot, N concentration in dry matter at 50% flowering stage, and grain yield were recorded at harvest. Response in nodule dry weight was significant but with other parameters it was marginal. On an average, the number of nodules ranged from 16.8/plant (Zn alone) to 37.3 (*B. japonicum* alone). The number of nodules was the highest with control (~45.8/plant). The dry weights of nodules ranged from 39 to 98 mg/plant. Nodule mass was the highest in control (98 mg/plant), followed by *B. japonicum* inoculation amended with borax @ 5 kg boron /ha. Maximum dry weight of roots was observed with control and *B. japonicum* inoculation with Zn amendment. Even though increase in grain yield was marginal, *B. japonicum* inoculation with boron amendment gave a maximum yield of 1850 kg/ha which was 52% higher than that of absolute control, and 59 % higher than that of *B. japonicum* alone.

Evaluation of soybean germplasm lines for nodulation by native rhizobia. Thirty germplasm lines of soybean were

Nodulation and yield of soybean with *B. japonicum* inoculation amended with micronutrients

Treatment	Nodules/ plant	Nodule dry weight/ plant (mg)	Root dry weight/ plant (g)	Shoot dry weight/ plant (g)	Yield (kg/ha)
Control	45.8	98	5.0	12.12	1216
B. japonicum	37.3	74	1.12	10.99	1160
Local check	20.3	39	0.58	6.12	1383
B. japonicum + B @ 5 kg/ha	27.9	81	0.81	7.2	1850
B. japonicum + Zn @ 5 kg /ha	22.1	60	5.0	7.58	1350
B. japonicum + Mo @ 4 g/kg	34.6	67	1.12	11.52	1367
Boron @ 5 kg/ha	28.9	64	1.1	11.33	1250
Zinc @ 5kg/ha	16.8	40	0.94	10.05	1150
Molybdenum @ 4g/kg seed as seed treatment	36.1	70	0.74	7.81	1350
B. japonicum + 7 + 8 + 9	24.7	55	0.96	9.3	1217
CD (0.05)	NS	16	NS	NS	NS

screened for nodule number, dry weights of nodule and shoot. Nodule number ranged from 3.0 to 35.6/plant, roots weight from 0.73 to 1.67 g/plant, and shoot dry weight from 6.82 to 14.06 g/plant. The germplasm line GP 06-22 gave the highest nodules per plant (38.0), while the line GP 06-10 gave the highest root weight (1.67 g/plant) and shoot dry weight (14.06 g/plant).

Selection of Azotobacter strains for enhancement in seed germination. The influence of *A. chroococcum* strains (JL 17, JL18, JL 104, A 41, JMS 100b) capable of utilizing complex carbon sources was assessed on seed germination, length of radicle and weight of seedling of wheat. Interestingly, response in seed germination of wheat was considerable with A 41 and JMS 100b. Maximum increase in the fresh weight of seedlings with JL 17 was followed by JMS 100b, JL 18, and JL 104. Response to inoculation in radical length was significant with JL 18 and JMS 100b.

Response in wheat seed germination with *Azotobacter* inoculation

A. chroococcum strains	Germination (%)	Weight of seedlings(g)	Length of radicle(cm)
Uninoculated control	71(22.24)	1.81(1.544)	1.40(1.378)
JL 17	75(22.75)	1.93(1.560)	1.52(1.399)
JL 18	80(23.57)	1.89(1.546)	1.66(1.476)
JL 104	78(23.22)	1.87(1.539)	1.47(1.401)
A 41	86(24.60)	1.84(1.531)	1.43(1.389)
JMS 100b	85(23.34)	1.90(1.552)	1.60(1.459)
S. Em.(±)	(0.604)	(0.006)	(0.028)
CD (0.05)	(2.39)	(0.028)	(0.124)

Figures in the parentheses are angular transformations of the original value

Selection of mutants of A. chroococcum for plant growth promotion and nitrogen fixation. Mutants of *A. chroococcum* strains sensitive to rifampicin (JL 17, JL 104 and RJ 1) were generated and compared with their wild types for nitrogen fixation and plant growth promoting activities.

It was observed that mutants JL 17 (2,5), JL 104 (2,6) and RJ 1 (3,5,6) were isogenic with respect to IAA production. However, mutants were found to very in nitrogen fixation (ARA activity) and 3,5 of JL 17, 6 and 8 of JL 104, and 2,4 and 6 of RJ 1 were isogenic.

Development of liquid bioinoculants for Azotobacter chroococcum with longer shelf life. The effect of glycerol, methyl crotonate, mineral oil and butanol on survival of *A. chroococcum* was evaluated on wheat seed. Glycerol and

Screening of rifampicin resistant mutants of *A. chroococcum* strains for IAA production and nitrogen fixation

A.chroococcum strain	IAA (µg/mg protein)			ARA (n moles/mg protein/hr)		
	JL 17	JL 104	RJ 1	JL 17	JL 104	RJ 1
Wild type	1.30	1.51	2.66	21.29	54.75	28.48
M 1	3.68	4.37	10.81	3.63	0.71	6.27
M 2	0.85	0.93	12.09	0.96	1.39	30.91
M 3	3.25	2.59	3.36	19.31	1.96	39.79
M 4	11.10	3.71	0.71	1.41	7.05	30.34
M 5	1.38	9.73	2.89	21.69	5.85	0.85
M 6	2.72	1.21	4.32	2.95	60.77	24.35
M 7	3.41	2.77	16.31	1.37	4.79	2.09
M 8	2.99	2.93	2.24	2.87	49.75	2.07
S Em ±	0.31	0.29	0.59	4.76	3.78	3.15
CD (0.05)	0.93	0.88	1.78	14.45	11.46	9.54

Figures are the angular transformation of the original value

methyl crotonate were found to support the viability of *A. chroococcum* on seed. The highest viability of *A. chroococcum* on seed was obtained when methyl crotonate was used as a seed additive. Butanol and mineral oil had deleterious effect on the viability of *Azotobacter*, and at the end of three days of incubation, a drastic reduction in the viability of *A. chroococcum* was observed on seed.

Twenty-seven liquid formulations of *A. chroococcum* were evaluated for stability at ambient temperature. No

Characterization of liquid formulation

Recipes	pH	Emulsion stability test				
		Separation of solids	Oily layer	Creamy layer	Suspension	Sedimentation
A	6.4	No	No	Yes	Good	Yes
C	5.9	No	No	No	Good	Yes
O	6.0	No	No	No	Good	Yes
P	6.2	No	Yes	No	Good	Yes
Q	6.2	No	No	Yes	Good	Yes
R	6.4	No	No	Yes	Good	Yes
S	6.4	No	No	Yes	Best	Yes
T	6.1	No	No	Yes	Good	Yes
U	6.5	No	No	Yes	Best	Yes
V	5.9	No	No	Yes	Good	Yes
W	6.5	No	No	No	Best	Yes
X	6.3	No	Yes	No	Good	Yes
Y	7.0	No	No	Yes	Good	Yes
Z	6.8	No	No	No	Good	Yes

separation of solids and oily layer appeared in any of the selected recipes.

3.11.2.2 Microorganisms as biocontrol agents

Biochemical characterization of anti-fungal compound against Rhizoctonia bataticola. Isolate HKA-15 was found to control *R. bataticola*, the causative pathogen for charcoal rot in soybean. The anti-fungal metabolite produced by the isolate HKA-15 was found to be very resilient in nature. It neither lost its anti-fungal activity during autoclaving (121^{0}C for 30 min) nor on treatment with protease enzyme.

The broth culture of the isolate HKA-15 was extracted with n-Butanol, concentrated to dryness, dissolved in minimum volume of methanol and spotted on TLC plates. Partial purification of the crude metabolite was carried out by exclusion chromatography. Anti-fungal activity was assessed *in vitro* using purified fraction of this metabolite.

The root colonizing ability of isolates HKA-15 and HKA-121 was tested by examining their growth on soybean roots. HKA-15 was found to be a better colonizer than HKA-121.

Identification of the biocide producing microorganism isolated from leaf compost. The isolate (4A) earlier identified as *Streptomyces purpeofuscus* (MTCC-8377) on the basis of their morphological and physiological characteristics was subjected to DNA sequencing. Its 16S rDNA fragment was amplified through PCR using universal primers. The amplified product was 1.5 kb size which was purified using microcon filters. The purified PCR product was cloned into pGEMT-Esay vector, checked for the presence of the insert and got it sequenced. The organism was BLAST searched and on the basis of similarity (~99%), it was designated as *Streptomyces albus*. The complete sequence of the 16S rDNA fragment of *Streptomyces albus* (MTCC-8377) submitted to NCBI was allotted an accession-No.EU-523135.

16S rDNA sequence of *Streptomyces albus*

GGCCGCCATGGCGGCCGCGGGAATTCGATTAGAGTTTGATCCTGGCTCAGGA
CGAACGCTGGCGGCGTGCTTAACACATGCAAGTCGAACGATGAAGCCGCTTC
GGTGGTGGATTAGTGGCGAACGGGTGAGTAACACGTGGGCAATCTGCCCTGC
ACTCTGGGACAAGCCCTGGAAACGGGGTCTAATACCGGATATGACACGGGAT
CGCATGGTCTCCGTGTGGAAAGCTCCGGCGGTGCAGGATGAGCCCGCGGCCT
ATCAGCTTGTTGGTGGGGTGATGGCCTACCAAGGCGACGACGGGTAGCCGGC
CTGAGAGGGCGACCGGCCACACTGGGACTGAGACACGGCCCAGACTCCTAC
GGGAGGCAGCAGTGGGGAATATTGCACAATGGGCGCAAGCCTGATGCAGCG
ACGCCGCGTGAGGGATGACGGCCTTCGGGTTGTAAACCTCTTTCAGCAGGGA
AGAAGCGCGAGTGACGGTACCTGCAGAAGAAGCACCGGCTAACTACGTGCC
AGCAGCCGCGGTAATACGTAGGGTGCGAGCGTTGTCCGGAATTATTGGGCGT
AAAGAGCTCGTAGGCGGCTTGTCGCGTCGGATGTGAAAGCCCGGGGCTTAAC
CCCGGGTCTGCATTCGATACGGGCAGGCTAGAGTTCGGCAGGGGAGATTGGA
ATTTCCTGGTGTAGCGGTGAAATGCGCAGATATCAGGAGGAACACCGGTGGC
GAAGGCGGATCTCTGGGCCGATACTGACGCTGAGGAGCGAAAGCGTGGGGA
GCGAACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGTTGGGCACTAG
GTGTGGGCGGCATTCCCCGTCGTCCGTGCCGCAGCTAACGCATTAAGTGCCC
CGCCTGGGGAGTACGGCCGCAAGGCTAAAACTCAAAGGAATTGACGGGGGC
CCGCACAAGCGGCGGAGCATGTGGCTTAATTCGACGCAACGCGAAGAACCTT
ACCAAGGCTTGACATACACCGGAAAGCCGTAGAGATACGGCCCCCCTTGTGG
TCGGTGTACAGGTGGTGCATGGCTGTCGTCAGCTCGTGTCGTGAGATGTTGGG
TTAAGTCCCGCAACGAGCGCAACCCTTGTCCTGTGTTGCCAGCAACTCCTTTC
GGGGAGGTTGGGGACTCACGGGAGACTGCCGGGGTCAACTCGGAGGAAGGT
GGGGACGACGTCAAGTCATCATGCCCCTTATGTCTTGGGCTGCACACGTGCTA
CAATGGCCGGTACAATGAGCTGCGATGCCGTGAGGTGGAGCGAATCTCAAAA
AGCCGGTCTCAGTTCGGATTGGGGTCTGCAACTCGACCCCATGAAGTCGGAG
TCGCTAGTAATCGCAGATCAGCATTGCTGCGGTGAATACGTTCCCGGGCCTTG
TACACACCGCCCGTCACGTCACGAAAGTCGGTAACACCCGAAGCCGGTGGCC
CAACCCCTTGTGGGAGGGAGTCGTCGAAGGTGGGACTGGCGATTGGGACGAA
GTCGTAACAAGGTAGCCGTACCGGAAGGTGCGGCTGGATCACCTCCTAATCA
CTAGTGAATTCGCGGCCGCCTGCAGGTCGACCATATGGGAG

rDNA fragment was amplified through PCR using universal primers. The amplified product was 1.5 kb size which was purified using microcon filters. The purified PCR product was cloned into pGEMT-Esay vector, checked for the presence of the insert and got it sequenced. The organism was BLAST searched and on the basis of similarity (~99%), it was designated as *Streptomyces albus*. The complete sequence of the 16S rDNA fragment of *Streptomyces albus* (MTCC-8377) submitted to NCBI was allotted an accession-No.EU-523135.

Fungicidal activity of the metabolites extracted from culture filtrate of Streptomyces albus. For testing antagonism amongst *S. albus* against *Alternaria solani* and *Macrophomina phaseolina*, the metabolites were extracted from culture filtrate of *S. albus* with ethyl acetate and butanol. The ethyl acetate extracted fraction showed 25% growth inhibition of *A. solani* at 200 ppm, whereas butanol fraction showed similar inhibition at 800 ppm. *Macrophomina phaseolina* was found to be more sensitive than *A. solani*, showing 50% growth inhibition at 10 ppm of ethyl extract fraction and at 200 ppm of butanol fraction.

Growth inhibition of *Alternaria solani* by the natural metabolite of *Streptomyces albus*

Ethyl acetate extracted metabolite (ppm)							
	0	25	50	100	200	400	800
Colony diameter (cm)	5.7	5.5	4.5	4.5	4.3	4.4	4.6
Growth inhibition (%)	0.0	4.34	21.7	21.7	25.2	23.4	15.6
Butanol extracted metabolite (ppm)							
	0	25	50	100	200	400	800
Colony diameter (cm)	5.7	5.0	4.7	4.5	4.6	4.4	4.3
Growth inhibition (%)	0.0	13.0	18.2	21.7	15.6	23.4	25.2

Growth inhibition of *Macrophomina phaseolina* by the natural metabolite of *Streptomyces albus*

Ethyl acetate extracted metabolite (ppm)						
	0	0.62	1.25	2.50	5.00	10.00
Colony diameter (cm)	9.0	6.9	5.9	5.8	5.1	4.4
Growth inhibition (%)	0.0	23.3	34.4	35.5	43.3	51.1
Butanol extracted metabolite (ppm)						
	0	12.5	25.0	50.0	100.0	200.0
Colony diameter (cm)	9.0	5.8	5.7	5.1	5.4	4.1
Growth inhibition (%)	0.0	35.5	36.6	43.3	40.0	54.4

3.11.3 Molecular Characterization of Agriculturally Important Microorganisms

3.11.3.1 Expression of *E. coli* clones for *mps* activity

Expression of *E. coli* clones for mps activity in terms of gluconic acid production was observed by TLC. In comparison to untransformed *E. coli*, clones tested showed detectable amount of gluconic acid activity in the medium. Since all other indicator tests performed in clones were positive, it is presumed that mps genes responsible for P-solubilization were successfully transferred to *E. coli*.

3.11.4 Exploration and Exploitation of Cyanobacterial Genetic Resource and *Azolla* for Agriculture and Industry

3.11.4.1 Genetic evaluation of cyanobacteria for H_2 production and N_2 fixation

Based on the sequence available from NCBI, the primers were synthesized for hydrogenase genes responsible for hydrogen production in *Chlamydomonas*. DNA extracted from heterocystous and non-heterocystous strains of cyanobacteria was amplified with primers for Hyd A_1 and Hyd A_2 genes. The PCR was carried out for Hyd A_2 genes. Two fragments of sizes 2500 bp and 1200 bp were amplified with the newly synthesized primer for Hyd A_2 in *Anabaena doliolum*.

3.11.4.2 Cyanobacterial diversity in organic field under rice-wheat cropping system

The molecular analysis of cyanobacterial strains isolated from soils of rice and wheat field revealed that they were distinct among themselves. Similarity matrix showed two clusters of *Nostoc* isolates, one for rice and the other for wheat. Similarly, the dendrogram of *Anabaena* isolates showed two main clusters at 50% similarity of 4 and 5 isolates, respectively. Of the four isolates in cluster one, 3 belonged to wheat and one to rice. The cluster two was further divided into two sub-clusters each with 4 isolates from wheat, whereas the other belonged to the soil from rice field.

3.11.4.3 Polyphasic approach towards analyzing diversity within *Anabaena* germplasm

A set of 70 *Anabaena* isolates (67 from diverse agro-ecological regions of India and 3 from American Type Culture Collection) were analyzed using data sets based on 58 variants of morphological attributes, 34 polymorphic bands from protein profiling, 35 polymorphic bands generated by 16S rDNA-RFLP analyses and 65 polymorphic bands generated through molecular profiling using repeat sequences. Analyses of combined data using clustering algorithm generated a dendrogram with four major groups with one outlier, AN50. The highest pair-wise similarity (0.71) was observed between AN63 and AN64 (isolates of Assam) and the pair-wise genetic similarity ranged from 0.22 to 0.62 for the rest of the strains. This study emphasized the utility of phenotypic and molecular methods for effective identification and robust taxonomy.

3.11.4.4 Interactive potential of BGA/*Azolla* and other bio-inoculants in rice-wheat-greengram cropping system

Field experiments were conducted to develop protocols for organic cultivation of *basmati* rice and wheat in rice-wheat-greengram cropping system. Inoculant of blue green algae (BGA) @ 2 kg/ha, *Azolla* @ 1.0 t/ha, vermicompost and FYM @ 5.0 t/ha were applied alone or in combination. These treatments were compared with absolute control ($N_0P_0K_0$) and recommended dose of chemical fertilizer ($N_{80}P_{40}K_{40}$). For rice, scented variety Pusa Sugandh 5 and for wheat HD 2687 were taken. Biomass of greengram was incorporated in soil

Effect of different organic treatments on grain yield of wheat and rice during 2007

Treatment	Grain yield (t/ha)	
	Wheat	Rice
Azolla(A)*	2.13	2.29
BGA (B)	2.21	2.19
FYM (F)	2.41	2.17
Vermicompost (V)	2.52	2.39
A+B	2.43	3.02
A+F	2.69	3.18
A+V	2.79	3.43
B+F	2.73	3.37
B+V	2.75	3.48
F+V	2.89	3.61
A+B+F	2.97	3.82
A+F+V	3.17	3.93
B+F+V	3.26	3.91
A+B+F+V	3.57	4.48
$N_{80}P_{40}K_{40}$	3.74	4.61
$N_0P_0K_0$	1.67	1.89
CD (0.05)	0.23	0.32

Azolla 1.0 t/ha; BGA 2 kg; FYM 5.0 t/ha; Vermicompost 5.0 t/ha
**Azotobactor* replaced *Azolla* in wheat

after picking of pods, and wheat was sown using zero tillage practice.

When inoculant of blue green algae was used in combination with *Azolla*, vermicompost and FYM, the entire requirement of *basmati* rice for nutrients was met in rice-wheat-greengram cropping system. The use of organic inputs not only enhanced soil organic C and available P but also improved microbial population/enzymatic activity of soil, thus making soil fertile for sustainable production of crops. Improvement in Fe, Zn and Mn contents of rice grain indicated that the use of organic inputs not only maintained soil productivity but also improved grain quality.

3.11.4.5 Biofertilizers in integrated nutrient management in rice-wheat cropping system

A field experiment on rice and wheat was conducted with 17 treatment combinations having two doses of chemical fertilizer (40 and 80 kg N/ha), two biofertilizers (*Azolla* and BGA) and one organic matter (FYM). The varieties taken were Pusa Sugandh 5 of rice and HD 2687 of wheat.

Results revealed a significant increase in grain yield of rice and wheat due to the application of biofertilizers and FYM alone or in combination with chemical fertilizers. There was a 58% increase in grain yield of rice with 40 kg N/ha, whereas the increase ranged from 73.5% to 98.6% when biofertilizers and FYM were applied in combination with 40 kg N/ha through chemical fertilizer. The increase in grain yield of rice was 108% over that of control when inoculants were applied with 80 kg N/ha. A similar trend in grain yield of wheat was observed with these treatments.

3.11.4.6 Studies on growth of *Azolla microphylla* under renewed metal stress and removal of metal under continuous process simulating wetland systems

Azolla, an aquatic microphyte has the ability to sequester heavy metals from the environment in which it grows. Its capacity in this regard depends on many factors including hydraulic retention time. An experiment was conducted to assess the ability of *Azolla microphylla* to grow, tolerate and accumulate metals (Cr and Ni) during renewed metal stress. *Azolla microphylla* was grown under continuous Cr stress (15-30 ppm). Although it could not tolerate the high stress of Cr, it could accumulate high concentration of Cr in its biomass. Studies on growth of *A. microphylla* under continuous stress of Ni showed its good tolerance to Ni and accumulation in biomass.

Accummulation of Cr and Ni in *Azolla* biomass under continuous process

	Dry weight (g)	Metal in dry biomass (ppm)
Cr		
Control	1.07	300
Medium +15 ppm	0.83	2700
Medium+30 ppm	0.63	2025
Tap water +15 ppm	0.87	698
Ni		
Control	0.47	10.65
Medium +1 ppm	0.49	94.35
Medium +5 ppm	0.41	40.95
Tap water +1 ppm	0.43	194.85

3.11.4.7 Ni sorption studies with dried *Azolla* biomass

The potential of the dried biomass of *Azolla* was examined for removal of Ni from waste water. This capacity of *Azolla* largely depends on high content of pectin in its cell wall. At higher Ni concentrations (10-50 ppm), accumulation of the metal was good in biomass. However, with increase in metal concentration beyond 50 ppm, saturation of binding sites occurred and no further accumulation of metal was observed in the biomass.

Effect of biomass concentration on removal of Ni by *Azolla microphylla*

Ni in water (ppm)	Ni removal (%) Biomass concentration (%)	
	0.5	**1.0**
0	-	-
10	60	89
50	74.25	99.2
100	69.2	69.66
500	91.8	91.6

3.11.4.8 Salt tolerance in *Azolla – Anabaena* symbiotic system

Azolla pinnata, *A. filiculoides*, *A. rubra*, *A. microphylla* and *A. species* were grown under normal and saline conditions *in vitro*. Response in growth was measured in terms of biomass and proline accumulation.

Salinity, in general, was found to have adverse effect on biomass production of different species of *Azolla*. However, species were found to vary in their response to salinity. Proline accumulation is an important parameter adopted by plants to maintain growth under stress conditions.

Growth of *Azolla* species under saline conditions

Species	Biomass (g)			Proline (µg/mg^{-1}f.w.)		
	NaCl (%)			NaCl (%)		
	0	0.5	Mean	0	0.5	Mean
A. pinnata	0.198	0.189	0.194	0.756	0.981	0.869
A. filiculoides	0.154	0.081	0.117	0.747	1.063	0.905
A. rubra	0.126	0.057	0.091	0.672	1.147	0.909
A. microphylla	0.258	0.237	0.248	0.784	1.343	1.060
A. species	0.238	0.217	0.228	0.700	1.567	1.130
Mean	0.195	0.156		0.731	1.220	

CD (P=0.05): concentration -0.003, species-0.004, and interaction- 0.420

The content of free proline in fronds of *Azolla* species enhanced significantly in comparison to that of other species on exposure to salinity. *Azolla microphylla* and *A. species* seemed to be more tolerant to 0.5% salt concentration than other species of *Azolla* as evident from their biomass production and significantly higher accumulation of proline under salt stress conditions.

3.12 ENVIRONMENTAL SCIENCES

3.12.1 Developing Weather-Derivatives-Based Insurance Products for Adapting to Climatic Risks

Risks of yield loss for different scenarios of high temperatures, deficit rainfall, frost, high humidity, fog, and unseasonal rainfall at harvest were characterised for wheat, potato, chickpea and mustard grown in northern India. Agricultural Insurance Company of India has used this characterization of climatic risks for developing their weather derivatives based insurance policy for lakhs of farmers. The research findings of IARI have been used by Agricultural Insurance Company of India in product designing for wheat, mustard, barley, gram and potato for the states of Rajasthan and M.P. The preliminary figures under this pilot study for two states for *rabi* season are as follows:

State	No. of farmers	Area (ha)	Sum insured(in lakhs)
Rajasthan	5,42,009	8,41,317	1,46,246
Madhya Pradesh	11,106	15,895	4,179

3.12.2 Global Warming Potential of Agricultural Soils

Estimates of green house gases (GHGs) emission from soils are important for preparing national inventories of GHGs emission and for developing mitigation strategies. For agricultural sector, IARI has been preparing this inventory in India for the last many years. To bring greater precision in these inventories, agro-ecological zone specific emission coefficients of nitrous oxides and carbon dioxide were developed using Infocrop model, and an inventory was prepared for rice-wheat growing regions. Our results showed that the total annual emissions from 27.4 million ha of wheat fields were 17.10 Gg and 43.20 Tg of N_2O-N and CO_2-C, respectively, with a cumulated global warming potential (GWP) of 164 Tg CO_2 equivalent. The global warming potential of 42.2 million ha of rice growing area was 48% higher than that of the area under wheat at 317 Tg CO_2 equivalents.

3.12.3 Adaptation Strategies to Reduce GHG Emissions from Rice and Wheat Crops

Simulation analysis has shown that adoption of alternative management practices like increasing splits in nitrogen fertilizer application would reduce GWP in rice by 12% and in wheat by 10%. It would also enhance the yields of both the crops. These strategies are also likely to increase the net profit of the farmers, especially if farmers can be given credit for mitigating GHG emissions.

3.12.4 Establishment of Research Infrastructure for Climate Change Studies

Facilities such as, free air CO_2 enrichment (FACE) and temperature gradient tunnels (TGT) were developed to screen crops/varieties to high temperature and carbon dioxide at different time periods at IARI. These facilities are being used to mimic closely the future climate and its impact on experimental crops.

FACE ring with anemometer and CO_2 supply system

CO_2 supply, recording and monitoring panel

3.12.5 Effect of High Temperature on Pollen Germination of Wheat

In order to study the effect of increased temperatures associated with climatic change on critical crop growth processes such as pollen sterility and pollen germination, a field experiment with 5 different wheat varieties sown at different dates was conducted. Pollen germination percentage on stigma was found to increase with increasing temperature. The upper limit of this could not be established this year. However, pollen germination was less in all wheat cultivars if temperatures decreased below 16 ^{0}C. Results also indicated that the *durum* varieties are more susceptible to temperature fluctuations compared to *aestivum* cultivars.

3.12.6 Effect of Continuous Increase in Temperature on Crop Yield

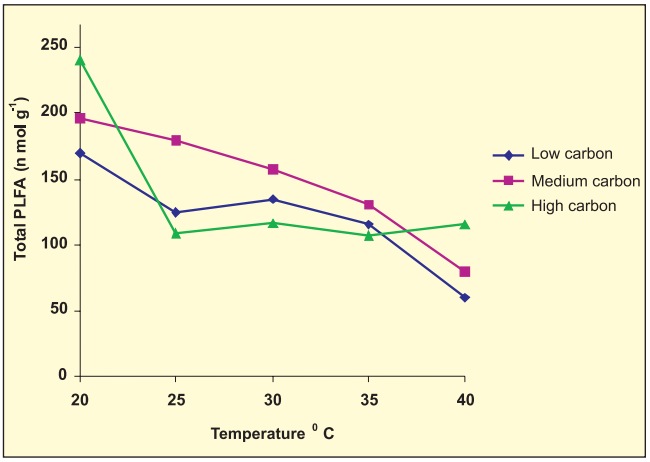
Three wet season crops (rice, greengram and soybean) and two dry season crops (potato and chickpea) were grown under temperature gradient tunnels (TGT) equipped with automatic temperature sensors at a particular distance with a continuous data logging system to assess the effect of varying thermal regimes on growth, yield and phenological traits of these crops. Continuous increase in temperatures under TGT exhibited gradual reduction in biological yield, economic yield and yield components in all these crops. Among the crops, rice showed the highest degree of reduction in grain yield by increasing temperature, which was mainly attributed to marked increase in spikelet sterility. Greengram, soybean and potato also showed reduction in their economic yield to varying extent which was mainly attributed to reduction in pods/plant and 1000 – seed weight, while seeds per pod was least affected both in greengram and soybean. Potato yield reduced gradually with the rise in temperature owing to reduction in the number of tubers/plant and tuber size.

3.12.7 Effect of Elevated CO_2 on Crop Yield

Two *kharif* crops (greengram and soybean) and two *rabi* crops (potato and chickpea) were grown under ambient and enriched CO_2 (550 ppm) conditions using FACE facility to assess the effect of elevated CO_2 level on growth and yield of different crops. Elevated CO_2 increased the yield of greengram, soybean and potato substantially (15-26%). Enhancement in crop yield was attributed to marked increase in the number of pods per plant and 1000 - grain weight in greengram and soybean, and the number of tubers/plant (19%) and size of tuber (26%) in potato. However, the number of seeds per pod was least affected by CO_2 enrichment.

3.12.8 Soil Microbial Community Dynamics in Response to Temperature in Different Soil Carbon Scenarios

The shift in the microbial community composition as measured by phospholipids fatty acid analysis (PLFA) was studied by incubating the soils with low carbon from Rajasthan (0.34% organic C), medium carbon from Hyderabad (0.59% organic C) and high carbon from Palampur (1.3% organic C), Sikkim (1.02% organic C) and Andaman and Nicobar Islands (0.96% organic C) at different temperatures. Twenty-six different PLFAs were classified as indicators for special microbial groups in the community. Microbial community composition was significantly influenced by temperature x carbon interaction. Total PLFA content in high carbon soil decreased significantly from 239.96 nmol g^{-1} to 108 nmol g^{-1}, when the temperature was increased from 20 ^{0}C to 25 ^{0}C. Further increase in the temperature led to the stabilization in the microbial biomass as determined by the PLFA. However, the



Soil microbial community dynamics in response to temperatures

medium carbon soil didn't show much decline in the PLFA content, whereas the low carbon soil showed 26% decline in PLFA content with the increase of 5°C temperatures. The decline observed in the high carbon and low carbon soils was largely due to the decrease in gram positive bacterial biomarker. The study demonstrates that under elevated temperature although there is a shift in the microbial communities, but how these affect the metabolism processes or cause changes in functional diversity, is yet to be established.

3.12.9 Coping Strategies of Farmers against Floods in Rice-Wheat Ecosystem

In a survey of climate induced natural disaster such as flood in the Ghaggar flood plains, out of 33 coping strategies, four main factors of different coping strategies were identified as having maximum percentage variation. These extracted factors were labeled as agronomic practices, family budget adjustments, help from social setup, and credit from financial institutions. The first factor (agronomic practices) accounted for 30.95% of the total variance and there were six coping activities which had significant loading on factor 1. The second factor (family budget adjustment) accounted for 15.76% of the total variance in the coping activities. Under this factor, there were six coping activities, which had significant factor loadings. Borrowing from relatives and friends, gifts from relatives and friends, and help from neighbors accounted for 9.56% of the total variance, and the factor was labeled as "help from social set up" factor. Under fourth factor, credit from financial institutions accounted for 7.29% of the total variance and it is directly related to the credit for agriculture operations, buying of fodder, and for daily household requirements. This analysis revealed that agronomic practices were the major coping operations adopted by farmers against the recurrent floods under rice-wheat ecosystem in the Ghaggar flood plains.

3.12.10 Establishment of *Jatropha* in Degraded Lands

Jatropha curcas was planted at three locations, namely, distillery effluent and flyash dumping site in Gajraula, J.P. Nagar district, U.P. farmers' field under paper mill effluent irrigation at Ahmedgarh, Sangrur district, Punjab, and ravines of Yamuna in Etawah, U.P. *Jatropha* showed good results in distillery effluent dumping site (4th year seed yield, 2.2 t /ha) and poor yields in ravines of Yamuna (2nd year yield, 0.05 t/ha) with mortality rate of 37% in 3000 seedlings planted in 2006 and 2007. *Jatropha* grew well in paper mill effluent irrigated fields with moderate yield (3rd year seed yield, 0.8 t/ha).

3.12.11 Economics of *Jatropha* cultivation under Various Conditions

Cost of cultivation of *Jatropha curcas* and *Pongamia pinnata* was worked out under irrigated and rainfed conditions. *Jatropha* starts giving returns after four years, whereas *Pongamia pinnata* starts giving returns after five years. Net income is more in *Pongamia* cultivation than in *Jatropha curcas* cultivation. The benefit cost ratio of different agroforestry and biofuel plant species at different discount rates revealed that *aonla*, was a much better option than *Jatropha* and *Pongamia* under dryland conditions.

3.12.12 Utilization of *Jatropha* Fruit and Seed Coat for Bioremediation of Lead, Cadmium and Chromium from Aqueous Solution

Seed coat and fruit coat of *Jatropha* waste products left out after the extraction of oil, were tested for bioremediation of metals from aqueous solution. Maximum adsorption of lead on fruit coat and seed coat was achieved in 60 minutes with particle size of 40 mesh, rpm 160, adsorbent doze of 0.5 – 1.0 g, pH 3 for fruit coat, pH 2 for seed coat, temperature 30°C and 50 ppm initial concentration of lead in aqueous solution. Elovich equation provided the best correlation of the experimental kinetic data at an initial solution pH 2 for seed coat and pH 3 for fruit coat at particle size of 40 microns. In the case of Cd, maximum adsorption on fruit coat and seed coat was achieved in 180 minutes with particle size of 40 mesh, rpm 160, adsorbent doze of 0.5 – 1.0 g, pH 6.0, temperature 30°C and 50 ppm initial concentration of cadmium in aqueous solution. As the initial concentration of lead and cadmium in the solution increased from 25 to 250 ppm, the adsorbed concentration of Cd decreased from 90% to 68% with seed coat and 84% to 57% with fruit coat and that of lead decreased from 95% to 82%. For chromium (VI), maximum adsorption on fruit coat and seed coat was achieved in 180 minutes with particle size of 40 mesh, rpm 160, adsorbent doze of 0.5 – 1.0 g, pH 2.0, temperature 30°C and 50 ppm initial concentration of chromium in aqueous solution. It can be concluded that utilization of *Jatropha* seed coat and fruit coat for bioremediation of heavy metals from wastewater will be useful for pollution control.

3.12.13 Bio-ethanol from Maize Grain

Fermentation of dry milled maize starch (var. Prabhat) was carried out with a selected strain of *Saccharomyces cerevisiae* (ITCC 1030) at 34°C, pH 5, 20 hours and 10%

dry substance. The saccharified starch obtained from maize after enzymatic saccharification yielded 5% ethanol in the bioreactor with 80% sugar utilization. Under optimized conditions, only traces of methanol and higher alcohols were found. Simultaneous saccharification and fermentation process for corn grain starch yielded ethanol on a par with that of two stage liquefaction and saccharification fermentation process.

3.12.14 Physio-chemical Characterization and Alternative Use of Waste Generated from Ethanol Production in Agriculture

Approximately 0.2 t of spent wash/t of sorghum biomass is available for agriculture or other uses. The main characteristics of the effluent/spent wash after fermentation and distillation are: pH 4.3; TSS 1.9 g/l; COD 19.7 g/l; total Kjeldahl N 0.055 g/l, and total P 0.035 g/l. Liquid waste generated from ethanol production can be used for ferti-irrigation in different crops. Irrigation with effluent up to 60% dilution was found suitable.

3.12.15 Utilization of Paper Mill Effluent in Agriculture

Studies on farmers' fields irrigated with paper mill effluent near Ahmedgarh in Sangrur district of Punjab and in vast tracts of *Tarai* region revealed the accumulation of sodium and ESP in soil as the levels of effluent application increased. However, it did not show any change in productivity of wheat and rice. Microbial diversity as estimated by BIOLOG analysis showed increased diversity in effluent irrigated fields. Effect of effluent on seed germination was more perceptible in vegetable crops as compared to foodgrain crops. Based on these studies, a monitoring protocol was formulated for safe utilization of treated paper mill effluent for irrigation of agricultural crops.

3.12.16 Impact of Surface Ozone on Crop Productivity

A field facility for assessing the impact of surface ozone on productivity of crops was established at the IARI experimental farm. The standardization of this experimental setup was carried out by growing rice under elevated ozone concentration (ambient + 25-30 ppb) in open top chambers (OTC). Growth and yield attributes, leaf area index (LAI) and other biochemical parameters were recorded in two varieties of wheat, PBW 343 and HD 2936 exposed to elevated ozone concentration (ambient + 30 ppb) from germination to maturity. There was a significant reduction in LAI at the flowering stage in both the varieties under elevated ozone concentrations. The chlorophyll a/b ratio decreased significantly at 65 DAS, indicating that the elevated ozone was creating stress in the plants. There was a 6% to 11% reduction in growth parameters and yield attributes at maturity. The grain yield decreased from 11% to 14% under elevated ozone treatment.

3.12.17 Land-Water Resource Degradation in Two Economically Contrasting Districts of NCR

Over the last two decades, the National Capital Territory (NCT, Delhi) has been encountering rapid growth, thereby placing pressures on the environment and natural resources of NCT, Delhi and other policy zones of National Capital Region (NCR). The government is unable to combat varied resource degradation problems in different policy zones of NCR owing to lack of any detailed spatial information on the type, extent and source of such problems in the region. The present study assessed the type, extent and source of major land-water resource degradation problems in the rural areas of two economically contrasting districts of NCR. The study revealed that 23.4% of agricultural lands in Gurgaon and 62.7% in Mewat were primarily surface (canal/drain) water irrigated. A large part of this surface water irrigated area in Mewat district was either waterlogged (7.4% area with $\leq$ 2 m ground water depth) or at risk of being waterlogged (17.1% area with 2-3 m ground water depth). Ground water of about 39% of Mewat district is salt -affected (EC_{mean} = 7.05 dS/m and SAR_{mean} = 7.71). Drinking water of almost the entire Mewat district was contaminated with Cr (2.0 - 3.23 ppm), Mn (0.80 - 1.55 ppm), Ni (0.02 - 0.10 ppm) and Pb (0.40 - 0.83 ppm). Ground water (43%) of the industrialized and Najafgarh drain water irrigated Gurgaon, (Pataudi and Farukh Nagar blocks) was also salt-affected, and with Cr > 0.05 ppm. Water in some areas in Gurgaon and Pataudi blocks was having exceptionally high (> 0.1 ppm) Ni concentrations, especially around the battery and automobile manufacturing units. Although Cr concentrations in the surface/sub-surface irrigation waters of both Gurgaon and Mewat districts were far above the maximum permissible limit of 1 ppm, their bio-available soil-Cr and Ni concentrations were within the permissible limit. The waterlogged/potentially waterlogged, carbonate/ bicarbonate rich salt-affected soils of Mewat district were having acute Zn deficiency (<0.6 ppm). Some areas with extremely high Fe (20–25 ppm) and Mn (10–25 ppm) concentrations were also noticed in the Gurgaon, Nuh and

Punhana blocks. Generation of reduced conditions owing to rice cultivation in areas with 3.0 – 3.5 m water depths appeared to be the main cause of such point contaminations. The study pointed out that dumping of industrial and domestic wastewaters, especially from NCT, Delhi into river Yamuna, and to some extent, from NCT, Delhi relocated hazardous industrial units into Najafgarh drain tributaries at Delhi-Gurgaon boundary, and poor "on-farm" and "off-farm" water management practices were the main reasons for extensive (point/non-point source) land-water degradation in Gurgaon and Mewat districts of NCR.

3.12.18 Assessment of Decomposition of Bt Cotton (MECH 162 +Bt) and its Near Isogenic Line (MECH 162 –Bt) Leaf Residues and Determination of Persistence of Bt Toxin in Soil

The impact of Bt crops on ecosystem functions was assessed by decomposition studies of leaf residues of Bt cotton and its near isogenic line in soil through lab incubation studies. Different amounts of leaf residues, viz., 0%, 0.1%, 0.5%, 1% and 2% representing varied amount of Cry 1Ac (Bt toxin), viz., 0 µg/g, 0.17 µg/g, 0.8 µg/g, 1.7 µg/g and 3.4 µg/g, respectively, were added to the soil. The amounts of C evolved as CO_2 increased with the increase in the concentration of added leaf material, irrespective of Bt or its near isogenic line in the soil. The rate of CO_2 evolution with the addition of the Bt leaf material at 2% showed a 5.5 times increase as compared to unamended soil (16.85 µg CO_2- C g^{-1}) at 73 days of incubation. However, the cumulative amounts, evolved were significantly lower from soil amended with its near isogenic leaves counterparts. Although the presence of the Bt toxin (2.2 µg/g soil) in the 2% Bt leaves amended soil environment was detected up to 42 days, it was very difficult to interpret whether CO_2 – C emission inhibition was due to the presence of Bt toxin in the environment as the toxin can have behaviours in the field different from that in the laboratory.

Amount of Cry 1Ac toxin at different intervals in soil amended with Bt cotton leaves

Days of incubation (days)	Toxin concentration (%)				
	0	0.1	0.5	1	2
14	0	<1.2	3.01 ± 0.1	4.19 ± 0.02	4.29 ± 0.1
28	0	<1.2	2.5 ± 0.1	3.6 ± 0.01	3.8 ± 0.1
42	0	<1.2	1.9 ± 0.02	2.7 ± 0.022	2.9 ± 0.1
56	0	<1.2	<1.2	<1.2	<1.2

3.12.19 Radiocesium Desorption from Soils as Influenced by Different Extractants

Information on the behavior of radionuclides in soils and its uptake by plants is warranted for devising effective strategies and developing agricultural counter measures to minimize their transfer from soil to human beings. An experiment conducted with ten soils representing different soil orders, which were previously treated with ^{134}Cs and allowed for equilibration up to three months with intermittent cycles of wetting and drying, indicated that sorption of radiocesium on soils is instantaneous and nearly 91.5% to 95.1% of ^{134}Cs adsorbed tenaciously on soils at the end of 24 h equilibration time. The desorption studies using ammonium oxalate, sodium oxalate, calcium chloride, ammonium chloride and sodium tetraphenyl boron extracting solutions showed that, in general with an increase in concentration of the extractants, the total Cs desorbed also increased (maximum being in Alfisols and Ultisols). Amongst the extractants tried, tetraphenyl boron was observed to be most efficient.

4. CROP PROTECTION

4.1 PLANT PATHOLOGY

4.1.1 Fungal Diseases

4.1.1.1 Wheat

Inheritance of resistance in bread wheat cultivars to leaf rust. Genetic analysis of three elite wheat cultivars, viz., GW 322, HUW 533 and HW 20454, with three pathotypes of *Puccinia recondita* f.sp. *tritici*, i.e., 77-1 (109R63), 104B (29R23) and 106 (0R9), revealed the presence of three dominant independent genes for resistance in GW 322 and dominant independent genes each for resistance in HUW 533 and HW 2045. Analysis of BC_1 and BC_2 with pathotype 106 (0R9) confirmed the above genes. F_2 segregation of intercrosses (diallel crosses) of test cultivars to pathotype 106 (0R9) did not show any susceptible segregant indicating the presence of at least one common gene in these cultivars.

Confirmation of stem rust resistance gene. The presence of stem rust resistance genes, viz., *Sr8a, Sr9b, Sr11* and *Sr31* either singly or in combination, was confirmed by test of allelism in five bread wheat cultivars, viz., HD 2501, HD 2329, HW 2044, WH 542 and PBW 343. Analyses of seedlings of F_2 generation of allelic crosses (test cultivar × known *Sr* gene) showed the presence of both *Sr9b and Sr11* in HD 2501and HD 2329; *Sr8a* and *Sr11* in HW 2045 and *Sr31* singly in HW 542 and PBW 343.

Adult plant resistance (APR) to yellow rust. Two pathotypes of yellow rust (*Puccinia striiformis tritici*), viz., 46S119 and 78S84 were used to evaluate the APR response of AVT entries under artificial epiphytotic conditions. HI 1539, HI 1544, HW 5021, PBW 579, VL 882, VL 892 and WH 1021 showed resistance to both the pathotypes of yellow rust.

Identification of sources of combined field resistance to stem and leaf rusts in durum wheat. A total of 108 *durum* wheat genotypes (selected from over 1100 lines evaluated at Indore during 2002-03), including released varieties, land races and indigenous as well as exotic genetic stocks, maintained their field resistance to both stem and leaf rusts (terminal rust severity up to 10S) at Indore and Mahabaleshwar during 2007-08 as well. Hence, these genotypes hold promise as stable sources of combined resistance to stem and leaf rusts for use in *durum* wheat improvement.

Identification of diverse genes for resistance to leaf rust in durum wheat. Genetic studies showed that seedling resistance to leaf rust pathotype 12-2 was conditioned by a single dominant gene each in HG 110 and Line 1172, and by a pair of dominant genes each in B 662, ED 2398-A and IWP 5019. Allelic tests showed that these genes were different from each other. Thus, eight diverse dominant genes were identified for leaf rust resistance, which are different from *Lr23*. The leaf rust resistance gene commonly postulated in Indian *durum* wheat genotypes as *Lr23* is ineffective against the leaf rust pathotype 12-2.

Gene postulation for rust resistance. Gene postulation of 52 advance lines was done at the Tutikandi Centre of the IARI Regional Station, Amartara Cottage, Shimla with the aim of selecting high yielding wheat genotypes with diverse resistant genes for leaf and stripe rusts. *Lr34* was the most frequent leaf rust resistance gene occurring in 42.3% genotypes either singly or in combination of other genes. Other leaf rust resistance genes postulated were *Lr26* (36.5%), *Lr1* (23%), *Lr23* (23%), *Lr13* (17.3%) and *Lr10* (3.8%). Similarly, three stripe rust resistance genes were postulated in above genotypes. *Yr18* was the most frequent gene (42.3%), followed by *Yr9* (36.5%) and *Yr2* (9.6%).

Variability in Bipolaris sorokiniana. *B. sorokiniana* isolates originating from different loacations varied in their cultural and pathogenic characteristics. The colony diameter after 7 days of incubation ranged from 20.3 mm (BS 95) to 63 mm (BS 63) and sporulation ranged from $1.1x10^7$ (BS 74, BS 94, BS 95) to $10x10^7$ (BS 69). Isolate BS 48 from Assam was non-sporulative. All the isolates were pathogenic and infection index ranged between 4.5 (BS 49) and 63.4 (BS 75). BS 49 from Assam was the least virulent and BS 75 from Wellington the most virulent.

Toxin characterization from Bipolaris sorokiniana. Phytotoxin from *B. sorokiniana* (BS-25) was identified as Bipolaroxin on the basis of NMR and spectroscopy. It is a sesquiterpenoid (MW 264.5) and forms the first report of its production by *B. sorokiniana.* Bipolaroxin was phytotoxic to *Phalaris minor*, *Avena sativa*, *Cynodon dactylon* but not to *Amaranthus tricolor*.

Developing SCAR marker for molecular diagnosis of Chaetomium globosum. Of the 12 universal rice primers (URPs) tested, primer URP-2R produced a uniform band of 1.9 kb in all the isolates of *C. globosum* but not in other species of *Chaetomium.* This fragment was sequenced and the specific primers were designed (Cg2-2® -22 bases; Cg2-5(F)-21 bases), which specifically amplified ~ 700bp product from *Chaetomium globosum*. No amplification was obtained from other species of *Chaetomium, Bipolaris* spp., *Aspergillus,* and *Fusarium* spp.

4.1.1.2 Rice

Screening for resistance against sheath blight. Of the 543 entries from IARI, New Delhi and the Directorate of Rice Research, Hyderabad evaluated against sheath blight under artificial epiphytotic conditions in field, SR 82, SR 88, CR 2340-3, RPHR 288-6, Ch 45, VL 4930, VL 7318, and VL 30249 were found promising.

Efficacy of fungicides in field. Seven fungicides, namely, Antracol 75WP, Companion 75WP, Dhanteam 75WP, Dhanustin 50WP, Indofil M-45 (75WP), Rhizocin 3L, Sitara 5EC were tested against sheath blight at different concentrations in field along with control. Pusa Basmati 1 was the test variety. All the fungicides tested were found effective against sheath blight. Companion 75WP was the most effective fungicide showing a disease reduction of 57% with highest yield, followed by Dhanustin 50 WP (54.9% disease reduction). In another study, two widely used fungicides, carbendazim 50WP and sheathmar 3L, were compared for their efficacy and cost effectiveness against sheath blight. Carbendazim 50 WP was found better than sheathmar 3L under artificial inoculation in field conditions.

Efficacy of different foliar treatments on control of bakanae disease caused by Fusarium moniliforme in paddy variety pusa 1121. Two foliar sprays of bavistin @ 0.25% or *Trichoderme viride* @ 0.4% and a combination of bavistin and *Trichoderma viride* 30 and 45 days after transplanting effectively controlled Bakanae disease in the field.

Bio-control of sheath blight of rice. Of the 29 different bio-control agents evaluated against *Rhizoctonia solani* in dual culture studies, the combination of *Trichoderma koningii* 5201 + *Chaetomium cochliodes* 3319 showed maximum inhibition of radial growth (59.7%), sclerotial number (81.0%), sclerotial size (75%) and germination (97.0%). Under field conditions also, pre-inoculation foliar spray of *T. koningii* 5201 + *C. cochliodes* 3319 showed maximum reduction in infected tillers (57.2%), relative lesion height (49.4%) and disease severity (74.6%). There was substantial increase in 1000-grain weight (141.5%), grain yield/plot (154.5%), and straw yield (124.7%).

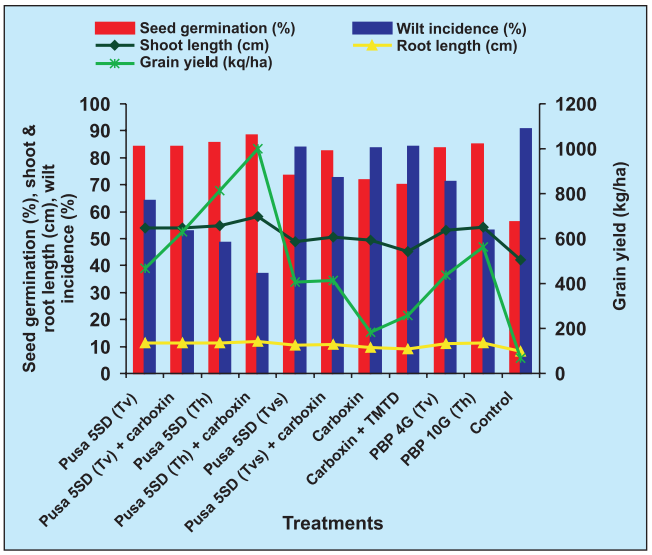
4.1.1.3 Maize

Resistance to diseases. Of the 205 entries in the IET and AET evaluated against Maydis leaf blight (MLB) and Banded leaf and sheath blight (BLSB) in artificial disease inoculations, the entries JH 11449, JH 11693, JH 11116, JH 11117, BH 4066, JH 10704 and SEEDTECH 2324 showed high level of resistance to both MLB (1.5) and BLSB (2.5). Of the 190 inbred lines evaluated against these two diseases, 11 lines, viz., LM 6, LM 14, DMSC 37, WinPink L5, WinPink L63, JCY 3-7-1-2-1-'b-1-1-4-1, JCY 3-7-1-2-1-'b-2-1-2-1, JCY 3-7-1-2-1-'b-2-1-3-1, HKI 164-TB 3-4-7, CML 164 and HKI 170(1+2) showed high level of resistance against MLB. SC 7-2-1-2-6-1 was registered (Reg. No. INGR 07025) with the National Genebank, NBPGR, New Delhi as a resistance source for Maydis leaf blight disease.

4.1.1.4 Chickpea

Evaluation of genotypes against wilt and Ascochyta blight. Of the 156 genotypes evaluated against wilt and Ascochyta blight, genotypes GJG 03-12, GNG 1488, GNG 1591, GNG 1688, PG 03-110, PG 9708-6, BG 2046, H 02-36, HK 02-201, CSJ 303, RSG 974, CSJD 125, and JSC 39 were resistant/moderately resistant against wilt, and genotypes GNG 1688, GNG 1744, GLK 22094, H 0038, GL 21107, H 99-9, H 00-249 and Flip 90-166 were resistant/moderately resistant against *Ascochyta* blight. The seeds of 10 genotypes H 01-36, PCS-8, H 01-08, H 99-291, Phule G 9425-9, PCS-9, PC 8-10, HK 00-2999, HK 00-300 and HK 01-2003 found resistant to wilt for three consecutive years (2004-2007) were deposited with the National Genebank, NBPGR, New Delhi with accession numbers 553468 to 553477.

Evaluation of Pusa 5 SD and Pusa Bio-pellets formulations of Trichoderma against wilt of chickpea and root rot of chickpea and mungbean. Different seed dressing



Effect of seed treatment with Pusa 5 SD and soil application of Pusa Bio-pellet formulations of *Trichoderma* species on seed germination, shoot and root length, wilt incidence and grain yield of chickpea under wilt sick field conditions

and soil application formulations of *Trichoderma* species were evaluated against wet root rot (*R. solani*) and dry root rot (*R. bataticola*) of chickpea and mungbean, and also wilt (*F. oxysporum* f. sp. *ciceris*) of chickpea. Amongst the seed dressing formulations evaluated, Pusa 5 SD (*T. harzianum*) was effective against wilt and dry root rot of chickpea as well as dry root rot of mungbean. Further, Pusa 5SD (*T. virens*) based formulation was found superior to others against wet root rot of chickpea and mungbean. The interaction of soil application of PBP 10G and Pusa 5SD (*T. harzianum*) + carboxin was found effective against wilt of chickpea and also dry root rot of chickpea and mungbean. Soil application of beads of *T. virens* (PBP-16G) and seed treatment with Pusa 5SD – a formulation of *T. virens* in combination with carboxin were found superior to others against wet root rot of chickpea and mungbean.

***Diversity among isolates of Fusarium oxysporum* f. sp. ciceris.** Evaluation of 64 *F. oxysporum.* f. sp. *ciceris* isolates on 14 varieties including 10 international differentials revealed that the isolates originating from different locations were highly variable, and more than one race was prevalent in each state. Genetic evaluation revealed that some of the RAPD (OPM 6, OPI 9, P 17, OPN 4, OPF 1, P 17, P 21 and SC 1), ISSR (ISSR 7, ISSR 11 and ISSR 12) and SSR (MB 17) markers clearly differentiated the isolates originating from different locations.

4.1.1.5 Urdbean

Resistance sources against major diseases. Of the 17 genotypes evaluated, P 1053, P 1063 and P 1066 showed multiple resistance against *Cercospora* leaf spot, *Macrophomina* blight and *Mungbean yellow mosaic virus*.

4.1.1.6 Mungbean

Integrated management of major diseases. Of the 12 treatments evaluated, seed treatment with carbendazim (bavistin) 50%WP + TMTD (thiram) 75% DS (1:1 ratio 2.5 g/kg) + thiamethoxam 70%WS (cruiser) (6 g/kg) and foliar spray of thiamethoxam 25% WG (actara) 0.02% at 21 days after sowing and carbendazim 0.05% at 35 days after sowing supported maximum seed germination (58.9%), shoot (53.1 cm) and root (14.8 cm) length, number of nodules (26.7/ plant), number of pots (51.8/plant), dry weight (66.2 g/plant), and grain yield (1380 kg/ha) along with minimum intensity of *Mungbean yellow mosaic virus* (10.0%) and *Cercospora* leaf spot (3.7%).

4.1.1.7 Pea

Resistance sources against powdery mildew. Of the 23 genotypes evaluated, P 30, P 34, P 35, P 40, P 47 and P 48 showed resistance against powdery mildew.

4.1.1.8 Pigeonpea

Host resistance against wilt. Resistant Gene Analogues (RGAs) were isolated, cloned and sequenced from resistant genotype ICP 8858 against highly pathogenic isolates of *Fusarium udum*. Seven classes of RGAs were identified with their constitutive nature of expression. Comparison of deduced amino acid sequences of the RGAs to products of known resistance genes revealed that the RGAs were as similar to each other as to resistant genes from other species. Sequence alignment showed motif of P-loop and Kinase 2a and most of the Kinase 2a motifs were showing TIR homology. Parallel studies on the evaluation of 18 isolates of *F. udum* revealed that these are highly variable and differentiated into highly pathogenic, moderately pathogenic and slow pathogenic isolates. These isolates showed different banding pathogens with RAPD primer OPA2 and OPA3.

4.1.1.9 Rapeseed and mustard

Multiple resistance sources. Entries PBC 9221 and GSL 1 showed resistance to white rust (WR), downy mildew (DM), powdery mildew (PM) and stem rot (SR) diseases.

4.1.1.10 Vegetables

Identification of mycelial compatibility groups (MCGs) in soil borne pathogens of vegetable crops. On the basis of intermingling and interaction zones that develop in the pairing, eight mycelial compatibility groups (MCGs) were identified in *Fusarium oxysporum* f. sp. *cucumerinum* (wilt of cucurbits), four in *Sclerotinia sclerotiorum* (stalk rot of crucifers)) and three in *Sclerotium rolfsii* (rots in vegetables and field crops).

Management of Sclerotinia sclerotiorum rot of cauliflower. The combination of FYM @ 50 t/ha + seed treatment with Th3 (0.4%) + seedling dip with *T. harzianum* (Th3) (0.4%) + garlic bulb extract (15%) spray was found effective in reducing the disease to 7.5% and increasing the seed yield to 381.2 kg/ha, followed by the combination of mustard cake @ 2.5 t/ha + seed treatment with Th3 (0.4%) + seedling dip with Th3 (0.4%) + garlic bulb extract (15%) spray, and the combination of vermicompost @ 10 t/ha + seed treatment with Th3 (0.4%) + seedling dip with Th3 (0.4%) + garlic bulb extract (15%) spray.

Crop phenology and management of diseases of cabbage*: (i) Black rot *(Xanthomonas campestris* pv. *campestris*).** All the stages of plant growth were susceptible and stomata, water pores and injury were sites of primary infection. Disease development was rapid between 18 °C and 26 °C under more than 80% relative humidity. However, rain splash helped in rapid disease spread. Need based application of streptocycline (200 ppm) reduced the incidence significantly (36%) over that of control (80%) in seed crop of cabbage. The calculated seed yield in the streptocycline treatment was 1650 kg/ha on the basis of 41 g/plant in comparison to 1216 kg/ha (30 g/plant). The rest of the treatments, viz., kavach (0.2 %) + streptocycline (200 ppm), copper oxychloride (0.3 %) + streptocycline (200 ppm) were statistically on a par, **(ii) Downy mildew *(Peronospora parasitica). The range of optimum temperature was between 18 °C and 26 °C and the disease spread was rapid at 26 °C under high humidity (>90%). No plant development stage was spared under the given environmental conditions. It is advised to avoid irrigation in the morning. Need based applications of Dithane M-45 (0.2%) or Ridomil MZ-72 (0.25%) gave excellent control, **(iii) Soft rot *(Erwinia carotovora).*** The curd stage was highly susceptible. However, frost or snow injury was pre-disposing factors. The disease was favoured by moderate temperature (22-25 °C) under high humidity (95-100%). Integration of mulching with preventive sprays of streptocycline (200 ppm) with copper oxychloride (0.3%) reduced the incidence to 13% in comparision to over 80% in control.

Survey and surveillance of diseases in Kullu valley. *Alternaria solani* was found to be associated with the mature and immature seeds of 6-9% apparently mature and healthy fruits of capsicum. The mycelium exhibited dirty white to grayish black look. The germination percentage of mature seeds was reduced by 30% hampering the seed quality.

More than 13% fruits of tomato varieties Marglobe and Sioux showed deformity in shape and colour appearance typical of tomato spotted wilt virus (TOSPOVIRUS). The symptoms appeared in the months of June to September. The virus was observed for the first time in this temperate zone of the valley.

4.1.1.11 Fruit crops

Soil solarization carried out for 10 weeks resulted in increase in temperature to a maximum of 39 ºC at 10 cm and to a maximum of 38 ºC at 20 cm soil depth. To study the effect of soil solarization on the survival of *Dematophora necatrix*, inoculums on infected roots (fine, secondary and primary roots) and fresh culture (7days old) multiplied on PDA in petri plate were buried under tarp (100 micron) at 10 cm, 20 cm and 30 cm soil depths for 10 weeks. Thereafter, the survival of the fungus was evaluated by taking isolations from each treatment. Soil solarization proved lethal to mycelial culture and fine roots segments at 10 cm depth, where almost all the segments failed to generate culture of the fungus. The survival of other inoculums at deeper soil depths though reduced to a varying degree as compared to those in unsolarized soil they were not completely killed. The survival of the fungus inoculum as primary root segments and old grain culture reduced by 61.66 per cent at 10 cm soil depth.

The apple rhizosphere, in general, is rich in microbial diversity. In order to monitor the microbial population and to isolate resident antagonists, surveys were conducted during active apple growing season. The soil samples were collected from different nurseries being grown by orchardists and the Department of Horticulture, viz., Bajaura, Raison, Doba, Kanog (Chopal), Durgapur, Kotkhai, Rampur, etc. in Kullu and Shimla districts. The enumeration of population of fungi, bacteria and Actinomycetes revealed that Kullu valley soils are rich in microflora as compared to the soils of Shimla. Out of the isolates studied, twelve fungi (*Trichoderma* spp. and *Glocladium* spp.) were found inhibitory to *Dematophora necatrix* and *Sclerotium rolfsii*. The cultural metabolites of some of them were also inhibitory. Though a large

number of bacteria and actinomycetes were isolated and evaluated against these two soil borne pathogens, none was found inhibitory.

The effect of different plant densities on apple rhizosphere microflora and the interaction of soil microflora with soil borne pathogens were also studied at research farm. A spur type variety, namely, Red Delicious grafted on *Malus baccata* Shillong rootstock had been planted in 60 m x 36 m plot size, at five spacings in three replications. The different spacings had different plant densities ranging from 4 to 49 plants per plot. The plants were planted with varying distances, as S-1 = 1.5 m x 1.5 m; S-2 = 2.0 m x 2.0 m; S-3 = 2.4 m x 2.4 m; S-4 = 3.0 m x 3.0 m; and S-5 = 4.0 m x 4.0 m. The relative abundance of various microorganisms on account of varying plant densities and depths was in decreasing order. For bacteria, it was 25.44 - 13.05x107 c.f.u./g soil (for S1-S5) and 35.42 - 4.94 x 107 c.f.u./ g soil (for 0-15 cm). For Actinomycetes, it was 11.55 - 9.05 x 105 c.f.u. / g soil (for S1- S5) and 10.83 - 9.83 x 105 c.f.u /g soil (for 0-15 cm). For fungi, it was 9.43 -6.16 x 104 c.f.u / g soil (for S1-S5) and 9.00 - 6.29 x104 c.f.u. /g soil (for 0-15 cm). For *Azotobacter,* it was 5.38 –1.94 x 104 c.f.u /g soil (for S1-S5) and 5.46-1.862 x104 c.f.u /g soil (for 0-15 cm). The number of various microorganisms showed variation with respect to each other and a gradual decrease was observed. It was found to be 17.42 x 107 c.f.u. /g soil (for bacteria), 10.37 x 105 c.f.u./g soil (for Actinomycetes), 7.67 x 104 c.f.u /g soil (for fungi) and 3.58 x 104 c.f.u /g soil (for *Azotobacter*).

Extracts of locally available medicinal plants were evaluated against *Dematophora necatrix* under *in vitro* conditions. Extracts of garlic, Banna (*Vitex negundoo*) and Bhang (*Cannabis sativus*) were quite effective and inhibited the growth of *D. necatrix* by 100%, 84% and 74%, respectively. However, species of *Lantana*, *Parthenium*, castor, *Tegitis*, *Azaderecta*, *Datura*, etc. were not as effective. Incorporation of soil Amendments (waste plant materials @5% w/w basis) into pot soil also resulted in increase in the populations of fungi, bacteria and Actinomycetes during their decomposition and afterwards as compared to those in non-amended soil. The maximum increase in fungal population was observed in castor ($40.23x10^4$) followed by that in wild marigold ($33.75x10^4$). Bacterial population was also maximum in castor ($207.64x10^5$) followed by that in *Lantana* ($144.27x10^5$) whereas Actinomycetes were maximum in garlic (31.96×10^3) followed by these in castor ($28.44x10^3$).

4.1.1.12 Large cardamom

Management of leaf and sheath blight disease of large cardamom. Against leaf and sheath blight disease of large cardamom, on-farm demonstrations were taken up at Singhik (North Sikkim) and Sribadam (West Sikkim). Among the measures evaluated, namely, soil application of *Trichoderma viride* formulation once after the annual harvest plus spraying the clump with *Pseudomonas fluorescence* formulation thrice at monthly intervals (in January, March and May); spraying the clump with 1% Bordeaux mixture thrice at monthly intervals (in January, March and May); and maintaining general hygiene in the plantation, the application of Bordeaux mixture resulted in significant reduction in the disease development in new shoots. The application of biocontrol agents also resulted in significant reduction in the disease development.

4.1.2 Bacterial Diseases

4.1.2.1 Legumes

Characterization of three bacterial blights in legumes based on symptomatological, cultural, pigmentation and RAPD profiles. Among three blights that affect legumes, halo blight (*Pseudomonas syringae* pv. *phaseolicola*) was easily differentiated by the presence of prominent halo surrounding the necrotic lesions as well as in pure culture (creamy white colonies, typical of *Pseudomonas*), whereas the other two blights, namely, common blight (*Xanthomonas campestris* pv. *phaseoli*) and fuscous blight (*X. campestris* pv. *phaseoli* var. *fuscans*) were differentiated by biochemical methods. The fuscous blight bacterium produced brown pigment in several media tested including NSA, NDA YGCA after 72 h, while common blight bacterium did not produce any brown pigment. Besides, common blight bacterium grew well in media containing xylose alone, whereas fuscous blight bacterium grew in medium containing xylose as well as mannitol. The fuscous blight bacterium was also differentiated from the others based on random primer generated profiles of total genomic DNA. Two amplicons of ~300 bp and ~1600 bp were obtained using the primer (SBSB02- 5′ TGA TCC CTG G3′) in fuscous blight bacterium but not in common blight bacterium and halo blight bacterium.

4.1.2.2 Vegetables

Biological control of black rot of cauliflower. *Bacillus subtilis* isolated from turnip leaf showed the potential to inhibit the growth of *X. campestris* pv. *campestris in vitro,* and the possibility of using it as bioagent to control the black rot of cauliflower is being explored.

4.1.3 Viral Diseases

4.1.3.1 Natural occurrence of viruses in mungbean and urdbean

Natural infection of *Mungbean yellow mosaic virus* (MYMV), *Urdbean leaf crinkle* (UBLC) and *Groundnut bud necrosis virus* (GBNV) on mungbean (18) and urdbean (9) cultivars was detected by symptomatology, transmission, electron microscopy, RT-PCR and ELISA. All the mungbean cultivars showed mixed infection of MYMV+UBLC. Except cultivars ML 668 and ML 818, all showed mixed infection of MYMV+GBNV, and except ML 668, ML 818 and MH 96-1, all showed mixed infection of UBLC+GBNV. Similarly, urdbean cultivars were infected by single and multiple infection. Except cultivars KU 301 and KU317, all showed mixed infection of MYMV+ GBNV and UBLC+GBNV.

4.1.3.2 Viral genomics

***Citrus tristeza virus*.** The complete coat protein (CP) gene from 25 CTV isolates (19 Darjeeling hills isolates, viz., CTK 2, CTK 4, CTK 5, CTK 6, CTK 7, CTK 9, CTK 8, CTK 10, CTK 13, CTK 15, CTK 16, CTK 17, CTK18, CTK 20, CTK 22, CTK 23, CTK 24, CTK 27 and CTK 30; four Delhi isolates, viz., CTB, CTP, CTD, CTN and two Bangalore isolates, viz., BNG-1 and BNG-2) and a 404 nucleotide (nt) fragment of 5 ORFIa variable region gene (VRG) (positioned from 52 between 1074 nt and 1478 nt) from 19 Darjeeling hills isolates were cloned and sequenced for determining genetic diversity. CTV isolates shared 90-99% identity in CP gene sequences and were grouped into three different clusters. CTV isolates also shared 83-98% identity in 52 ORFla VRGs and many Indian CTV isolates were genetically related to exotic isolates, SY568 (California, severe) and VT (Israel, severe).

In continuation of the activity for search of a mild strain of CTV, citrus samples from Pune and other regions of Maharashtra were collected and screened by monoclonal antibodies (MCA13). Three isolates that were negative with monoclonal antibody reaction were tested by RT-PCR using CTV 5 region specific primers. The sequences of these three isolates were related to severe strain of CTV from Bangalore sharing up to 98% identity, suggesting that the MCA13 negative isolates are not mild as observed from the CTV isolates from other countries, and that the Indian CTV isolates were different.

Sequencing of complete genome of Indian citrus ringspot virus. The complete genome of *Indian citrus ringspot virus* (ICRSV) infecting Kinnow mandarin of Hoshiarpur (Punjab)(ICRSV-H) was sequenced using 7 different sets of primers designed from the ICRSVK1 (Kinnow mandarin, Delhi isolate) sequence available in GenBank. ICRSV-H genome was 7560 nt long and showed 99.6% identity in nucleotide sequence with ICRSVK1. ICRSV-H also showed six ORFs, identical to that of ICRSVK1. However, both nucleotide and amino acid substitutions were observed in ORF 1 (putative RNA dependent RNA polymerase), ORF 2, ORF 3 and ORF 4 (triple gene block). Only substitution in nucleotide but not in amino acid was observed in ORF 5 (Coat protein gene). No substitution either in nucleotide or amino acid was found in ORF 6 (nucleic acid binding protein). The sequence analysis further revealed that ICRSVK1 and ICRSV-H were more close to Potexviruses than to other groups of filamentous viruses such as Carlaviruses, Fovreaviruses, Vitiviruses, Trichoviruses and Capilloviruses.

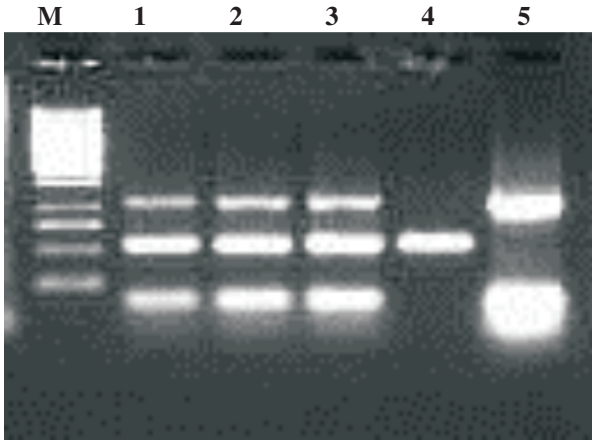
Complete genome sequence of Banana streak virus (BSV). Complete genome of BSV from a banana (Poovan) isolate from Trichy was sequenced using different sets of primers. BSV genome was 6994 nt long and shared 85% nucleotide sequence with a Chinese isolate of BSV. Further analysis of the sequence is in progress.

Sequencing of 16S, 23S and 16S-23S intergenic spacer region of ribosomal DNA of greening citrus bacterium. 16S (1417 bp), 23S (247 bp) and 16S-23S intergenic spacer region (620 bp) of ribosomal DNA of greening bacterium {*Candidatus liberibacter asiaticus (Cla)*} in Kinnow mandarin (Ludhiana) were sequenced for the first time in India and showed maximum identity with corresponding region of Cla sequenced from other countries.

Sequencing of small (s) RNA of Groundnut bud necrosis virus (GBNV). Genome organization and complete nucleotide (nt) sequence of the small (s) (AY871098) RNA segment of GBNV (mungbean isolate) was determined. sRNA was 3057 nt long and had two ORFs in an ambisence arrangement separated by an intergenic region (IGR) of 773 nt. The large ORF (1320 nt) was on viral sense strand (v) and encodes non-structural protein (NSs) of 440 aa long. The small ORF (831 nt) on viral complementary sense (Vc) encodes 277 aa nucleocapsid protein (N). The size of the 5 and 3 NCRs were 66 nt and 67 nt, respectively.

4.1.3.3 Molecular diagnosis

Simultaneous detection of citrus pathogens. Duplex PCR for simultaneous detection of citrus pathogens in naturally infected Sathgudi sweet orange, viz., *Indian citrus ring spot virus* (ICRSV) and *Citrus tristeza virus* (CTV), *Citrus mosaic virus* (CMBV) and greening bacterium (Cla) and CMBV and ICRSV was standardized. Natural infection of CMBV and ICRSV in Sathgudi sweet orange orchard in Nagari (A.P.) was confirmed by electron microscopy.



Simultaneous detection of CMBV and ICRSV. Lane M: marker; lanes 1-3: CMBV+ICRSV; lane 4: CMBV; and lane 5: only ICRSV

Nucleic acid extraction protocol. A cost effective RNA extraction protocol was earlier standardized for efficient detection of ICRSV and CTV from bark and leaf tissue. This extraction protocol also worked for template preparation for the detection of a DNA virus (CMBV). A multipurpose kit for template preparation of both RNA and DNA viruses in citrus is under evaluation.

4.1.3.4 Transgenic resistance

Agrobacterium-mediated transformation of tomato. To develop transgenic tomato against bud blight caused by *Groundnut bud necrosis virus* (GBNV), putative tomato transformants of CO 3, Pusa Early Dwarf (PED) and Pusa Ruby (PR) generated through *Agrobacterium*-mediated transformation using nucleo-capsid protein (N) gene sense and antisense constructs were screened for the presence of N gene. Thirteen of 45, 5 of 23 and 17 of 43 putative transformants from CO 3, PED and PR, respectively, were PCR positive. Of the 35 PCR positive transformants, nine transformants were Southern positive. Lines CO3S1, CO3S12, PRS1, PRS3, PRA2 and PRA4 possessed single copy of the transgene, while lines CO1S2, PRA1 and PRA5 possessed two copies of the transgene. Five of nine lines were positive for N gene expression in DAC-ELISA.

Molecular analysis of putative transgenic of tomato varieties with N gene of GBNV

Variety	Putative transformants	Genomic Southern	Number of insert	ELISA
CO 3	S1T0	+	1	+
	S2T0	+	2	+
	S12T0	+	1	+
PR	S1T0	+	1	+
	S3T0	+	1	+
	A1T0	+	2	NT
	A2T0	+	1	NT
	A4T0	+	1	NT
	A5T0	+	2	NT

*Absorbance at 405 nm more than two times of the transformed control was considered positive; + : positive; -: negative; NT: not tested

Agrobacterium-mediated transformation of groundnut. Transgenic groundnut (*Arachis hypogaea*) lines with sense and antisense coat protein (CP) gene of *Tobacco streak virus* (TSV) were generated by *Agrobacterium*-mediated transformation of de-embryonated cotyledons of cultivar JL 24. Approximately 180-200 days were required between explant transformation and hardening of transformants in the glasshouse. Genomic Southern analysis revealed two transgenic lines (S15, AS2) with single copy and one transgenic line (S3) with two copies of the CP gene. CP expression was observed in transgenic lines with CP gene (S3, S15) by ELISA. Evaluation of the transgenic lines for resistance to TSV is in progress.

Development of Papaya ringspot virus (PRSV) gene constructs. Coat protein (CP) gene of PRSV isolates originating from two different locations (Bilaspur in Chattisgarh; and Coimbatore in Tamil Nadu) was used as transgene to confer resistance. CP genes cloned in pDrive vector (3.85 kb) were mobilized into binary vectors (pBI121 and pBinAR) both in sense and antisense orientations. Constructs were then mobilized into *Agrobacterium tumefaciens*, and the conjugants analysed by colony PCR were supplied to the Central Institute of Subtropical Horticulture (CISH), Lucknow for papaya transformation. To confer broad spectrum resistance against PRSV, truncated CP gene constructs were also prepared.

Viral gene constructs developed for papaya transformation

Viral gene	Gene source	Orientation	Vector	Mobilized to		Remarks
				E. coli	*A. tumefaciens*	
Full CP (861 bp)	PRSV (Bilaspur isolate)	Sense Antisense	pBI121 pBinAR	+ +	+ +	Shared with CISH, Lucknow for papaya transformation
Full CP (858 bp)	PRSV (Coimbatore isolate)	Sense Antisense	pBinAR pBI121	+ +	+ +	
Truncated CP (~410bp)	PRSV	Truncated	pBinAR	+	+	Ready to share with CISH, Lucknow

Development of CTV gene construct. CTV isolates from Darjeeling hills (CTK5, CTK9, CTK 10 and CTK13), Bangalore (BNG1 and BNG2) and Delhi (CTB and CTP) were selected for developing CP gene constructs in sense and antisence direction. Sense and antisense CTV CP constructs (four each) were developed in pBinAR binary vector.

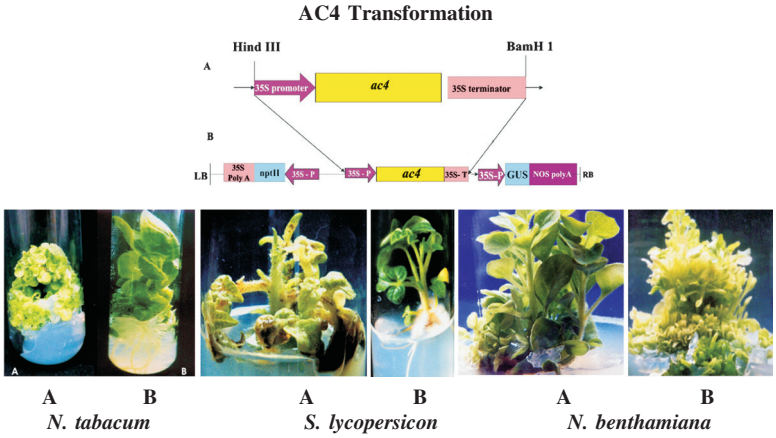
Non-inoculated Non-transgenic control **Inoculated** **Non-inoculated Transgenic (3.4 line)**

Challenge inoculated transgenic potato plants of cv. Kufri Giriraj (line 3.4) with PVY in the growth chambers

Evaluation of resistance in transgenic potato lines. Seven lines of transgenic potato cv. Kufri Giriraj were developed using coat protein (CP) gene from *Potato virus Y* (PVY). Based on the genomic Southern, two transgenic lines, 2.2 and 3.4 were selected for the evaluation of resistance to PVY in environmentally controlled plant growth chamber (Conviron) in the National Phytotron Facility at IARI. The transgenic line-2.2 had poor growth as leaves were narrow and stems were thin and lanky, whereas the transgenic line-3.4 had luxuriant growth with bold leaves and stems. The inoculated non-transgenic plants developed mild greenish mosaic symptoms on the upper leaves, and petiole necrosis on the lower leaves, whereas no symptoms were observed in the inoculated transgenic plants. Electron microscopic analysis of the inoculated plants showed the presence of PVY in the nontransgenic plants, whereas no PVY virus particles were observed in the transgenic plants. As transgenic plants contained CP gene, virus infection following challenge inoculation was judged by PCR using non-CP primer from NIb region which showed specific amplification of 660 bp fragment in the inoculated non-transgenic plants but not in any inoculated transgenic plants tested. The absence of symptoms and virus by EM and RT-PCR in PVY challenged transgenic potato plants indicates resistance to PVY.

The transgenic line-3.4, which showed excellent growth and resistance to PVY in plant growth chamber, was micro-propagated 10 times successively over a period of nine months and then examined for the presence of transgene in five randomly selected plants. PCR showed specific amplification of CP gene in all these selected plants indicating the stability of transgene.

Characterization of RNAi suppressor of ToLCNDV. The AC4 gene of *Tomato leaf curl New Delhi virus* (ToLCNDV) was sequenced. The sequence analysis revealed 96% homology with severe strain of ToLCV, and 75-85% homology with other mono and bipartite viruses causing leaf curl disease in India. The presence of certain conserved amino acids and motifs similar to other viral suppressors and the PAZ domain of dicer



Phenotypic observation of AC4 in *N. tabacum*, *S. lycopersicon*, and *N. benthamiana*: A- transformed, and B- degenerated

protein directly reflects its role in binding with small RNAs and hence playing a crucial role in development and defence. For establishing its direct involvement in plant development, the ToLCNDV-AC4 was used to transform *N. tabacum* and the transformants obtained showed severe developmental abnormalities suggesting its direct role in plant development.

Resistance evaluation of existing promising leaf curl resistant transgenic lines under contained trials. Molecular analysis of transgenic lines PEDAR-12 and PEDAR-26 from T-1 to T-4 generations suggested non-Mendalian inheritance. Non-Mendelian inheritance of the transgene may be due to the positional effect or recombinational rearrangements. Further studies with larger sample size are in progress to establish gene inheritance in transgenic lines.

Development of transgenic resistance to Mungbean yellow mosaic virus in soybean. Replication initiation protein construct of *Mungbean yellow mosaic virus* (MYMV) in antisense orientation (MYMV0Rep-AS) under 35S promoter was used to transform soybean cultivar JS 335 through *Agrobacterium.* Of the 535 putative transformants from embryonic tip (397) and cotyledonary explants (138), thirty-two transformants developed roots and molecular analysis of these transformants is in progress. In order to circumvent the problem of rooting, biolostic delivery of the MYMV-Rep-AS was attempted, and a total of 62 plantlets were obtained.

4.1.3.5 Citrus

Survey, collection and maintenance of virus and virus-like pathogens infecting citrus. *Citrus tristeza virus* (CTV) isolates were collected from West Sikkim and Lower Chhibo Busti (Kalimpong), indexed and maintained on *kagzi* lime (*Citrus aurantifolia*). One isolate of greening pathogen was collected from Sikkim orange (*Citrus reticulata*) in Zoom (West Sikkim), and two isolates were collected from Kalimpong, and one each was collected from Darjeeling orange (*C. reticulata*) and pummelo (*Citrus grandis*). The isolates were indexed on Darjeeling orange and mausambi (*Citrus sinensis*).

Surveys of four declining orange orchards in the Zoom region of West Sikkim revealed that the incidence of greening disease is 32.25%. Symptoms of incidence include yellow mottling, pale green discolouration of young leaves, general yellowing and sectorial chlorosis in canopy. Affected trees were sparsely foliated and produced lop-sided fruits with greenish-orange mottle. Greening-affected pummelo trees also exhibited similar foliar symptoms. The fruits from affected trees were lop-sided which, even when ripe, had large greenish patches on the rind.

Biological characterization of Citrus tristeza virus isolates from Darjeeling hills. Of the 20 CTV isolates from Sikkim and Darjeeling hills being maintained at IARI Regional Station, Kalimpong, the results of indexing of seven isolates on five different citrus species, viz., *kagzi* lime (*C. aurantifolia*), Darjeeling orange (*C. reticulata*), mausambi (*C. sinensis*), rough lemon (*Citrus jambhiri* Lush), Rangpur lime (*Citrus limonia* Osb.) are tabulated below:

Biological characterization of *Citrus tristeza virus* isolates from Darjeeling hills

Isolate	Symptoms on				
	***Kagzi* lime**	**Darjeeling orange**	**Mausambi**	**Rough lemon**	**Rangpur lime**
Ichchhey Busti – 2 (Source: *Kagzi* lime)	Vein clearing; die-back	Mild stem pitting	No symptom	Mild stem pitting	Mild stem pitting
Kalimpong – 2 (Source: *Kagzi* lime)	Vein clearing; vein flecking; vein corking; stem pitting; die-back	Yellowing of leaves; vein corking; Stem pitting	Stem pitting	Vein corking; stem pitting	Yellowing of midribs;vein corking
UBKV (Source: Mandarin)	Vein corking; die-back	No symptom	Vein corking	Interveinal chlorosis; vein corking; mild stem pitting	Interveinal chlorosis;vein corking; mild stem pitting
Upper Dalep (Source: *Kagzi* lime)	Vein clearing; mild stem pitting; die-back	———-	No symptom	———	Inward curling of young leaves
CDRS (Source: Darjeeling orange)	Vein clearing; Vein corking die-back	vein corking; die-back	Vein corking; die-back	Vein corking;	Vein corking
Chhibo Busti Source: (Darjeeling orange)	Vein clearing; vein corking; die-back	Vein corking; chlorosis; die-back	Vein corking; die-back	———	———
Mirik (Source: Darjeeling orange)	Vein clearing; vein corking; die-back	Vein corking; die-back	———	Vein corking	Vein corking; die-back

Monitoring of aphid vector population in *kagzi* lime plantation by yellow coloured traps placed at different heights of 1', 2', 3', 4', 5' and 6' recorded the maximum of 345 aphids/ trap in the fourth week of January. The trap placed at 1' height recorded the highest aphid catches compared to those placed at other heights. ELISA test identified eight isolates, i.e., M1, M2, Tm, Aphid transmitted, Katol, Shrirampur, Donde and IARI, Pune positive for CTV antisera.

4.1.3.6 Papaya

Visual observations on aphid colonization on papaya revealed the maximum number of 19.6 aphids (nymphs & adults) per plant on inoculated papaya plants transplanted in October, and these were identified as *Myzus persicae*, *Ceratovacuna lanigera, Macrosyphum* species and *Toxoptera aurantii*. Weed plants grown in and around papaya plantations such as *Cucumis melo*, *Alternanthera sessilis, Datura metal* and *Xanthium indicum* proved to be alternative hosts for *Papaya ring spot virus* (PRSV). In a screening trial, all the eight cultivars tested showed PRSV incidence (13.2-97.6%) by flowering stage. The variety Madhubala showed the least infection (13.2%) followed by the varieties CO 2 (39.8%) and Pusa Nanha (44.8%) at hundred per cent flowering stage.

Studies on the effect of roguing of PRSV infected plants on the productivity of papaya revealed that plant height at flowering was significantly higher in treatment combinations where PRSV infected plants were uprooted. However, the difference in the collar diameter was statistically non-significant.

It was demonstrated that five rows of banana planted as border crop on the periphery of papaya plantation was successful in reducing the number of aphid-vectors when compared with their number outside the border crop. The number of aphid-vectors found inside the border crop of banana was about 68% less than that found outside the border crop.

4.1.3.7 Management of virus diseases in capsicum

In capsicum, three varieties, Shanta, Tara and Indra, were screened for the incidence of virus diseases under field conditions. All the three varieties were susceptible to *Pepper veinal mottle virus* and *Cucumber mosaic virus*. The variety Indra showed the highest incidence of virus diseases (35-40%). Virus diseases in the field grown capsicum varieties Shanta, Tara and Indra could be effectively managed by regular alternate sprays of neem oil (1%) and diamethoate (0.1%) along with 2 applications of Thimet at 40 days' interval.

4.1.3.8 Peri-urban vegetables

Surveys. Surveys around Pune revealed the occurrence of PRSV-W in various cucurbits, viz., bottlegourd (15-20%), spongegourd (15-18%), ridgegourd (5-8 %) and pumpkin (10-15%).

In poly-house grown capsicum, the incidence of *Pepper veinal mottle virus* (30-35%) and *Cucumber mosaic virus* (42-47%) in the varieties Bomby and Lario was recorded. In field grown capsicum, the occurrence of *Pepper veinal mottle virus* (18-20%) and *Cucumber mosaic virus* (25-30%) was recorded in the variety Indra.

Varietal screening of cucurbits. Four varieties each of bottlegourd, ridgegourd, spongegourd, cucumber and pumpkin were screened for virus diseases under field conditions. A *Poty virus* was recorded in the bottle gourd varieties Arjun and Samrat. In spongegourd, all four varieties were susceptible to PRSV-W infection. The infection ranged from 8% to 10%.

The occurrence of WBNV in watermelon in February to March sown crop was higher (50-70%) because of the building up of thrips populations during this period as compared to that in the crop sown from the 2nd fortnight of December to January (3-5%).

The occurrence of viral infections was recorded in the cucurbitaceous vegetables, namely, ridge gourd (*Luffa acutangula*), sponge gourd (*Luffa cylindrica*), bitter gourd (*Momordica charantia*) and pumpkin (*Cucurbita moschata*), grown in and around Kalimpong during *kharif*. The affected plants exhibited vein clearing, vein banding, light and dark green mosaic and various deformations in leaves. In ELISA, the sap of infected plant materials reacted positively with polyclonal antibodies to *Potyvirus* group.

4.1.3.9 Large cardamom

Characterization of the virus causing foorkey disease. Four infected clumps of the large cardamom cultivar Ramsey were used for PCR-amplification of *foorkey* virus genome. Tissue samples, namely, fully expanded leaves, youngest unfurled leaves (core leaves), meristem tips, old roots and newly emerging roots were extracted. Genome fragments of the *foorkey* virus could be amplified using three different sets of primers designed from the *Banana bunchy top virus*

(BBTV) DNA1, DNA2, DNA3 components and a set of primers from BBTV common stem loop region. The amplified products of putative replicase and coat protein genes were cloned. The putative *rep*-gene was sequenced. It had 83% sequence homology with BBTV master *rep*-gene. Amplification of viral genome could be achieved only in the tissues from the youngest unfurled leaves and meristem tips.

4.1.3.10 Orchids

Characterization of the virus infecting Cymbidium and Coelogyne. Two important viruses, namely, *Cymbidium mosaic virus* (CymMV) and *Odontoglossum ring spot virus* (ORSV) are ubiquitous with orchid cultivation in Sikkim and Darjeeling hills. CymMV and ORSV may infect orchid genera either singly or in combinations. Immunological studies detected mixed infection of CymMV and ORSV in Cymbidium and other orchid genera. Electron microscopic (EM) studies of the infected samples also revealed the presence of both flexuous filamentous particles of CymMV and rigid rods of ORSV. Besides these two viruses, a number of viruses having *Rhabdovirus*-, *Potyvirus*- and *Badnavirus*-like particles were found to be associated with different orchid species. EM studies of the leaf tissue of *Cymbidium* spp. infected with mosaic streak disease and the leaf tissue of *Coelogyne* spp. infected with ring spot disease showed the presence of *Rhabdovirus*-like particles either alone or in combination with ORSV.

Electron microscopic detection of mixed infection of CymMV and ORSV in *Cymbidium* spp.

4.1.3.11 Tapping panel dryness of rubber

R-PAGE analysis of grafted trees revealed that TPD is graft transmissible. One hundred per cent (100%) transmission was observed when both stock and scion were from the affected source, up to 70% when the stock source was positive, up to 42% when the stock source was negative and the scion source was positive. In such case where both the stock and scion were from apparently healthy source, small percentage of plants showed the presence of TPD. Characterization of LMW-RNA -like bands associated with TPD is in progress.

4.1.4 Mushroom Cultivation

Strain improvement in mushroom. Significant increase in button mushroom (*A. bisporus* strain S-11) yield was obtained in two consecutive trials with UV radiation dose of 30 h and gamma radiation dose of 0.6 kGy. However, in the third year trial, yields were on a par with that of the control. In *Pleurotus sajor-caju* and *P. florida* also, 18-25% increase in yield was obtained with gamma (0.8 kGy) and UV (3 h) radiated cultures in 4 weeks' cropping period.

4.2 ENTOMOLOGY

4.2.1 Insect Pest Management

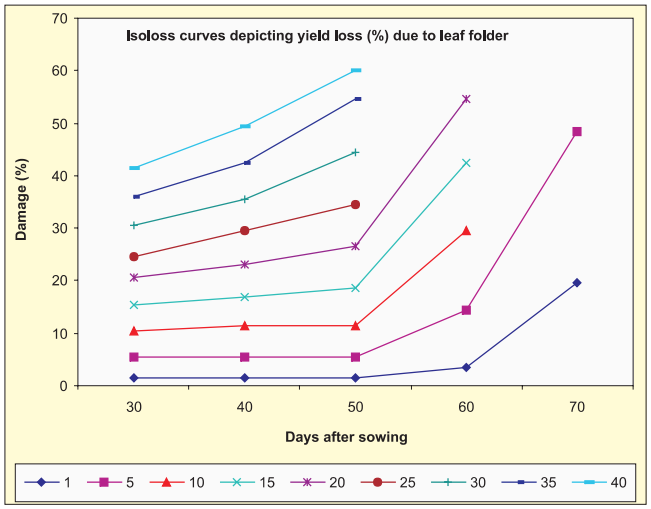
4.2.1.1 Cereals

Regression models developed for rice stem borer incidence in relation to weather factors were validated with pest incidence and weather data of *kharif* 2005 and *kharif* 2006. The models predicted the stem borer damage to be 5.8%, 14.6%, 7.1% and 3.7% in comparison to 5.4%, 12.6%, 3.0% and 4.9% damage observed at Aduthurai, Coimbatore, Pattambi and Warangal, respectively, during 2005. The predicted stem borer damage was 6.6%, 16.3%, and 4.5% compared with 7.4%, 12.5% and 8.3% damage observed at Coimbatore, Pattambi and Warangal, respectively, during 2006. The models predicted the stem borer damage well at Coimbatore during both the years, at Aduthurai and Warangal during 2005, and at Pattambi during 2006.

Validation of rice stem borer-weather models

Station	Stem borer damage (%) during *kharif* season			
	2005		2006	
	Predicted	Observed	Predicted	Observed
Aduthurai	5.8	5.4	-	-
Coimbatore	14.6	12.6	6.6	7.4
Pattambi	7.1	3.0	16.3	12.5
Warangal	3.7	4.9	4.5	8.3

InfoCrop, a crop-pest model was used to simulate crop losses due to leaf folder (*Cnaphalocrosis medinalis)*, and stem borer on rainfed rice in Khulgad watershed, Almora, Uttarakhand. Yield loss data were then used to formulate iso-loss curves, which depicted various combinations of pest damage and crop age resulting in the same yield loss. The crop was found to be prone to leaf folder attack more up to 50 days after sowing than during later growth stages. The crop was prone to stem borer attack more during post-flowering stage than during pre-flowering stage.



Isoloss curves for leaf folder damage in rice in Khulgad watershed in Almora, Uttarakhand

4.2.1.2 Pulses

Field experiments on evaluation of different morphological characters of chickpea cultivars in relation to the damage caused by *Helicoverpa armigera* were undertaken during *rabi*. Mexico Local recorded the maximum height gain from 60 days to 90 days after sowing (DAS), i.e., 28.33 cm to 36.7 cm, respectively and the lowest height gain in the cultivar JG 62 (31 cm) at 90 DAS. At 100 DAS, the maximum number of leaves was observed in ICC 3279 (18.67 leaves per branch) and the lowest in Mexico Local (4 leaves/branch). Oviposition on Mexico Local ranged from 0.5 to 3.26 eggs/plant, when observed from 60 to 110 DAS, indicating that this cultivar was more preferred for oviposition. Relatively very less number of eggs was laid on BG 1103 (0.56 eggs/plant). At 125 DAS, Mexico Local recorded the maximum number of larvae (3.13) per plant. These results have concluded that plant height was negatively correlated with the number of branches and positively correlated with the number of leaves/branch. Cultivars that recorded higher number of eggs, had recorded higher egg and larval counts in subsequent generation too. High humidity within the bushy plants attracted more female moths for oviposition, which was absent in spreading type of cultivars. The correlation between yield and total number of pods was found to be positive, whereas negative correlation occurred between yield and number of eggs, number of larvae and number of damaged pods.

In pigeonpea during *kharif* 2007 the population of borers was negligible and did not cross the economic threshold level.

4.2.1.3 Oilseeds

A total of 73 germplasm/cultivars of *Brassica* were screened against mustard aphid *Lipaphis erysimi* during *rabi* 2006-07. The minimum Mean Aphid Infestation Index (MAII) varied between 0.25 and 2.65 at flowering. At pod stage, the minimum MAII ranged between 0.5 and 4.5 when graded on a scale of 0 to 5. An insecticidal trial was conducted with oxydemeton methyl and imidacloprid at 40 g a.i./ha and 60 g a.i./ha; thiamethoxam at 20 g a.i./ha and 40 g a.i./ha; acetamiprid at 40 g a.i./ha; chlorpyriphos at 500 g a.i./ha and endosulfan at 700 g a.i./ha. All the treatments were found effective against the aphid up to 7 days after spraying. Thereafter, the aphid migrated from the plant because of the rise in temperature during February. The reduction percentages due to treatments ranged between 78% and 92%.

A field trial to estimate the increase in seed yield and other components of mustard due to pollination by *Apis mellifera* and other pollinators on a recently released variety of *Brassica juncea* JD 6 revealed an increase in seed yield by 25%; number of pods per plant by 33.2%; number of seeds per pod by 20.2% and 1000-seed weight by 33.3%.

4.2.1.4 Cotton

A field experiment to evaluate insecticides against major insect pests of cotton was conducted during *kharif,* 2007 on variety P-8-6. Four sprays were required to suppress the population of insect pests throughout the crop season. Thiomethoxam 25 WG @ 100 g a.i./ha, caused the highest reduction in the population of *Bemisia tabaci* by 82.2% and 84.4%, and in the population of *Amrasca biguttula* by 84.8% and 84.1% at seven days after first spray and second spray, respectively. However, it was on a par with imidacloprid 17.8 SL @ 20 g a.i./ha and acetamiprid 20 SP @ 25 g a.i./ha.

Spinosad 45% SC @ 75 g a.i./ha was found to be superior against bollworm *Earias* spp. with the highest

reduction in larval population (72.3%) at seven days, minimum damage to fruiting bodies (19.3%) and green bolls (11.8%) after third spray, and was on a par with emamectin benzoate 5% SG @ 11 g a.i./ha and profenophos 50 EC @ 75 g a.i./ha. Similarly, after fourth spray, the highest reduction in larval population, (83.4%) and the lowest damage to fruiting body (5.3%) and green boll (3.3%) were recorded with spinosad 45% SC @ 37.5 g a.i./ha + profenophos 50 EC @ 500 g a.i./ha. The minimum pink bollworm (*P. gossypiella)* infested open boll damage (9.8%), loculi damage (18.1%) and the highest yield of 2.78 t/ha were observed in treatment with spinosad 45% SC @ 37.5 g a.i./ha + profenophos 50 EC @ 500 g a.i./ha followed by emamectin benzoate 5% SG @ 11 g a.i./ha used as a third spray, as against those observed in the untreated control (1.79 t/ha).

4.2.1.5 Soybean

Ninety soybean lines (PYT- I =18, PYT- II = 22, IVT = 42 and AVT II = 8) were evaluated during *kharif* against stem fly and *yellow mosaic virus* (YMV) disease transmitted by whitefly. Variety DS 2207, which showed resistance consistently for the last three years, was identified as a promising source of resistance.

4.2.1.6 Vegetables

An insecticidal trial on okra variety Pusa Anamika with seven treatments and baby-corn as border crop along with a control having no baby corn was conducted during 2007. Five treatments had the seed treated with either thiamethoxam (70WS) or imidacloprid (70WS) @ 3 g a.i./kg with abamectin (1.8 EC), spinosad (45 SC), emamectin (5% SG) and Econeem (10,000 ppm of Azadirachtin) in different combinations. All the seed treated plants exhibited significantly less number of leafhoppers *Amrasca biguttula biguttula* (4.0 - 8.3/15 plants) compared to baby-corn check (12/15 plants) as well as control (22/15 plants) at 35 days after sowing. Okra border cropped with baby-corn without any insecticidal intervention was also found effective in managing leafhopper with 12.0, 11.3, 19.7 and 30.0 leafhoppers at 35th, 43rd, 50th and 57th day after sowing, respectively, as compared to control where the population count was 22.0, 33.0, 56.0 and 67.0 leafhoppers/15 plants, respectively.

Six insecticides, viz., alphamethrin, cypermethrin, endosulfan, spinosad, emamectin and Neem Baan, were evaluated against fruit fly in bittergourd variety *Chaman* (F_1 hybrid). Per cent infestation (number-by-number basis) due to *Bactrocera cucurbitae* varied from 7.8 to 16.4 against 17.5% in control. On weight-by-weight basis, alphamethrin @ 20 g a.i./ha was the most effective followed by emamectin benzoate @ 15 g a.i./ha and Neem Baan (1500 ppm) @ 1ml/l.

Modern synthetic insecticides and botanicals were evaluated against the tobacco caterpillar (TC), *Spodoptera litura* in the seed crop of cabbage when transplanted in early August. At one month stage of the crop, 42.92% plant infestation of TC was recorded. It was followed by two fortnightly sprays of different insecticides. After one month of these sprays, minimum TC infestation was recorded in the case of endosulfan (0.05%), followed by cypermethrin (0.01%) sprays. Maximum net yield of cabbage, i.e., 59.8 t/ha was however, recorded in the case of cypermethrin followed by Bt and endosulfan.

Comparative effectiveness of modern synthetic insecticides and botanicals against *Spodoptera litura*

Insecticides	Per cent plant infestation (DAT)		Cabbage yield (t/ ha)
	0	28	
Dharek 4g DLP/l	16.00 (23.21)	14.30 (22.26)	53.00
Bt (Halt @ 1g/l)	14.30 (21.72)	10.70 (19.37)	58.20
Dimilin(0.01%)	18.30 (25.04)	13.10 (21.16)	55.40
Endosulfan(0.05%)	16.40 (23.05)	2.80 (9.21)	57.40
Neem (Neem-excel (0.015%)	17.10 (23.04)	16.80 (22.88)	50.45
Cypermethrin (0.01%)	14.80 (22.38)	10.30 (17.17)	59.80
Thiamethoxam (0.02%)	15.70 (23.17)	15.60 (22.78)	54.00
Control	29.20 (32.47)	15.70 (23.29)	48.10
SE	6.83	5.74	7.18
CD(P=0.05)	NS	11.93	NS

DAT- Days after treatment. Figures in the parentheses are arc sin $\sqrt{}$ per cent x+0.5 transformation

In the seed crop of cauliflower, maximum seed yield obtained was 364. 3 kg/ha when carbofuran was applied @ 0.5 g/plant, 15 days after transplanting. It was followed by need based rogor (0.05%) sprays against cabbage aphid (CA), *Brevicoryne brassicae*, endosulfan (0.05%) spray on 25th April against cabbage butterfly (CB), *Pieris brassicae* and another endosulfan spray against thrips in the first week of May.

Maximum seed yield of cabbage, i.e., 1384.33 kg/ha was obtained when monthly, cypermethrin (0.01%) sprays were given at the vegetative stage, followed by two endosulfan sprays at the reproductive stage.

4.2.1.7 Storage entomology

Studies on the efficacy of various extracts of *Caesalpinia crista* as grain protectant against

Callasobruchus chinensis infesting green gram were undertaken. Significantly reduced egg laying was observed in all the treatments. Methanol extract was more effective at various concentrations when observed 30 days, 60days and 90 days after treatments followed by butanol and hexane extracts. No adult emergence was observed in any of the treatments after 30 days and 60 days except from seeds treated with hexane extract, although adult emergence was observed in all the treatments except in higher concentration of butanol extract when experiment was conducted 90 days after treatment. There was no adverse effect of these extracts on the viability of the seeds even after 180 days of treatment.

Susceptibility to commercial formulation of deltamethrin was reduced by 3.4 times after 5 generations in the larvae of *Trogoderma granarium*. Toxicity of commercial formulations of bifenthrin, malathion and dichlorvos when studied against F_1 and F_6 larvae of *T. granarium* indicated that bifenthrin, although most toxic to F_1, was least toxic to the F_6 generation.

4.2.2 Biological Control

Economic mass production of *Bacillus thuringiensis* was attempted on four media including defatted mustard cake, defatted cotton seed extract, bone meal and nutrient broth for their ability to produce higher amounts of spores. The highest spore count of *B. thuringiensis* var. *kurstaki* HD-1 was observed in the case of media prepared using cotton seed extract followed by mustard extract based media and nutrient broth + Mg, while the least growth of *B. thuringiensis* var. *kurstaki* HD-1 was noticed in bone meal extract based media.

Studies on the comparative life history of *Zygogramma bicolorata* on two weeds, namely, *Parthenium hysterophorus* (exotic) and *Xanthium strumarium* (indigenous), were carried out in the laboratory. The beetle could complete its development in 26.94 ± 3.88 days and 34.59 ± 3.51 days at 28 ± 1°C and 45-65% R.H., when fed on *P. hysterophorus* and *X. strumarium,* respectively. Females lived longer than males in both cases and laid more number of eggs when *P. hysterophorus* was provided as food material. These studies provide an evidence of the oligophagous nature of *Z. bicolorata.*

4.2.3 Insect Physiology

Investigations on baseline susceptibility of *H. armigera* populations collected on Bt cotton from Mansa, Muktsar, Bhatinda, Hisar and Raichur to Cry1Ac toxin indicated a variation of 57-fold in the insect susceptibility compared to that of the most tolerant population, thus showing no evidence of resistance development.

The genetic inheritance of Cry1Ac resistance was examined in *H. armigera* by intermating resistant and susceptible populations. Reciprocal F_1 crosses were done by mating susceptible Vadodara female × Bharuch male (SR) and susceptible Vadodara male × Bharuch female (RS). Sibmating was also done for maintaining purity of both resistant and susceptible lines. Progenies of both F_1 hybrid and sibmating were subjected to bioassay using seven concentrations ranging from 0.001 µg/g to 3.0 µg/g diet using the diet incorporation method. On the basis of the 4-day mortality data, the LC_{50} was estimated and the degree of dominance calculated to determine the mode of inheritance. F_2 hybrids were subjected to bioassay and the mortality data analyzed, and the degree of dominance (D) was estimated. The responses of F_1 progeny from reciprocal crosses differed statistically from each other indicating that the inheritance of Cry1Ac resistance is sex influenced and semidominant.

Inheritance of MVP Bt Cry1Ac in *Helicoverpa armigera*

Cross	Female (@&) × Male (B&)	LC_{50} (µg/gm diet)	FL at 95%	D-value
1.	S x S	0.0028	0.0004-0.0065	-
2.	R x R	0.638	0.411-1.02	-
Reciprocal F_1 Hybrid				
3	S × R	0.146	0.089-0.226	0.299
4	R × S	0.55	0.304-1.09	0.782
F_2 Hybrid				
9	(S × R) × (S × R)	0.39	0.23-0.686	-
10	(R × S) × (R × S)	0.286	0.18-0.428	-

R (Resistant) = Bharuch population ; S (Susceptible) = Vadodara population

Investigations on toxicity of Cry toxins to neonates of cabbage butterfly *Pieris brassicae* and *Diacrisia obliqua* indicated that Cry1Ac was more toxic (LC_{50}= 0.065 µg/ml) than Cry1Ab (LC_{50}= 0.20 µg/ml) to neonates of *P. brassicae* than to *D. Obliqua* while Cry1B was more toxic (LC_{50}= 1.82 µg/ml) than Cry1C (LC_{50}= 2.43 µg/ml) to neonates of *D. obliqua* on a four-day bioassay. Bioassays on a seven -day basis were more sensitive to differentiate toxicities of Cry1B and Cry1C against *D. obliqua.*

Eighty-seven germplasm accessions of cereals (rice, maize, barley, wheat and oats) received from NBPGR, DRR and other sources were assayed in the laboratory for trypsin

and chymotrypsin inhibitory activities using synthetic substrate BApNA, and expressed as TIU and CIU, respectively. Among these five barley accessions had high trypsin inhibitory activity (~ 40 TIU/mg protein). Trypsin inhibitory activity was more compared to chymotrypsin inhibitory activity in all the cereals tested. Only one accession of maize (51705) had comparable activity (30.50 TIU) as that of barley. The trypsin inhibitory activity of rice, wheat and oats accessions was below 10 TIU/mg of seed protein. Hence, barley seed is a potential source for isolation of protease inhibitors for use in transgenic studies aimed at insect pest management.

Trypsin inhibitory activity of barley accessions

Barley accessions	TIU/mg seed protein	CIU/mg seed protein
IC 82680	43.96	15.97
IC 82512	43.04	8.79
IC 82506	44.02	5.08
IC 79590	39.81	8.38
IC 60712	35.44	6.34

Laboratory studies on the effect of dihydrodillapiole on pyrethroid resistance associated esterase inhibition in third instar larvae of *Spodoptera litura* populations from Delhi and Guntur indicated that α-naphthyl acetate hydrolysable esterase activity (µmoles/mg protein/min) in Delhi population was less compared to that of Guntur population. Insecticide resistance associated esterases in Delhi population of *S. litura* were inhibited by pre-treatment with dihydrodillapiole and the reduction was instantaneous initially and sustained for about 3 h post treatment and equilibrated at 4 hr post treatment. The esterase activity of Guntur population increased within 3 h and this increase was almost double. The highest increase was 1.28 µmoles / mg/min at 2 h post treatment. Subsequently, the esterase activity reduced to values lower than 0.70 µmoles at 4 h to 12 h post treatment in Guntur population. At a later stage, there was a clear trend of regaining esterase activity to the initial level. The variation observed was clearly triphasic, suggesting homeostatic regulation of esterase activity, though suppressed by dihydrodillapiole transiently.

4.2.4 Insect Toxicology

Laboratory studies on the susceptibility of different populations of *S. litura* to various insecticides revealed that the larvae from Bangalore and Guntur were 3.56, 1.1, 1.8 and 1.9 folds and 10.4, 4.8, 17.2 and 7.8 folds resistant to cypermethrin, fenvalarate, lambdacyhalothrin and emamectin benzoate, respectively, compared to Delhi population. However, Bangalore population was susceptible to profenophos and indoxacarb.

Relative resistance of *S. litura* populations from various locations to synthetic insecticides

Insecticides	LC_{50} (%)		
	Delhi	Bangalore	Guntur
Cypermethrin	0.0112	0.0399 (3.56)	0.1162 (10.37)
Fenvalerate	0.0314	0.0361 (1.14)	0.1503 (4.78)
Lambdacyhalothrin	0.0110	0.0202 (1.84)	0.1896 (17.24)
Profenophos	0.0662	0.0302 (0.46)	0.1490 (2.25)
Indoxacarb	0.0051	0.0033 (0.64)	0.0073 (1.43)
Emamectin benzoate	0.0035	0.0066 (1.88)	0.0274 (7.82)

Note: Figures in parantheses are fold change with respect to Delhi population taken as unity

CNSL (Cashewnut shell liquid) oil and partially hydrogenated preparations were evaluated at 1% concentration for their insecticidal properties against *H. armigera* neonates by 'artificial-diet-surface-incorporation' method in a 'no-choice' assay. CNSL-treatments resulted in delayed larval- and pupal-periods and deformed larvae. Hydrogenated-CNSL was more active than CNSL and exhibited 75% mortality till pupation as against 20% and 23.3% in aqueous and acetone blanks, respectively. The insecticidal activity is attributed to stomach poisoning in 'diet-surface-incorporation', while no contact toxicity by 'direct-spray' method was recorded against five-day old larvae.

IGR activity of hexane, methanol and chloroform extracts of *Andrographis paniculata* was evaluated against *S. litura* larvae through diet incorporation method and compared with that of azadirachtin 50%. Treatment with various concentrations of methanol extract and azadirachtin resulted in formation of abnormal adults while hexane and chloroform extracts resulted in only 33.3% normal adult formation at a concentration of 0.07%.

Effect of extracts of *Andrographis paniculata* on normal adult emergence

Extract	Concentration (%)				
	0.007	0.01	0.03	0.05	0.07
Hexane	61.1	50.0	50.0	44.44	33.33
Methanol	-	-	-	-	-
Chloroform	72.28	55.56	38.89	36.66	33.33
Azadirachtin 50%	-	-	-	-	-
Control	94.75				

Toxicity of commercial formulations of nine insecticides, viz., endosulfan, metasystox, thiomethoxam, imidacloprid, acetamiprid, chlorpyrifos, fipronil and dimethyl demeton was studied in the laboratory against mustard aphid *L. erysimi*. Results showed thiomethoxam to be the most toxic while endosulfan was the least toxic.

Relative toxicity of different insecticides against *Lipaphis erysimi*

Insecticides	χ^2	d.f.	Y = a + bx	b ± SE	LC $_{50}$(µgml^{-1})	Fiducial limit	
						Min.	Max.
Thiomethoxam 25WG	1.85	4	Y = 7.205 + 1.276 x	1.276±0.194	0.019	0.014	0.026
Endosulfan 35 EC	0.44	3	Y = 8.011 + 1.597 x	1.597± 0.243	130	101	168
Acetamiprid 20 SP	2.91	5	Y = 8.660 + 1.231 x	1.231± 0.165	11	8	14
Metasystox 25 EC	1.78	3	Y = 9.882 + 1.137 x	1.137± 0.259	1	0 .8	2.0
Dimethoate 30 EC	1.57	4	Y = 5.334 + 1.258 x	1.258± 0.208	0.542	0.386	0.760
Imidacloprid 17.8 SL	2.66	4	Y = 5.358 + 1.016 x	1.016± 0.184	0.444	0.310	0.636
Chlorpyriphos 20 EC	3.22	4	Y = 7.500 + 0.686 x	0.686± 0.124	2	1.0	4.0
Fipronil 5.00 SC	0.38	4	Y = 6.002 + 1.244 x	1.244± 0.178	0.156	0.116	0.210

4.3 NEMATOLOGY

4.3.1 Biodiversity

4.3.1.1 Plant parasitic nematodes

Nematode biodiversity. An extensive survey conducted in high altitude of Ladakh region of Jammu and Kashmir. The cereal cyst nematode *Heterodera avenae* was the most predominant nematode associated with wheat and barley grown in Rumtse (between Keylong and Leh), Nimmo, Mulbek (between Leh and Kargil) and Drass (between Kargil and Srinagar) with a population of 14-16, 10, 30-35 and 12 cysts/200 cm^3 soil, respectively. Several plant parasitic nematode genera, namely, *Hoplolaimus*, *Helicotylenchus*, *Tylenchorhynchus, Rotylenchulus, Hemicriconemoides, Pratylenchus, Hemicycliophora, Macroposthonia, Criconemoide, Meloidogyne, Heterodera, Xiphinema, Siddiqia*, *Aphelenchus,* and *Aphelenchoides* were encountered on different crops in Rudra-Prayag, Dehradoon and Tehri Garhwal districts of Garhwal region of Uttarakhand. However, *Meloidogyne incognita* and *M. hapla* were predominant in the samples collected from the rhizosphere of vegetables in home gardens and irrigated agricultural land and oak forest. Among all the nematodes, cephalobids were found to have the highest absolute frequency (80), followed by *Helicotylenchus pseudorobustus* (68), *Aphelenchus avenae* (51), *M. incognita* (21), *Mylonchulus truncatus* (11), *Hoplolaimus seinhorsti* (9), *Pratylenchus thornei* and *Xiphinema insigne* (8 each), *Rotylenchulus reniformis* (5), *Hemicycliophora typica* (3), *Hemicriconemoides mangifaere* (2) and *Tylenchorhynchus annulatus* (1). The nematode bio-diversity studied in three districts (Mahasumund, Dhantari and Durg) of Chhatisgarh revealed predominant population of rice-root nematode *Hirschmanniella oryzae* encountered with 100% frequency distribution.

The distribution of plant parasitic and beneficial nematodes in Gujarat was mapped.

4.3.1.2 Entomopathogenic nematodes

New EPN strains isolated. Four strains of *Steinernema,* one each from Uttar Pradesh and Jammu and Kashmir and two from West Bengal were isolated. Based on the morphological and morphometrical features of the infective juveniles and males and females of the two generations, the strains were identified as *S. riobrave* from Uttar Pradesh; *S. carpocapsae* from Jammu and Kashmir; and *S. tami* and *S. carpocapsae* from West Bengal. *S. riobrave* was characterized by having paired horn-like structures on the lip regions of its infective juveniles with the presence of additional pair of papillae on its males and the presence of tail mucro only in second generation females.

Insecticidal fractions purified. Two insecticidal fractions were purified from *Photorhabdus luminescens*, a symbiotic bacteria residing in the gut of nematode *Heterorhabditis indica* (IARI strain). Hundred per cent mortality to the neonates of *Galleria mellonella* larvae was recorded in PD1C and PD3 after 60 h and 72 h, respectively, when fed orally. PD1C when further denatured and fed to the larvae showed a delayed inception of mortality starting at 72 h (60%), 84 h (90%), 96 h (100%). Remaining fractions did not show oral toxicity upon denaturing.

Ecological characterization of S. riobrave. The infectivity and development of *S. riobrave* was studied at six different temperature conditions (10 °C, 15 °C, 20 °C, 25 °C, 30 °C and 35 °C). The optimum temperature for the infectivity and reproduction of the nematode was found to be 30 °C with an optimal range of 25-35 °C. To know the optimum moisture required for the species, its infectivity was recorded at different

moisture levels (1%, 3%, 5%, 7%, 9%, 11%, 13%, 15%, 17% and 19% w/w). The nematodes could successfully penetrate the insect at 3-19% moisture, the maximum penetration being at 9% level, which was found to be the optimum.

Bioefficacy of Steinernema thermophilum formulated in Pusa NemaGel against sub-terranean termite (Odontotermes obesus) infestation in maize. A biopesticidal formulation, namely, Pusa NemaGel based on an indigenous heat tolerant entomopathogenic nematode *Steinernema thermophilum* was developed. The efficacy of NemaGel was tested against subterranean termite (*Odontotermes obesus*) infestation on maize, under field conditions. A single application of NemaGel at the time of sowing showed 90-100% reduction in termite infestation and significant improvement in crop health and yield parameters, compared to those in untreated control. NemaGel treatment was also superior to the treatment with pesticide (three applications of Chlorpyriphos).

4.3.2 Mechanism of Resistance

Out of 58 genotypes of pigeonpea (*Cajanus cajan*) screened for their resistance against pigeonpea cyst nematode, *Heterodera cajani*, only one wild type genotype, ICP 16144 of *C. platycarpus* was found to be resistant; three genotypes (Pusa 2007, Pusa 855 and DW 55) of *C. cajan* showed moderately resistant reactions.

Spray with salicylic acid (SA) altered the susceptibility reaction of the susceptible cowpea cultivar Pusa Komal against *M. incognita*. This work emphasizes the importance of evaluating induced systemic resistance. Irrespective of treatments, ß-1,3-glucanase (E.C. 3.2.1.39) activity in cowpea, roots increased with the nematode inoculation. This shows that SA improved the performance of the host plants and was found on a par with that of the resistant cowpea cultivar C 152.

Effect of salicylic acid on ß-1,3-glucanase (E.C. 3.2.1.39) activity at different intervals on cowpea infecting *Meloidogyne incognita*

	Uninoculated		Inoculated	
	15 D	30 D	15 DAI	30 DAI
SA 50 ppm	0.31	0.44	0.32	0.49
SA 100 ppm	0.90	1.26	1.22	1.35
Carbofuran 1kg a.i./ha	0.96	1.36	0.99	1.41
Carbofuran 1.5 kg a.i./ha	0.98	1.40	1.06	1.49
C 152 (Resistant)	1.09	1.42	1.12	1.55
Untreated Pusa Komal (Susceptible)	0.77	0.81	0.89	1.21

DAI : Days after inoculation

The genetics of resistance of wheat to the cereal cyst nematode *Heterodera avenae* was studied with respect to F_1s, F_2s, and backcross progenies of cross combinations Raj 1482 × Raj MR 1. All F_1s were found resistant to cereal cyst nematode and the F_2 population segregated in 3 resistant : 1 susceptible ratio. Thus, resistant gene showed monogenic dominance over susceptibility. The back cross (test cross) segregated in 1 resistant : 1 susceptible ratio, once again confirming the monogenic dominant nature of resistant gene.

Mode of segregation for nematode resistance in the parents in different generations of the cross Raj 1482× Raj MR 1

Source Parents/cross	Generation	No. of plants/ families		Total plants observed	χ^2	Mode of segregation
		R	S			
Raj 1482	P_1	-	10	10		
CCNRV 1	P_2	10	-	10		
Raj 1482 × Raj MR 1	F_1	12	-	12		
	F_2	46	14	60	0.089^{ns}	3:1
(Raj 1482 × Raj MR 1) × Raj 1482	BC_1 (Test cross)	29	60	31	0.05^{ns}	1:1
(Raj 1482 × Raj MR 1) × Raj MR 1	BC_1	60	-	60		

ns = non significant

4.3.3 Nematode Management

A field trial was conducted at Jhundpur village of Sonepat district of Haryana against rice root-knot nematode *Meloidogyne graminicola.* Carbofuran @ 1.5 kg a.i./ha and neem seed powder (NSP) showed maximum reduction in nematode population (32%) and increased the yield compared to that of the check.

Another experiment was conducted on tuberose in farmers' fields at Muradnagar (Uttar Pradesh) heavily infested with root-knot nematode. The six plots (5 m x 5 m size) treated with phorate and carbofuran @ 2 kg a.i./ha and 4 kg a.i./ha showed good plant growth compared to the plants in untreated areas, with 25% to 60% reduction of root-knot nematode population in the soil of treated plots. However, the reduction was more in carbofuran treated plots in comparison to that in phorate treated plots at the same dose.

A field trial conducted on cowpea cultivar V 240 with 8 treatments revealed that there was maximum reduction in the population of *Rotylenchulus reniformis* with neem oil emulsion @ 500 ppm for 30 min seed soak followed by

Trichoderma harzianum @ 2 kg/ha + carbofuran 3G @ 1 kg a.i./ha, whereas the highest yield was recorded with neem oil, *Trichoderma harzianum* + carbofuran.

In yet another field trial conducted in a plot size of 4 m x 3 m in RBD and replicated four times the seedlings of brinjal cultivar Pusa Purple Long treated with neem oil emulsion @ 500 ppm for 30 min were transplanted in rows in the main field. Carbofuran (3G), triazophos (40 EC), phorate (10 G), carbosulfan (35 EC) and chloropyriphos EC were applied after a month of transplanting. Results indicated the maximum reduction of *R. reniformis* population in triazophos and carbofuran treated plots with increased yield of brinjal followed by that in chloropyriphos treatments.

Various species of cyanobacteria or the blue-green algae are reported to produce toxins. *Synechococcus nidulans* (*Anacystis nidulans*) is a unicellular cyanobacterium with spherical to rod shaped cells, 0.6-2.1 µm in diameter, solitary or grouped in irregular clumps. This cyanobacterium causes immobility in *M. incognita* juveniles leading to reduced invasion and hatching. The sonicated cell culture (S) of *S. nidulans*, caused significantly higher mortality in plant-parasitic nematodes (59.1% in *M. incognita*, 48.9% in *H. avenae*), compared to that in beneficial nematodes (23.5% in *H. indica* and 30.2% in *C. persegnis*) in *in vitro* trials.

4.4 AGRICULTURAL CHEMICALS

4.4.1 Development of Natural and Synthetic Agrochemicals and their Adjuvants

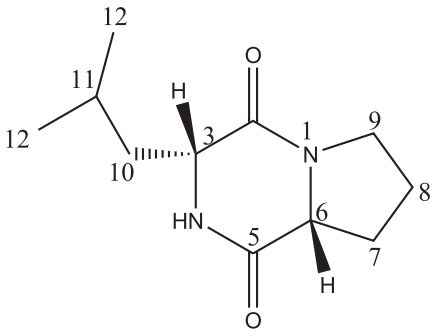
4.4.1.1 Botanical pesticides

Isolation and characterization of bioactive glucosinolates in leaves and seeds of Brassica juncea. Glucosinolates, namely, 2-propenyl glucosinolate (Sinigrin), 4-pentenyl glucosinolate (Gluconapin), 5-methylsulfonylpentenyl glucosinolate, 8-methylsulfonyloctyl glucosinolate and 4-hydroxy, 3-(apiosyloxy) benzyl glucosinolate from seeds and n-propyl glucosinolate, 2-hydroxy-2-methylpropyl glucosinolate, 3-methylthiopropyl glucosinolate, 4-methyl-thiobutyl glucosinolate, 3-indolylmethyl glucosinolate, 4-methoxy-3-indolylmethyl glucosinolate, 8-methylsulfonyloctyl glucosinolate and 3,4-dihydroxybenzyl glucosinolate from leaves of *B. juncea* were isolated as intact glucosinolates and analyzed by ESI-Mass spectroscopy in direct infusion mode. GLSs showed moderate antifungal activity against the two phytopathogenic fungi *Macrophomina phaseolina* and *Fusarium oxysporum*.

Identification of cyclic dipeptide from Photorabdus luminescens. A cyclic dipeptide or diketopiperazine was isolated for the first time from the entomopathogenic bacterium *P. luminscens* in liquid culture and identified as the 3-isobutyl-hexahydro-pyrrolo[1,2-a] pyrazine-1,4-dione or cyclo(-Pro-leu), a cyclic peptide on the basis of 1H-NMR and 13C-NMR. The IR spectrum showed the presence of OH group at 3590 cm^{-1} and amide at 3380 cm^{-1} and 1670 cm^{-1}. It showed a violet colour reaction with anisaldehyde/sulphuric acid and turned blue with chlorine/*o*-anisidine, pointing to a peptide. It showed strong fungicidal activity against agriculturally important fungi, namely, *Rhizoctonia bataticola, Sclerotium rolfsii, Pythium apanidermatum, P. debarynum* and *R. solani.*

Minimum inhibitory concentrations (MIC) of cis cyclo (leucyl-prolyl) from *P. luminescens* against fungi of agricultural importance

Fungus	MIC (mg ml^{-1})
P. Debarynum	12.50
Rhizoctonia bataticola	25.00
Pythium aphanidermatum	25.00
Sclerotium rolfsii	50.00
Rhizoctonia solani	6.25



Cyclo(-Pro-leu), a cyclic peptide

Rice sheath blight disease management by the use of botanicals through root dip method. Eight essential oils (Tagetes, patchouli, wintergreen, geranium, palmarosa, lemon grass, cedarwood and clove oils), azadirachtin concentrate, bis(n-propyl)disulfide, three plant extracts (*Piper betle*, chinaberry, and garlic cloves extracts), three aroma chemicals (alpha-terpineol, linalylacetate and alpha-terpinyl acetate) along with standard fungicide Bavistin were tested at two concentrations (0.5% and 1.0%). The rice seedlings were dipped in the above formulations for three hours prior to transplanting. Systemic activated resistance induction of these botanicals was assessed. The per cent infection was calculated, and the results showed that all the

test chemicals caused reduction of the disease incidence. Bavistin, chinaberry extract, azadirachtin concentrate, garlic bulb extract, clove oil, linalyl acetate and alpha-terpinyl acetate gave 24.2-29.2% control at one per cent test concentration. Considering the long gap between treatment and disease expression as well as dilution of active ingredients due to biomass accumulation, these results are significant and would provide new insights into SAR induction.

4.4.2 New Synthetic Products

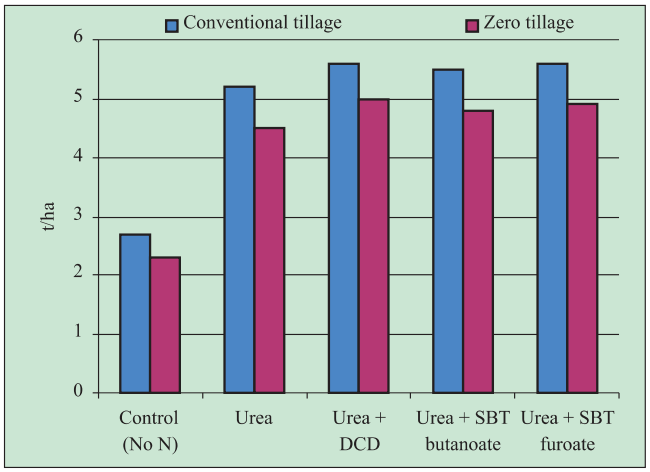
Nucleic bases, nucleosides and their derivatives as nitrification inhibitors. Nineteen various nucleic bases, nucleosides and their derivatives were evaluated for nitrification inhibitory activity in a laboratory incubation experiment at 5% and 10% of urea-N applied for a period of 30 days. The nitrification rates (NR) for all the test compounds ranged from 14.9% to 38.4%, 34.7% to 77.4% and 69.0% to 95.9% nitrification inhibition after 10, 20 and 30 days, respectively. Uracil, 5-Flourouracil, and cytosine showed significantly lower NRs and emerged as promising compounds.

Effect of nucleic bases, nucleosides and their derivatives on the per cent nitrification inhibition

Compounds	Dose (%)	Nitrification rate (%) Period of incubation (days)		
		10	20	30
5-Flourouracil	5	14.9	36.2	76.6
Uracil	5	16.4	50.3	69.4
Cytosine	5	20.5	40.0	72.2
DCD	5	20.1	40.3	76.5
Urea (alone)	-	59.1	90.6	97.7
CD (5%)		4.4	4.6	3.4

Note: Urea-N applied to all the treatments @ 200 ppm

Field evaluation of s-benzylisothiouronium (SBT) salts. A study was conducted to assess the effect of the two most promising SBT salts, namely, SBT butanotate and SBT furoate (identified during lab studies) on the yield of the wheat variety UP 2338 (N: 120 kg N/ha in three splits; inhibitor dose: 10% of urea N). Both the compounds were found to be superior to urea alone treatment and were on a par with the reference inhibitor, dicyandiamide (DCD) under both conventional and zero tillage systems. The compounds were also found effective in the reduction of nitrous oxide emissions.



Effect of SBT salts on grain yield of wheat

Evaluation of hydrogel performance under rainfed conditions. A pilot experiment was conducted to explore the feasibility of hydrogel use in maize crop under rainfed conditions. An increase in the rate of germination and establishment, plant growth and per cent survival was observed when hydrogel was applied along with the seed at the time of sowing @ 5 kg ha^{-1}. The use of Pusa hydrogel coupled with aqua-ferti technique led to significant enhancement in crop yield as compared to those of control, hydrogel alone and aquaferti alone.

4.4.3 Pesticides: Risk Assessment, Environmental Fate and Remedies

4.4.3.1 Supervised field trials for pesticide risk assessment

Persistence and risk assessment of imidacloprid on onion and tomato. A field experiment was conducted to study persistence and risk assessment of imidacloprid on onion and tomato when sprayed @ 20 g a.i. ha^{-1} and 40 g a.i. ha^{-1} for both the crops/trials. Residues of imidacloprid reached non detectable level in 7-10 days in tomato after the treatments, whereas no residues were detected at harvest in onion samples. The 4x dose of 80 g a.i. ha^{-1} of imidacloprid did not exhibit any phytotoxic symptom on both the crops and plant compatibility was good. A waiting period of three days is suggested for tomato crop, and seven days for green onion.

Risk assessment of thiacloprid on okra. The residence time of thiacloprid was evaluated on okra fruits and its seeds and soil under the crop when sprayed @48 g a.i. $ha^{-1}$and 96 g a.i. ha^{-1}. The thiacloprid residues dissipated at a faster rate during the initial stage compared to that in the later period. However,

residues were short lived and attained the below detectable level around 10th day. The theoretical maximum residue contribution values were lower, (i.e., 0.081 - 0.151 mg person^{-1} day^{-1}) than the maximum allowable concentration of 0.5 mg person^{-1} day^{-1}. Okra seeds and soil collected at the final harvest of the crop did not show the presence of thiacloprid residues.

Persistence of spinosad on brinjal, cauliflower and okra. Supervised field trials were undertaken to study the persistence of spinosad on brinjal (variety Pusa Kranti), cauliflower (variety Snowball 16) and okra (variety Pusa A 4) following spray treatment with spinosad (Tracer 45. 5%) @ 75 g a.i. ha^{-1} and 150 g a.i. ha^{-1} at flowering/fruiting stage. The residues persisted till day 7 in brinjal fruits as well as on cauliflower curd and okra at the recommended dose of application with half-life of 3.76 days. Based on the results, a waiting period of 1 day is suggested for brinjal, 7 days for cauliflower, and 3 days for on okra in the case of spinosad treatment.

Persistence of indoxacarb on pigeonpea. Indoxacarb (Avaunt 14.5 SC) was evaluated for persistence on pigeonpea. Foliar application of indoxacarb was made @ 75 g a.i. ha^{-1} and 150 g a.i. ha^{-1} on pigeonpea (variety Pusa 855) at 50% pod formation stage. The residues persisted till day 15 in green pods, and were below 0.03 mg kg^{-1} in harvest grain samples. Residues were below the detectable limit in harvest grains (< 0.03 mg kg^{-1}). The half-life of dissipation was 2.1 days and 1.0 day at the recommended and double the recommended dose, respectively.

Persistence of bifenthrin on chickpea and pigeonpea. Persistence of bifenthrin was studied on chickpea (variety Pusa 256) and pigeonpea (variety Pusa 855) following spray treatment @ 25 g a.i. ha^{-1} and 50g a.i. ha^{-1} at 50% pod formation stage. The residues were found below the detectable limit in chickpea and pigeonpea grains (< 0.01 mg kg^{-1}), at harvest. Therefore, the schedule is considered to be safe from the toxicity point of view.

Persistence of fipronil on mustard, okra and gram. Mustard (variety Pusa Bold) at 50% pod formation stage, okra (variety Pusa A 4) and gram (variety Pusa 362) were sprayed with fipronil (Reagent 5% SC) @ 50 g a.i./ha and 100 g a.i./ha at flowering/fruiting stage. The residues in mustard persisted till day 10 in green pods and were below the detectable limit in harvest grains (< 0.05 mg kg^{-1}), whereas no residues of fipronil were detected in okra fruits from day 10 onwards. Results revealed that in gram, the residues persisted beyond 5 days at recommended dose with a half life of dissipation of 1.04 days, and at harvest, the grains did not contain any residues. Based on the calculations, a waiting period of 3 days is suggested for mustard, okra and gram.

4.4.3.2 Environmental fate of pesticides

Leaching behavior of bifenthrin in soil. Leaching of bifenthrin was studied in soil column under saturated flow condition. The analysis of soil cores at different depths for the different treatments revealed that as the volume of water added increased, bifenthrin moved to lower depths. Although bifenthrin residues were detected up to 15 cm depth, bifenthrin in most cases remained in the top 0-10 cm (>99%) layer. Even with 240 ml water addition (equivalent rainfall of 19 cm), residues leached only up to 15 cm depth. For all other treatments, bifenthrin residues were detected only up to 10 cm depth. In all the cases, the major amount was found in 0-5 cm depth (>90%). The leaching data clearly show that bifenthrin is highly immobile in soil.

Sorption of atrazine on flyash. Coal fly ash, a byproduct from lignite fired thermal power stations, is a low cost adsorbent and can be used for clean up of waste water containing pesticides. Atrazine retention capacity on fly ash from its aqueous solution was studied. The sorption of atrazine (1: 50 (w/v) fly ash to water ratio) at concentrations ranging between 2.5 ppm and 10 ppm was performed using batch method. Per cent sorption of atrazine at these concentrations ranged between 98% and 86%. Analysis of the atrazine sorption data using Langmuir equation indicated that atrazine sorption capacity of fly ash was 3333.3 mg/g, but correlation coefficient (r^2) value was 0.951. This suggests that atrazine sorption on fly ash is better explained by Freundlich equation because of relatively higher r^2 value. Results indicate that atrazine sorption on fly ash is affected by its particle size, especially at higher concentration. Maximum retention capacity was expressed by 150-250 µ fraction followed by >250 µ and <150 µ fraction. Desorption studies of atrazine indicated that at initial herbicide concentration of 10 ppm, nearly 9% of atrazine was desorbed after three repeated desorptions. The present study indicates that this low cost adsorbent can be used for clean up of atrazine contaminated water.

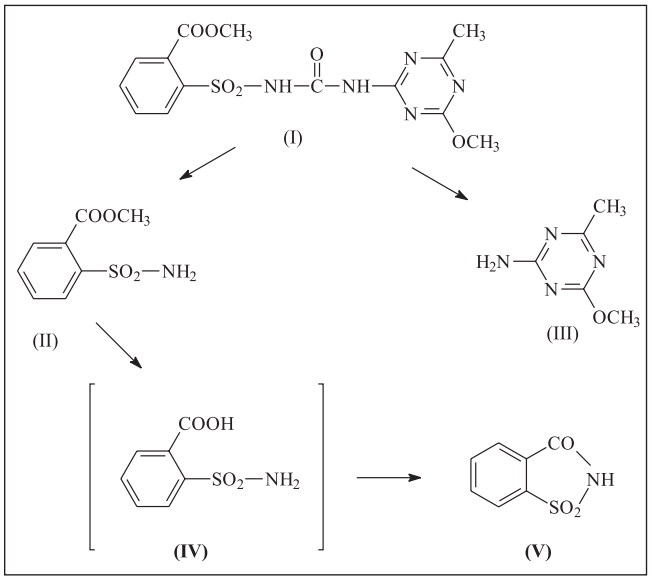
Effect of biocompost on pesticide persistence in soil. The effect of biocompost (prepared from sugar industry wastes, i.e., press mud and spent wash which are rich in carbon, potassium and other micro nutrients along with micro-biological bacteria and fungi) applied at the rate of 2.5% and 5.0% on degradation of metribuzin-a triazine herbicide, in sandy loam soil from IARI, New Delhi field was studied. Metribuzin was more persistent in flooded condition than in non-flooded moisture regime in bio-compost-unamended soils, and the respective half life values were 41.2 days and 33.4 days. Application of biocompost to soil incubated under non-flooded moisture regime decreased

the degradation rate of metribuzin; therefore, herbicide was more persistent in biocompost-amended soils than in natural soil. Half life values of metribuzin in T-0, T-1 and T-2 treatments under non-flooded moisture regime were 33.4 days, 38.1 days and 42.4 days, respectively. This may be due to higher sorption of metribuzin in biocompost-amended soil which resulted in reduced bioavailability of metribuzin in soil solution. However, the application of biocompost to soils incubated under flooded moisture regime did not effect metribuzin degradation and the half life values for treatments T-1 and T-2 were 40.1 days and 39.1 days, respectively.

Degradation constants for metribuzin in soils

Treatment	K_{obs} x 10^{-3} (d^{-1})	$t_{1/2}$ (day)-1	r^2-1
Non-flooded			
T-0	-9.0	33.4	0.962
T-1	-7.9	38.1	0.982
T-2	-7.1	42.4	0.993
Flooded			
T-0	-7.3	41.2	0.986
T-1	-7.5	40.1	0.997
T-2	-7.7	39.1	0.984

Photodegradation of metsulfuron methyl. Phototransformation of metsulfuron methyl (I, herbicide) was investigated on glass surface under sunlight and UV light. The major photoproducts identified are methyl-2-sulfonyl-amino-benzoate (II), 2-amino-6-methoxy-4-methyltriazine (IV) and saccharin (O-sulfobenzoimide) (III). Half life of metsulfuron methyl under UV and sunlight was found to be 0.5 day and 7.8 days, respectively.



Photodegradation pathway of metsulfuron methyl as thin film

Decontamination of thiacloprid residues. Zero-day contaminated okra fruits, when washed with tap water, dislodged about 47-50% residues of thiacloprid. The corresponding reductions due to washing followed by steaming were around 78-79%. Washing followed by steaming was found to be more efficient than simple washing with water in removing the residues from the contaminated fruits.

4.4.3.3 Analytical methods

HPLC analysis of herbicide mixture (metsulfuron and clodinafop) in soil and wheat. A simple HPLC method was standardized for the simultaneous residue analysis of clodinafop and metsulfuron methyl in soil and wheat grains using an RP-18 column and acetonitrile-water with acidic pH as the mobile phase at a flow rate of 0.5 ml min^{-1} at 234 nm. Recoveries were in the range of 85-90% with detection limits for clodinafop and metsulfuron methyl as 0.02µg g^{-1} and 0.1µg g^{-1}, respectively.

4.4.4 Improvement in Safety and Efficacy of Pesticide Formulations

4.4.4.1 Flowable slurry (FS) formulation of azadirachtin-A

Azadirachtin-A was encapsulated in nanosized amphiphilic polymers. By dissolving encapsulated azadirachtin-A in appropriate solvents, flowable slurry (FS) formulation for seed treatment was developed.

4.4.4.2 Onion seed pellets

Pellets of onion seed for improving its vigour, germination and handling, were developed. These were developed with carriers, surfactant and binding agent, as required. The seed was pre-mixed (w/w) with the carriers (w/w) (kaolinite, bentonite, hydroxy ethyl cellulose, carboxy methyl cellulose, vinylpyrrolidone, polyethyl methacrylate), and binding agent (lignosulphonate, gum acacia, *guar* gum). The pellets were spherical. An average diameter of the pellet in cross-section can be from about 1 mm to about 7 mm.

4.5 WEED MANAGEMENT

4.5.1 Effect of Tillage and Weed Control Practices on Performance of Cotton

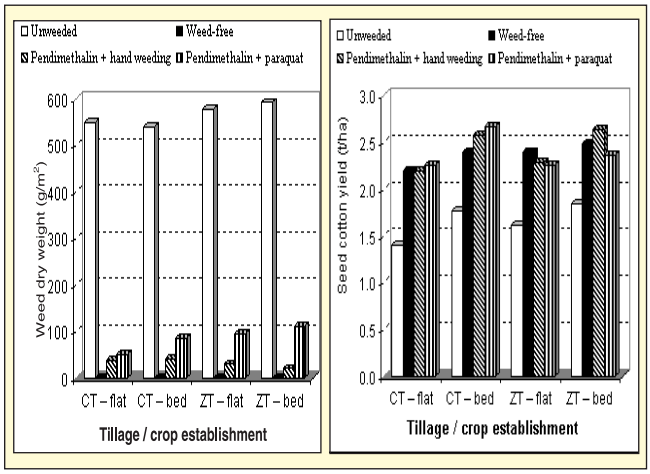
A field experiment was initiated in *kharif* 2007 on Bt cotton cv. SCH 22 to study the effect of different tillage and

crop establishment practices, viz., conventional tillage – flat sowing, conventional tillage – bed sowing, zero tillage – flat sowing and zero tillage – bed sowing (permanent beds); and weed control practices, viz., unweeded control, weed-free, pendimathalin + hand weeding, and pendimethalin + paraquat spray. Cotton was sown after the harvest of wheat on 30th May at 70 cm x 50 cm spacing. Pendimethalin was applied @ 1.0 kg/ha. Hand weeding was done at 35 days and directed spraying of paraquat was done with 0.5% solution at 35 days in the inter-row spaces.

Effect of tillage and weed control practices on growth and yield performance of cotton

Treatment	Plant height at maturity (cm)	Weed dry weight (g/m²)	Seed cotton yield (t/ha)	Dry weight of sticks (t/ha)
Tillage / crop establishment				
Conventional – flat sowing	96.8	212.7	2.01	6.56
Conventional – bed sowing	110.4	222.2	2.35	7.74
Zero tillage – flat sowing	99.5	234.4	2.14	6.33
Zero tillage – bed sowing	109.1	241.0	2.33	7.01
CD (P=0.05)	6.8	NS	0.25	1.12
Weed control practices				
Unweeded control	92.9	565.0	1.66	3.74
Weed free	103.4	-	2.37	7.93
Pendimethalin + hand weeding	112.3	32.5	2.42	8.02
Pendimethalin + paraquat	107.2	85.3	2.38	7.95
CD (P=0.05)	4.3	21.8	0.17	0.64

Growth of cotton plants was better in bed-sown crop with pre-emergence application of pendimethalin, while no differences were observed between tilled and untilled crops. Plant height was significantly more but bolls/plant were similar under bed sowing compared with flat sowing. Weed dry weight was also not affected owing to tillage and crop establishment practices. On the other hand, controlling weeds with pendimethalin along with hand weeding or paraquat spray increased the height and bolls/plant significantly over those of unweeded control. Seed cotton yield was significantly higher in bed-sown than in flat-sown crop under both conventional and zero tillage conditions. The absolute increase in yield was 0.19-0.34 t/ha under bed planting over that of flat sowing. Interestingly, the crop under zero tillage and that under conventional tillage performed equally well. Similarly, both the weed control treatments involving pendimathalin application along with hand weeding or paraquat spray gave similar seed cotton yield, being on a par with weed-free treatment. These results suggest that sowing of cotton on permanent beds after wheat harvest and directed-spraying of paraquat at 35 days following the pre-emergence application of pendimethalin are beneficial practices for improving productivity of cotton.



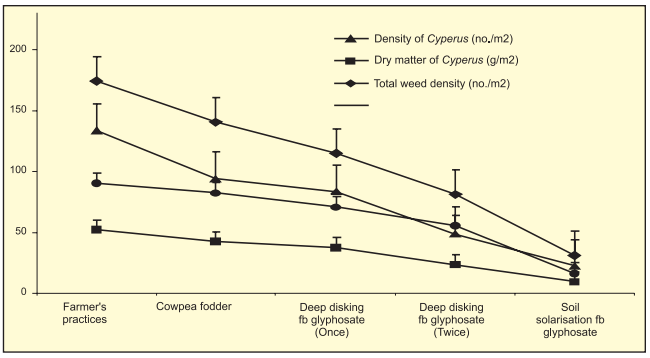
Effect of tillage and weed control practices on weed dry weight and seed cotton yield (CT - conventional tillage, ZT- zero tillage)

4.5.2 Sequential Application of Metribuzin for Weed Management in Soybean

A field experiment was conducted during *kharif* season 2007 to standardize the dose of metribuzin as pre-emergence and post-emergence, and its time and volume rate for weed control in soybean.

Weed infestation was significantly lower in herbicide treatments compared to that in weedy check. Pre-emergence application of metribuzin at 0.25 kg/ha and 0.5 kg/ha significantly inhibited the growth of weeds, and with similar soybean seed yields. Metribuzin as pre-emergence @ 0.25 kg/ha was also comparable when supplemented with post-emergence application, irrespective of dose and volume in terms of weed control and soybean seed yield. However, post-emergence metribuzin application proved a bit phytotoxic to soybean, irrespective of dose (100 g/ha and 200 g/ha), volume (200 l/ha and 400 l/ha) and time of application (20 DAS and 30 DAS).

Dehydrogenase activity 40 DAS was higher in the pre-emergence application of pendimethalin @ 0.75 kg/ha and metribuzin @ 0.25 kg/ha and 0.5 kg/ha, the highest being in metribuzin @ 0.25 kg/ha. Significantly higher total microbial population recorded in these treatments further corroborates this. Pre-emergence application of 0.25 kg/ha of metribuzin recorded the lowest residue level, but its pre-emergence application @ 0.5 kg/ha proved more effective towards soybean yield and controlling the difficult-to-control *Cyperus rotundus* to some extent.



Effect of solarization and glyphosate on *Cyperus* and total weeds

Effect of pre-emergence and post-emergence application of metribuzin on weed growth and soybean yield

Treatment	Weed dry weight at 40 DAS (g/m^2)	Soybean yield (t/ha)	Dehydrogenase at 40 DAS (mg TPF* /g soil/day)	Total microbial population at 40 DAS (n x 10^6)	Herbicide residue in soil (ppm)
Weedy check	34.0	0.92	109.86	104.70	0.00000
Weed -free check		1.47	117.75	111.14	0.00000
Pendimethalin @ 0.75 kg/ha	9.5	1.10	136.46	206.20	0.00550
Metribuzin (MTB) pre-em. @ 0.5 kg/ha	4.5	1.36	138.86	208.20	0.00140
MTB pre-em. @ 0.25 kg/ha	8.8	1.33	179.50	250.90	0.00005
MTB pre+ post-em (0.1 kg/ha, 200 l/ha, 20 DAS)	9.7	1.25	116.90	174.12	0.00040
MTB pre+ post-em (0.1 kg/ha, 400 l/ha, 20 DAS)	9.1	1.25	111.03	158.12	0.00045
MTB pre+ post-em (0.1 kg/ha, 200 l/ha, 30 DAS)	7.6	1.19	105.16	130.14	0.00030
MTB pre+ post-em (0.1 kg/ha, 400 l/ha, 30 DAS)	7.0	1.11	115.73	152.10	0.00038
MTB pre+ post-em (0.2 kg/ha, 200 l/ha, 20 DAS)	8.2	1.13	113.50	156.10	0.00052
MTB pre+ post-em (0.2 kg/ha, 400 l/ha, 20 DAS)	9.7	1.08	111.75	144.00	0.00061
MTB pre+ post-em (0.2 kg/ha, 200 l/ha, 30 DAS)	11.2	1.16	115.51	136.14	0.00050
MTB pre+ post-em (0.2 kg/ha, 400 l/ha, 30 DAS)	10.0	1.12	110.70	130.10	0.00067
CD (P =0.05)	7.2	0.02		28.76	

*TPF -2,3,5-triphenylformazan

4.5.3 Integrated Management of *Cyperus rotundus* in Soybean

A field experiment was conducted during *kharif* 2007 to study the effect of tillage, smothering crop, soil solarization and glyphosate on tuber viability, long-term control of *Cyperus rotundus* and productivity of soybean. Treatments included summer cowpea for fodder, deep disking followed by (fb) glyphosate @ 1 kg/ha once, deep disking fb glyphosate @ 1 kg/ha twice, soil solarisation for 30 days fb glyphosate @ 1 kg/ha and farmers' practices combined with imazethapyr @ 75 g/ha 20 DAS, *in situ Sesbania* grown and mulched, and two hand weedings.

Soil solarization supplemented with glyphosate and deep disking followed by glyphosate (twice) significantly reduced the population and dry weight of *Cyperus rotundus* and consequently resulted in higher soybean seed yield. Deep disking followed by glyphosate (once) and summer cowpea for fodder also proved superior to farmers' practice in terms of reduction in density and weight of *Cyperus*. Two hand weedings 3 and 5 weeks after sowing were most effective, while, *in situ Sesbania* grown and mulched and imazethapyr @ 75 g/ha 20 DAS were intermediary in terms of reducing the population and dry weight of *Cyperus rotundus*.

4.5.4 Evaluation and Management of Cross-Resistance in *Phalaris minor* Biotypes Across Punjab and Haryana

Isoproturon-resistant *Phalaris minor* biotypes numbering 311, collected from 311 villages of Punjab and Haryana, were tested against clodinafop-propargyl (30 g/ha, 60 g/ha, and 120 g/ha), sulfosulfuron (16.25 g/ha, 32.5 g/ha, and 65 g/ha) and pinoxaden (25 g/ha, 50 g/ha and 100 g/ha) at the National Phytotron Facility, IARI, New Delhi.

Characterization of *Phalaris minor* biotypes on the basis of sensitivity reactions to clodinafop

Sensitivity reactions	Biotypes
Highly resistant (0-20 % phytotoxicity at 120 g/ha clodinafop)	PN 011, PN 126, PN 131 (Punjab); HR 003, HR 016, HR 017, HR 050, HR 073, HR 078, HR 123, HR 178, HR 182 (Haryana) (12)
Resistant (0-20 % phytotoxicity at 60 g/ha clodinafop)	PN 006, PN 036, PN 079, PN 080 (Punjab); HR 001, HR 031, HR 079, HR 086, HR 094, HR 179, HR 187, HR 189 (Haryana) (12)
Moderately susceptible/ resistant (0-20 % phytotoxicity at 30 g/ha clodinafop)	PN 001, PN 003, PN 005, PN 014, PN 042, PN 073, PN 082, PN 083, PN 098, PN 132, PN 134, PN 144 (Punjab); HR 006, HR 010, HR 012, HR 013, HR 014, HR 021, HR 022, HR 032, HR 072, HR 083, HR 087, HR 089, HR 090, HR 093, HR 114, HR 116, HR 117, HR 118, HR 119, HR 120, HR 128, HR 159, HR 183, HR 185, HR 188, HR 190 (Haryana) (38)
Susceptible	Rest biotypes (249)

The response of *Phalaris minor* biotypes to clodinafop was variable across doses. Of the 311 biotypes, 224 biotypes were completely killed by clodinafop. However, the rest 87 biotypes showed variable phytotoxicity/tolerance depending on the dose of clodinafop. Their resistance index ranged from 1- 41, indicating higher the resistance index, greater is the magnitude of cross-resistance. Of these, 12 biotypes –3 of Punjab and 9 of Haryana were rated as highly resistant to clodinafop. There were 12 biotypes– 4 of Punjab and 8 of Haryana which were resistant, and 38 biotypes– 12 of Punjab and 26 of Haryana which were moderately susceptible/resistant. All 311 *Phalaris* biotypes showed 100% mortality at the recommended doses of sulfosulfuron and pinoxaden. It is apparent that cross-resistance to sulfosulfuron has not cropped up despite it being used for the last few years and pinoxaden is a new herbicide to which *Phalaris minor* has never been exposed.

4.5.5 Integrated Weed Mangement Practices in Onion

A field experiment was conducted during *rabi* season of 2006-2007 to find out the suitable integrated weed management practice for effective weed management in onion.

Sequential application of pendimethalin @ 0.75 kg/ha as pre-emergence followed by (fb) pendimethalin @ 0.75 kg/ha as broadcast (sand mix) at 30 days after transplanting (DATP), fluchloralin @ 1.0 kg/ha pre-plant incorporation (PPI) fb fluchloralin @ 1.0 kg/ha as broadcast, pendimethalin @ 1.0 kg/ha + 1 hand weeding and fluchloralin @ 1.0 kg/ha + 1 hand weeding recorded a bulb yield on a par with that obtained with 3 hand weedings. The lowest bulb yield (3.12 t/ha) was recorded in unweeded plot due to severe weed competition. Pre-emergence application of oxyflurofen at 0.25 kg/ha did not prove effective in controlling weeds.

Effect of weed control treatments on weed growth and bulb yield of onion

Treatment	Dose (kg a.i./ha)	Weed population (No./ m^2)	Bulb yield (t/ha)	Weed control efficiency (%)	Net returns (Rs./ha)
Pendimethalin pre-em	1.0	49	23.75	73.51	101217
Pendimethalin pre-em+1 HW	1.0	40	27.92	78.39	130247
Pendimethalin fb pendimethalin	0.75+0.75	21	28.75	88.65	136922
Fluchloralin PPI	1.0	58	24.17	68.65	110720
Fluchloralin PPI+1 HW	1.0	44	27.50	76.22	128182
Fluchloralin fb fluchloralin	1.0+1.0	30	28.36	83.78	134913
Oxyflurofen pre-em	0.25	103	11.24	44.32	33068
Oxyflurofen+1 HW	0.25	63	16.04	65.95	59326
Oxyflurofen fb oxyflurofen	0.25+0.25	100	14.17	45.95	49580
Two hand weedings	-	53	26.87	71.35	122892
Three hand weedings	-	17	30.84	90.81	141470
Weedy check	-	185	3.12	-	14608(-)
CD (P=0.05)	-	13	2.69	-	-

4.5.6 Comparative Efficacy of Different Herbicides on Weed Growth and Productivity of Direct-Seeded Rice

A field experiment was conducted during *kharif* 2007 to evaluate the efficacy and selectivity of new herbicides in direct-sown non-*basmati* rice.

Repeated hand weeding caused the highest reduction in weed population, closely followed by pre-emergence application of pendimethalin (1000 g/ha) and butachlor (1000 g/ha) and post-emergence tank-mix application of oxadiargyl

(70 g/ha) and fenoxaprop (60 g/ha). Repeated hand weeding recorded the highest grain yield (4.33 t/ha), which however was on a par with that of post-emergence tank-mix application of oxadiargyl + fenoxaprop (70 +60 g/ha) and ethoxysulfuron + fenoxaprop (20 + 60 g/ha). Pre-emergence application of both pendimethalin and butachlor resulted in toxicity and the lowest increase in grain yield amongst herbicide treatments, despite achieving the highest weed control efficiency (86.0-86.7%).

Effect of weed control treatments on weed growth and productivity of direct- seeded rice

Treatment	Dose (g a.i./ha)	Weed population (No./m^2)	Panicle length (cm)	Grain yield (t/ha)	Weed control efficiency (%)
Ethoxysulfuron	20	56.6	22.0	2.92	35.6
Ethoxysulfuron	30	45.3	23.3	3.11	48.4
Fenoxaprop-p-ethyl	60	50.3	22.6	3.08	42.8
Fenoxaprop-p-ethyl	80	40.3	25.2	3.36	54.1
Oxadiargyl	70	30.6	21.8	3.50	57.3
Oxadiargyl	90	28.0	22.5	3.83	68.1
Ethoxysulfuron + fenoxaprop	20+60	24.0	25.8	4.17	72.7
Oxadiargyl + fenoxaprop	70+60	16.0	26.2	4.17	81.8
Butachlor pre-em	1000	12.3	18.8	2.61	85.9
Pendimethalin pre-em	1000	11.6	17.4	2.50	86.7
Weedy check	-	88.0	11.5	1.83	
Repeated weeding	-	8.6	27.6	4.33	90.1
CD (P=0.05)	-	8.2	3.4	0.31	

5. BASIC AND STRATEGIC RESEARCH
(Covers partly NRCPB)

5.1 PLANT BIOTECHNOLOGY

5.1.1 Transgenic Expression of a CMS Associated Gene Inducing Male Sterility in *Arabidopsis thaliana*

A novel mitochondrial gene was identified to be associated with cytoplasmic male sterility in *Brassica juncea* alloplasmic lines. To test whether it is directly involved in causing male sterility, the coding sequences of this gene were translationally fused with a mitochondrial targeting signal and the fusion construct was cloned downstream to CaMV35S promoter in a plant transformation vector. Transgenic *Arabidopsis* plants containing the gene were obtained following floral dip transformation and selection of T_1 seeds on kanamycin containing medium. Most of the transgenic plants showed various degrees of pollen sterility indicating that the gene is involved in causing cytoplasmic male sterility.

Transgenic *Arabidopsis* expressing male sterility

5.1.2 Indian Mustard (*Brassica juncea*) Expressing β-Farnesene Synthase for Repellence to Mustard Aphids (*Lipaphis erysimi*)

Earlier the National Research Centre on Plant Biotechnology (NRCPB) reported the isolation of a cDNA encoding β-farnesene synthase, its cloning in a plant expression vector with the constitutive promoter CaMV35S and its incorporation into the mustard cultivar Varuna in order to develop aphid repellency. This year, the Centre has carried out advancement of generation of the transgenic plants. In the primary transformation event, *nptII* gene, which confers resistance to kanamycin was used as selectable marker. The seeds harvested from T_0 plants were

Segragation of T_1 seedlings on kanamycin medium

sown on MS media supplemented with 100 ppm kanamycin. In about one week only the kanamycin resistant seedlings were able to elongate and grow normally whereas the susceptible seeds could not either germinate or the seedlings failed to grow further after initial sprouting. T_1 generation of selected kanamycin resistant plants was grown in

T_1 transgenics in net house

contained conditions and extensive molecular analyses were carried out on the T_1 plants to follow the segregation and expression level of the incorporated gene. Some of the T_1 plants demonstrated avoidance of aphid infestation to a significant level. The inflorescence of each T_1 plant was

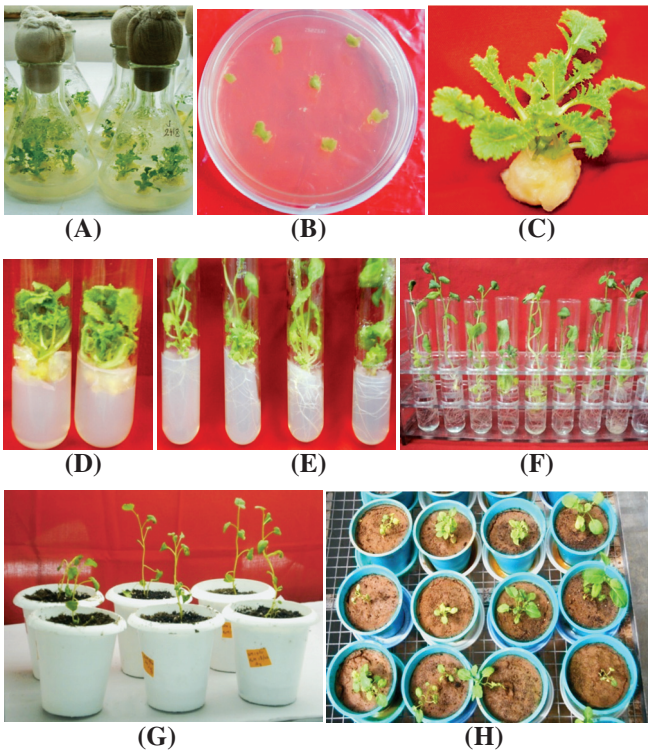
covered with paper bag to ensure selfing. Seeds were harvested and stored appropriately for the next season.

5.1.3 Isolation of a Full Length cDNA of Mungbean Lectin

Based on the sequences of lectin genes available in databank, conserved regions were identified and degenerate primers were designed. These primers were used for the amplification of 3′ end of the lectin cDNA of mungbean. A single fragment of 560 bp was amplified, cloned and sequenced. Complementary reverse-specific primer was designed and used for the cloning of the 5′ end sequence of the lectin cDNA by 5′ RACE based on the sequence of 3′ RACE fragment. A 644 bp fragment was amplified, cloned and sequenced. From the sequences of the 3′ and 5′ RACE products, the primers for full-length cDNA were designed and the fragment of 1204 bp was amplified.

5.1.4 Transformation and Regeneration of *Brassica juncea*

The stem segments of *Brassica juncea* cultivars Pusa Jaikisan and Varuna were excised from 3-4 weeks' old *in-vitro* grown shoots and precultured. The stem segments were co-cultivated with *Agrobacterium* GV3101 containing chickpea lectin gene. The co-cultivated explants were finally transferred onto MS medium containing BA (2 mgl^{-1}) + IAA (0.2 mgl^{-1}) + cefotaxime (250 mgl^{-1}) + Kan (20 mgl^{-1}). Well developed shoots were observed after 6 weeks of inoculation, which were further used for shoot multiplication and rooting.



Transformation of *Brassica juncea* cv. Varuna: (A) generation of stem segments; (B) co-cultivation of stem segments; (C) multiple shooting; (D) explants in shooting media; (E) explants in rooting media; (F) hardening of plantlets; (G) acclimatization of plantlets; and (H) plantlets in Phytotron

The co-cultivated stem segments showed up to 30-35% shoot formation with about 1.8 and 2.5 average number of shoots per explants for Varuna and Jaikisan respectively. The shoots were transferred to rooting medium having ½ MS+ 0.2 mg/l IAA and showed up to 80% rooting. The rooted plantlets were hardened and acclimatized by using agropeat soaked in ½ strength liquid MS medium. The well hardened plantlets were shifted to phytotron growth chamber.

5.1.5 Pigeonpea Genomics Initiative

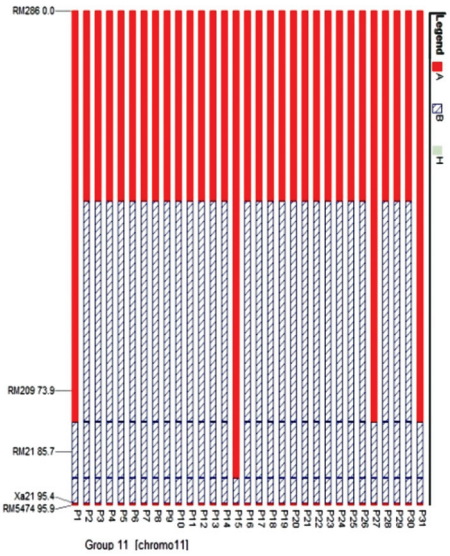
Pigeonpea (*Cajanus cajan*) is the second most important grain legume for India after chickpea. The pigeonpea genomics project involving NRCPB, New Delhi, IIPR, Kanpur, BHU, Varanasi, PDKV, Akola, UAS, Dharwad and ICRISAT, Hyderabad from India and UC Davis, USA was initiated under the Indo-US Knowledge Initiative in November, 2006. The aim of the sub project at NRCPB is to create a rich genomic and EST resource for mapping of agronomic traits, and facilitate gene discovery to assist the crop improvement programmes in pigeonpea. The Centre is mining the EST sequences generated primarily at the Centre for SSR and SNP markers and plans to use these for mapping of genes responsible for important agronomic traits. Different parts of the pigeonpea plant, e.g., leaf, root, flower, bud and seed, were used to generate cDNA libraries and sequence a large number of ESTs to take care of the problem of paucity of marker availability. The pigeonpea plants were also subjected to various abiotic stresses including drought, flooding and methyl jasmonate treatment to enrich the ESTs for stress responsive genes in the National Phytotron Facility at IARI. A total of 21 cDNA libraries were prepared and about 9,776 ESTs were sequenced. Two varieties of pigeonpea, namely, Asha and UPAS 120, and a wild species *C. scaraboides* were used for RNA isolation and cDNA synthesis. Out of the total 9,776 ESTs produced, the Centre has already submitted 776 sequences to the NCBI GenBank, and another 9000 EST sequences are under process of submission. The EST database was mined for the presence of SSRs, and 28 SSR markers were developed and are being used for polymorphism survey between Asha and UPAS 120 for the creation of the first reference genetic map of pigeonpea.

5.1.6 Fine Mapping of QTLs for Salinity Tolerance in Rice Variety CSR 27

Soil salinity is a major factor limiting rice production in the coastal, inland and canal irrigated areas of India. The aim of this study is to identify genes from salt tolerant variety CSR27, which has a traditional salt tolerant land race Nona Bokra in its lineage. Earlier, the Centre had mapped four major quantitative trait loci (QTLs) for salt tolerance on rice chromosomes 1, 2, 3 and 8 using a mapping population developed from the cross between CSR 27 (which has a tissue tolerance mechanism for coping with the salt stress) and a salt susceptible variety MI 48. In *kharif* 2007, F_7 RILs of CSR 27 × MI 48 were grown at IARI, New Delhi for multiplication and generation advancement. The recombinant inbred lines (RILs) were genotyped using additional markers in the mapped QTL regions for salt tolerance on rice chromosomes 1, 2, 3, and 8. Both simple sequence repeats (SSR) and gene based markers mined from the rice genome database were used to search for polymorphic markers between the two parents. The identified QTLs were for seedling injury score, Na^+ content, K^+ content, Na^+ / K^+ ratio and Cl^- content in stem and leaves at vegetative and reproductive stages.

5.1.7 Release of Improved Pusa Basmati 1 and Pyramiding of Additional Bacterial Blight Resistance Genes in *Basmati* Rice Background

Bacterial blight (BB) caused by *Xanthomonas oryzae* pv. *oryzae* is a serious constraint to *basmati* production in the country. Earlier, two genes (*xa13* and *Xa21*) for BB resistance from a non-*basmati* donor line IRBB55 were combined with the *basmati* quality traits of Pusa Basmati 1 through molecular marker-assisted selection (MAS) in collaboration with the Division of Genetics, IARI. One of the recombinant lines, Pusa 1460-01-32-6-67 (IET-18990) was further evaluated in the Advanced Varietal Trial of the All India Coordinated Project and based on its performance, it was identified and released for commercial cultivation as a new variety named Improved Pusa Basmati 1 during the year 2007. Its performance in the farmers' field was highly encouraging. Background analysis revealed that this line inherited most of the regions from Pusa Basmati 1, which are linked to *basmati* quality traits. The possibility of linkage drag was also minimum in respect of chromosomes 8 and 11 carrying the two genes for BB resistance respectively. Marker based analysis suggested that this variety having the *basmati* quality traits and BB resistance can be used as a combiner in *basmati* hybrid breeding programme. With the objective of adding more BB resistance genes in the *basmati* background, a large segregating population was generated using Basmati 370 and IRBB60, a non-*basmati* rice line carrying four genes namely, *Xa4*, *xa5*, *xa13* and *Xa21*. This population will now be screened for identification of suitable recombinants possessing all the four BB resistance genes and the *basmati* traits.



Background analysis for rice chromosome 11. The vertical bars correspond to 31 different recombinants initially short-listed. Red region represents Pusa Basmati 1 chromosomal region, and the hatched segments were from the non-*basmati* parent IRBB55. The line having the maximum length of red segment and thus minimum possible linkage drag is Improved Pusa Basmati 1

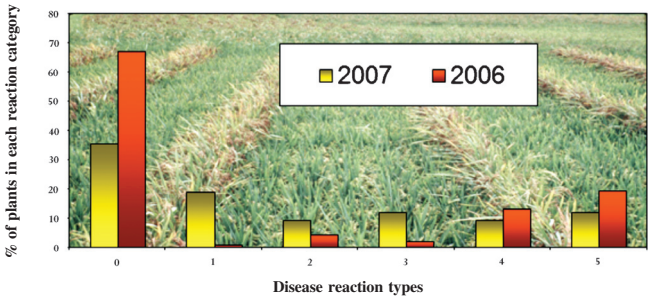
5.1.8 Development of Transgenic Rice by the Use of *AtDREB1A* Gene

The gene construct containing *AtDREB1A* gene for drought tolerance under stress inducible *rd29A* promoter and *hpt*II selection marker in pCAMBIA1200 binary vector was used for genetic transformation. Totally, 66 plants from 32 independent events involving rice variety Pusa Sugandh 2 (PS2) were generated through biolistic transformation. In the case of IR 64, two plants were produced from two independent Calli. The putative transformants (T_0 plants) were grown in phytotron growth chamber. The transgenicity of T_0 plants from 23 independent events of PS2 and 1 independent event of IR 64 was confirmed by PCR amplification using *hpt*II and *AtDREB1A* gene specific primers. The expected fragments of size 897 bp and 450 bp were obtained, respectively. The integration of transgene was further confirmed by Southern hybridization by using *DREB* gene specific radio-labelled probe. Two of the plants in which clear hybridization was observed, had single copy transgene integration. The seeds collected from these two Southern positive T_0 plants and non-transformed control

plants were germinated on hygromycin containing medium to study the segregation pattern. One hundred per cent (100%) mortality was observed in control plant. In the case of two Southern positive lines, the segregation ratio observed was 3(Hyg^R):1(Hyg^S), further suggesting a single locus insertion of the transgene. Hygromycin resistant T_1 seedlings and non-transformed lines were grown individually in phytotron and drought stress (water deficit) was induced by withholding irrigation for 7days. The total RNA was isolated and amplified in RT-PCR using the *AtDREB1A* gene specific primers with tubulin as an internal control. The higher level of expression of *AtDREB1A* gene in stressed transgenic PS2 plants as compared to that in non-stressed transgenic plants was observed. This indicated up-regulated expression pattern of this gene under stress as observed earlier in rice by several studies. Further molecular and phenotypic characterization of the transgenics is in progress.

5.1.9 Transgenic Rice Lines with Blast Resistance Genes

Blast resistance gene *Pi-k*^{h} was mapped and cloned from rice line Tetep. Blast susceptible line Taipei 309 (TP309) has already been genetically transformed with cloned rice blast resistance gene *Pi-k*^{h}. The transgenic lines containing *Pi-k*^{h} genes were further evaluated with the same



Reaction of transgenic lines containing *Pi-k*^{h} gene to *M. grisea* in T_2 generation

isolate of *Magnaporthe grisea* in T_2 generation. Transgenic rice lines (T_1) inoculated with *M. grisea* in 2006 showed that 67.01% of the plants exhibited very high degree (Reaction Type 0) of resistance to the pathogen. Rest of the plants showed different degrees of resistance to blast. The percentages for reaction types 1, 2, 3, 4 & 5 were 0.7, 4.15, 2.07, 13.24 and 19.48, respectively. In the subsequent generation (T_2), the pattern of resistance was the same and the percentages of plants in different reaction categories (on a 0-5 scale) were 35.7, 19.04, 9.52, 11.90, 9.52 and 11.90, respectively.

5.1.10 Molecular Characterization of Apple

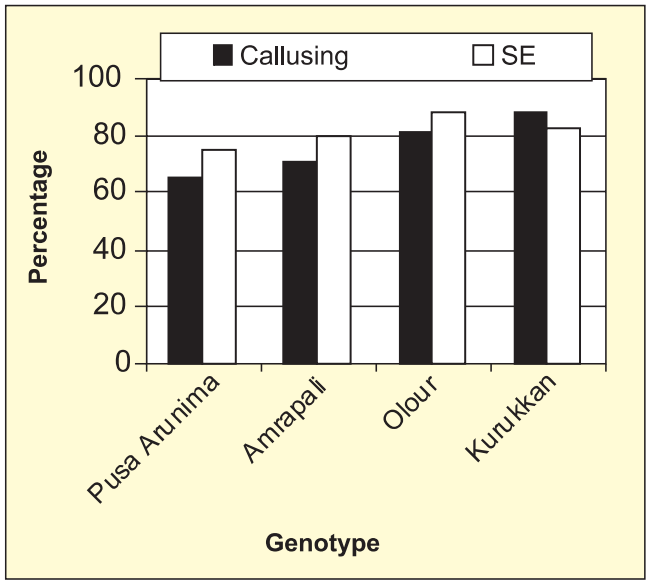
DNA fingerprinting protocol was developed to identify apple (*Malus* × *domestica* Borkh) genotypes using microsatellite markers. Twenty-one polymorphic Inter Simple Sequence Repeat (ISSR) markers were used to characterize 46 apple rootstocks representing different genera, species and varieties. The used ISSR primers produced 130 bands with a mean of 6.19 bands per primer with the size ranging from 300 bp to 1700 bp. The resolving power generated by the 21 primers ranged from 1.174 (Primer UBC-850) to 5.696 (Primer ISSR-3). The Polymorphism Information Content values in all the genotypes varied from 0.28 to 0.62. Primers based on (AC)n and (AG)n repeats generated polymorphic bands ranging from 8 to 10. Genetic similarity ranging from 43.5% to 82.2% suggested high degree of divergence in the used genotypes. The cluster analysis based on UPGMA and bootstrap analysis separated 46 genotypes into three major clusters and three sub-clusters. Two genotypes, namely, *Cydonia oblonga* and Early Strawberry formed independent identity and did not group with other rootstock clusters. Cluster 1 included 3 species and 3 varieties, Cluster 2 was the largest group with 13 species and 23 varieties. The sub-cluster 2a had 13 genotypes, cluster 2b had 21 genotypes (9 species and 12 varieties) and 2c had 2 varieties. The smallest cluster was 3, which had 2 genotypes. The high discriminating power of the loci suggested that selection of highly informative ISSR primers (ISSR-1, ISSR-3, ISSR-6, ISSR-7, UBC-808, UBC-829, UBC-854 and UBC-886) could be deployed to study genotypic diversity of popular varieties, hybrids and rootstocks. The present study reveals that genus *Cydonia* and *Prunus*, though a member of pomoideae had different genomic constitution.

5.1.11 Micro-propagation and Improvement through Tissue Culture of Fruit Crops

5.1.11.1 Mango

In vitro culture using nucellus tissue. With a view to propagating mango through *in vitro* means, nucellus tissue was cultured for callus induction and somatic embryogenesis

in two genotypes, each in mono- and poly-embryonic types, i.e., mono-embryonic - Pusa Arunima and Amrapali, and poly-embryonic - Olour and Kurukkan. Immature 40 to 45-day-old fruitlets (20-25 in each) were collected for excision of nucellus, which were then cultured in complete darkness. Callus induction was noted after four weeks of culture. Callus induction was comparatively better and, in general, high in poly-embryonic genotypes compared to that in mono-embryonic types. Among poly-embryonic genotypes, Kurukkan gave the highest callusing (85.0%) followed by Olour (78.2%). Amongst mono-embryonic genotypes, Amrapali was found more responsive (80.6%) followed by Pusa Arunima (68.3%). The induced calli were transferred onto callus multiplication medium comprising B5 (macro salts) + MS (micro salts + organics) + 200 mg/l L-glutamine + 100 mg/l casein hydrolysate + 100 mg/l activated charcoal + 60 g/l sucrose and supplemented with 4.0 mg/l 2,4-D + 0.5 mg/l IAA. The calli upon transfer to hormone-free medium



Callus induction and somatic embryogenesis in mango genotypes

induced somatic embryos. Somatic embryogenesis frequency was higher in Olour followed by Kurukkan compared to mono-embryonic genotypes. At present, 7 cultures in Kurukkan, 5 in Amrapali, 2 in Olour and 1 in Pusa Arunima are surviving which have been sub-cultured for further regeneration.

Shoot tip culture in mango. Limited success (almost nil) on micropropagation has been met in mango using vegetative explants owing to various inherent problems like high degree of microbial contamination, excessive phenol exudation, browning of medium, explant necrosis, etc. Hence, an attempt was made to use shoot tip explants from field-grown plants in two mango cultivars Amrapali and Pusa Arunima. Different pre-treatments such as addition of phenol binding agents, antioxidants, etiolation of stock plants, etc. were tried to minimize *in vitro* phenol exudation and improve culture establishment. Among individual treatments, control, i.e., T_0 registered significantly higher levels of phenols and POD activity when compared with other treatments. The peroxidase activity was estimated to be the lowest (706.49 unit l^{-1}) in T_3. Irrespective of pre-treatments, variety Pusa Arunima exhibited significantly higher levels of peroxidase (1779.00 unit l^{-1}) than Amrapali (1688.66 unit l^{-1}). Polyphenolaxidase activities were also estimated in shoot tip explants as affected by different pre-treatments. Pre-treatments comprising T_2 = Etiolation + antioxidant agitation (ascorbic acid @ 100 mg l^{-1} + citric acid @ 50 mg l^{-1}) and T_3 = Etiolation + agitation with 0.2% PVP were effective in reducing phenolics and minimum catecholose activity in the two genotypes while Cresolase activity was minimum with T_3 = Etiolation + agitation with 0.2% PVP. All the pre-treatments tried proved significantly superior in respect of reducing the PPO activity. It was observed that the *in vivo* polyphenol oxidase activity and phenol content of mango shoot tip explants were significantly lowered by etiolation treatment.

5.1.11.2 Guava

In guava genotypes, namely, Pusa Srijan and Allahabad Safeda, attempts were made to root the *in vitro* regenerated micro-shoots. Different IBA levels were tested individually and in combination of activated charcoal. The rooting was, in general, higher in Allahabad Safeda though the cultures in Pusa Srijan were lost due to contamination. Of the different media tested for achieving higher root induction, the maximum success was achieved in Allahabad Safeda. Thirteen cultures yielded 3 shootlets per culture which were sub-cultured on to rooting media. In Pusa Srijan, four cultures with seven shoots were cultured. The highest success (88.3%) was achieved on MS medium supplemented with 1.0 mg/l IBA + 100 mg/l activated charcoal followed by 2.0 mg/l IBA + 100 mg/l AC (72.5%) and 1.0 mg/l IBA (70.2%). Rooting was earliest in the medium comprising MS supplemented with 1.0 mg/l IBA + 100 mg/l AC (14.5 days) followed by 2.0 mg/l IBA + 100 AC (15.5 days) and 1.0 mg/l IBA (15.6 days). The result suggested that Pusa Srijan was a shy rooter

even under *in vitro* conditions and it was in accordance with previous year's finding.

5.1.11.3 Grape improvement through *in-ovulo* embryo rescue

Field hybridization was attempted by using six combinations involving seedless × seedless and early maturing seeded × seedless genotypes and selfed seedless combinations. Immature ovules resulting from these crosses were cultured 21 days of post pollination. Of the 1,407 ovules cultured, 68 germinated and finally 32 plantlets were successfully hardened and transplanted in the field for evaluation. The highest number of plantlets (12) was obtained in cross Pearl of Csaba × Beauty Seedless.

***In-ovulo* embryo rescue and plantlet regenration in grape**

Cross	No. of ovules cultured	No. of ovules germinated	No. of plantlets regenerated
Pusa Urvashi × Perlette	315	15	4
Pusa Urvashi × Beauty Seedless	98	11	3
Pusa Urvashi × Pusa Seedless	345	19	5
Pusa Urvashi × Hybrid 75-32	67	5	2
Pusa Urvashi (Selfed)	198	4	2
Pearl of Csaba × Beauty Seedless	245	56	12
Pearl of Csaba × Perlette	139	67	10
Total	**1,407**	**177**	**38**

5.2 BIOCHEMISTRY

5.2.1 Isolation and Characterization of *fad2-1* Gene Encoding ω-6 Desaturase from Soybean

Gene silencing constructs, sense, antisense and ihp were designed for selective and efficient suppression of *fad2-1* gene encoding ω-6 desaturase in the developing seeds of soybean. These constructs – pBinihp, pBinCONAS and pBinCONS– were mobilized into *Agrobacterium tumefaciens* strain GV3101 and confirmed by colony PCR with bar specific primers (BarF & BarR), which amplified a 500 bp amplicon.

The floral dip transformation system was successfully standardized, and the *Agrobacterium tumefaciens* GV3101 carrying pBinihp, pBinCONS and pBinCONAS separately, were used for *in plant* transformation of *Arabidopsis thaliana* ecotype Columbia. Confirmation of integration of transgene into host genomes was further confirmed by PCR of genomic DNA of T_1 plants by using bar gene specific primers, which gave the expected size of amplicon (500bp).

PCR positive plants were raised for another generation, and Southern hybridization was performed with genomic DNA of T_2 plants with *bar* gene probe. Southern-blot analysis showed the presence of single transgene insertion in CONAS8 and multiple insertions in others, i.e., CONS14, ihp1, ihp9 and ihp14. The strongly hybridizing bands in almost all lines also suggested tandem, possibly inverted repeat insertions of transgenes at some loci.

5.2.2 Expression of *DGAT* Gene in *E. coli*

The diacylglycerol acyl transferase encoding cDNA was cloned in an *E. coli* expression vector $pMalC_2$ and got it expressed. The molecular weight of the expressed recombinant protein corresponded to the derived molecular weight of the translation product of *DGAT* gene.

5.2.3 Isolation and Characterization of Lysophosphatidic Acid Acyltransferase Gene from *B. juncea*

Using gene specific primers, PCR amplification was carried out using genomic DNA. Sequence analysis of genomic clone designated as BJLPAATG is an intronless gene showing 1288 bp and had 30 nucleotides at 5′ untranslated region (UTR), 1173 bp coding region and 85 bp at 3′ UTR. This is the first intronless *LPAAT* gene reported from *B. juncea*. It showed maximum homology of 99% and 98% with mRNA of earlier reported *B. napus LPAAT* sequences (Z95637 and Z49860) at nucleotide and amino acid levels. This protein has been predicted to be endoplasmic reticulum localized and also has a plastidial transit peptide of 82 aa N-terminal with two prominent conserved domains (324-EGTR-327 and 223-NH-224).

The *LPAAT* cDNA isolated from *B. juncea* developing seeds designated as BJLPAATcDNA has total 1009 bp encoding a polypeptide of 332 amino acids with a 5′ UTR of 11 nucleotides and was partial with respect to 3′ end. The BJLPAATcDNA showed maximum homology with *B. napus* ACT2 – mRNA (AF111161) at nucleotide level. BJLPAATcDNA was predicted to be a plastidial enzyme expressed more in seeds. It has ten conserved domains between all sequences and the largest was of six amino acids (PEGTRS), showing the common phylogenetic origin of these isoforms.

5.2.4 Isolation and Characterization of Differentially Regulated Genes under Moisture Stress in Rice

The present study was aimed at isolating differentially expressed gene sequences in rice with respect to water deficit stress (WDS). cDNA synthesized from leaf tissue of rice genotype N22 undergoing WDS was cloned in TriplEx2 vector. The library was excised from TriplEx2 to pTriplEx2. Random recombinant clones were used as probes for Northern analysis. A 802 bp sequence encoding a complete coding sequence of 318 bp along with 5′ and 3′ UTR regions and showing homology to Zn inducible protein was isolated and cloned. Sequence was submitted to Genbank (Accession # 195479).

Instead of individual genes, transcription factors could regulate various stress inducible genes cooperatively or separately. Primers were designed for putative transcription factor genes of different classes like bzip, MYB, MYC, AP2, etc., in *Oryza sativa* by using the data base. Genomic DNA/cDNA was amplified. A 964bp cDNA clone encoding AP2 transcription factor was submitted to Genbank.

5.2.5 *In silico* Analysis of a cDNA Sequence Encoding an Antiviral Protein (BBAP-II) from *Bougainvillea xbuttiana* and its Expression in *E. coli*

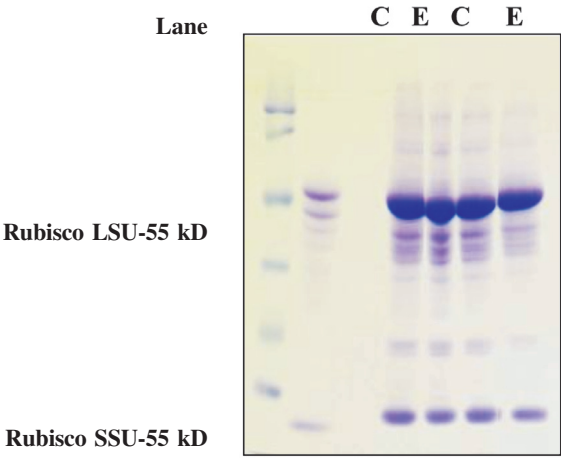
A ~1.2 kb clone was obtained and sequenced. The cDNA sequence was found to be 1168 bp long and AT rich without restriction sites. The homology search did not show any significant homology with other known AVPs/RIPs. The full-length cDNA was translated into all six reading frames; the longest ORF was found to be 849 bp long that encodes 282 amino acid residues. The theoretical amino acid composition obtained by using BioEdit software revealed the basic nature of the protein with predicted molecular weight to be 31.52 kd. The clustal W alignment of the deduced protein with a number of AVP/RIPs showed a strong homology in conserved region, which is the active site of the protein. The coding region of the isolated cDNA clone was PCR amplified and cloned in the expression vector, pMAL-c2X and transformed to *E. coli* TB1 cells. A non-toxic protein product was obtained after expression of recombinant vector in *E. coli* TB1 cells under inducible conditions.

5.3 PLANT PHYSIOLOGY

5.3.1 Physiological Constraints Limiting Productivity

5.3.1.1 Analysis of physiological constraints limiting photosynthesis and grain growth

Photosynthetic response of wheat cultivars to elevated temperature. Wheat (*Triticum aestivum* L.) cultivars HD 2285 and HD 2329 were grown in control (C) and heated (E) open top chambers (OTCs) from sowing to maturity. Photosynthesis rate (Pn) of E grown plants showed a greater sensitivity to high temperature. Pn of flag leaf measured at respective growth temperature was lower in E grown plants compared to that of C grown plants. The CO_2 and light response curves of photosynthesis also showed lesser response in E grown plants compared to those of C grown plants. The pattern of light and CO_2 response curves



SDS-PAGE profiles of leaf soluble protein at anthesis stage in wheat cultivars grown in control (C) and heated OTCs (E). Lane 1: molecular weight marker; lane 2 : marker Rubisco; lane 3 : HD 2285 (C); lane 4 : HD 2285 (E); lane 5 : HD 2329 (C); and lane 6 : HD 2329 (E)

of photosynthesis as affected by elevated temperature indicated Rubisco limitation in E grown plants. This was further substantiated by the observed decrease in Rubisco activase activity in E grown plants compared to that of C grown plants. The decrease in Pn under elevated temperature thus appeared to be due to a decrease in activation state of Rubisco catalyzed by Rubisco activase. Identification and incorporation of thermo-stable Rubisco activase into crop plants would possibly improve thermo-tolerance of these plants.

Stage dependent sensitivity of wheat cultivars to elevated temperature. Wheat (*Triticum aestivum* L.) cultivars HD 2285 (relatively tolerant) and HD 2329 (relatively susceptible) were raised under control (C) and elevated temperature (E) in open top chambers (OTCs) for the entire period of growth and development till maturity. In one set of chambers, high temperature treatment was given only after anthesis stage. The mean maximum temperature was 3 °C higher in heated OTCs compared to that in control OTCs. HD 2285 was found to be more susceptible than HD 2329 to moderately high temperature stress during the entire period of growth and development in terms of dry matter and yield. However, when moderately high temperature exposure was given after anthesis, the heat susceptibility index showed HD 2285 as highly stress tolerant and HD 2329 as a susceptible type. The greater susceptibility of HD 2285 to moderately high temperature exposure during the entire period of growth and development compared to that of HD 2329 was because of a greater reduction in tillers and consequent reduction in ear number per plant. The present study, therefore, revealed that cultivar HD 2285 which is tolerant to terminal high temperature would become susceptible when high temperature spells come during pre-anthesis period. There is a need, therefore, to develop wheat varieties which are not only tolerant to terminal high temperature stress but also to a warmer climatic condition.

Heat susceptibility index (S) for dry matter production, grain growth and yield in wheat cultivars grown in control (C) and heated (E) OTCs for the entire period of growth and development, and temperature treatment given only after anthesis

Cultivar	S for total dry matter plant^{-1}	S for grain yield plant^{-1}	S for 1000 grain weight
High temperature throughout growing season			
HD 2285	1.222***	1.292***	0.888**
HD 2329	0.720**	0.648**	2.944***
High temperature after anthesis			
HD 2285	0.115*	0.117*	0.326*
HD 2329	1.962***	1.798***	1.717***

Kinetics of nitrate uptake and expression of transporters. The wheat seedlings were incubated in a range of nitrate solutions (0.01mM-10mM) for various time intervals and time course of nitrate uptake rate was estimated. Pattern of uptake was similar in seedlings grown under both ambient CO_2 and elevated CO_2. Uptake of nitrate irrespective of N treatments was higher under elevated CO_2 when seedlings were incubated in low concentration of nitrate solution (up to 80 µM).

High affinity transporter (HANT) was expressed under low external nitrate concentration and its expression was higher in ECO_2 grown seedlings as compared to that in ACO_2 grown seedlings; Expression of HANT gene in the roots of both ambient and elevated CO_2 grown seedlings increased with the increasing external nitrate concentration up to 0.1mM, and at higher nitrate concentration, no expression of HANT was observed.

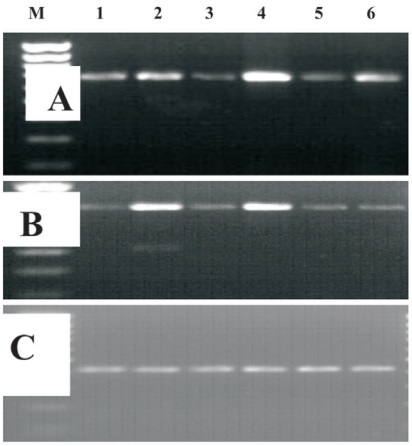
5.3.2 Improvements in Abiotic Stress Tolerance in Crop Plants: Physiological Approaches

5.3.2.1 Identification of morpho-physiological traits associated with stress tolerance

Identification of wheat genotypes for high temperature. An experiment was conducted in field condition with thirty-six genotypes, selected from all regions of the country, under normal and late sown field conditions. The genotypes, which took longer duration for anthesis, were found to be relatively susceptible while early duration types were found to be more tolerant to high temperature. It is felt that the tolerant genotypes completed their reproductive cycle relatively faster than susceptible types (duration between anthesis and maturity). In tolerant genotypes, heat shock proteins (HSPs) play an important role in acclimation of a genotype. It is suggested that selection on the basis of both yield stability index (YSI) and heat susceptibility index (HSI) could be possible, and could lead to selection of suitable parents for enhancing productivity of wheat under late planting and resource limited conditions.

5.3.2.2 Understanding the mechanism of stress tolerance at cellular and biochemical levels

Differential response of green gram* (*Vigna radiata* (L.) Wilczek) *genotypes and wild species to waterlogging and adaptive mechanisms. Waterlogging caused a gradual decrease in relative water content (RWC), chlorophyll content (Chl) in leaves, and membrane stability index (MSI) in leaves and root tissues in all the genotypes. However, wild genotypes *Vigna luteola* and *Vigna sublobata*, tolerant genotypes T 44 and MH 96-1 maintained greater levels of RWC, Chl and MSI than those of susceptible genotypes (Pusa Baisakhi and MH 1K-24). Wild genotype, *Vigna luteola* performed best with



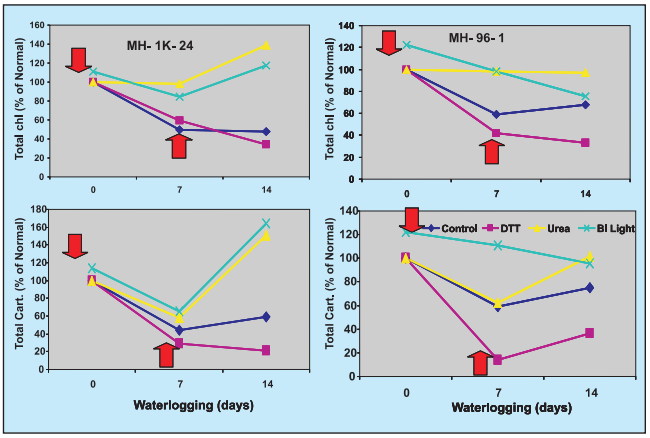
RT-PCR expression analysis of sucrose synthase (A), alcohol dehydrogenase (B), and *tubulin* (C) genes under waterlogging stress and control conditions (M : ladder; 1 : control - *V. luteola*; 2 : treated *V. luteola*; 3 : control T 44; 4 : treated T 44; 5 : control Pusa Baisakhi; and 6: treated Pusa Baisakhi)

reference to physiological, biochemical and molecular characteristics, followed by *Vigna sublobata* (wild genotype). However, these were very poor yielder. Tolerant genotypes have higher root carbohydrate levels, while susceptible genotypes have lower root carbohydrate levels. Waterlogging resulted in decline in, non-reducing and reducing sugars in susceptible genotypes, while tolerant genotypes showed increase in reducing sugars, which was parallel to the increase in sucrose synthase (SS) activity. Alcohol dehydrogenase (*ADH)* gene expression and activity, responsible for fermentation pathway, which allows continuation of glycolytic pathway was greater in tolerant genotypes. Greater SS activity, non-reducing sugars and ADH activity was responsible for better survival of *Vigna luteola,* T 44, MH 96-1 and *Vigna sublobata* (tolerant genotypes and wild species).

Deduced protein sequences for sucrose synthase showed 95%, 93% and 98% similarity between *Vigna luteola* and T 44; T 44 and Pusa Baisakhi; *Vigna luteola* and Pusa Baisakhi, respectively. *Vigna radiata* complete DNA sequence (CDS) (Acc. No. D 10266) showed 98%, 94%, and 100% similarity with *Vigna luteola*, T 44 and Pusa Baisakhi, respectively. Sucrose synthase (pfam00862) catalyze the synthesis of sucrose from UDP-glucose and fructose. This family includes the bulk of the sucrose synthase protein. However, the carboxyl terminal region of the sucrose synthases belongs to the glycosyl transferase family pfam00534.

RT-PCR amplified alcohol dehydrogenase cDNAs of *Vigna luteola*, T 44 and Pusa Baisakhi were sequenced and about 650 bp of partial coding sequence were compared with *Phaseolus acutifolius ADH* gene (Acc. No. Z23170,complete gene 1143 bp). All the three genotypes showed more than 95% similarity with *Phaseolus acutifolius* full coding sequence of *ADH* gene. Conserved domains were identified in all the 3 genotypes using 'PROSITE'. Partial amino acid sequence of *ADH* showed two conserved domains: (1) ADH_Zn, Zinc containing alcohol dehydrogenase signature (PS 00059) (amino acid residues 26-40 in *Vigna luteola*; 24-38 in T 44 and Pusa Baisakhi), where H(Histidine) is the Zinc ligand, which is the 2nd ligand of the catalytic Zinc atom, and (2) ADH_N, Alcohol dehydrogenase GroES-like domain (amino acid residues 83-96 in *Vigna luteola*; 80-93 in T 44 and Pusa Baisakhi). Green gram genotype Pusa Baisakhi showed an amino acid replacement at 86th position by Q(Glutamine) whereas other genotypes had K(Lysine) in that position. This may be one of the reasons for the less expression of *ADH* in Pusa Baisakhi under waterlogged condition compared to that in other genotypes.

Effect of photosynthetic pigments manipulation effect on photosynthetic activity and yield of green gram under waterlogging. In order to analyze and understand the photosynthetic pigment basis of waterlogging tolerance in green gram, a pot culture experiment using two diverse genotypes, i.e., MH - 96-1(tolerant to waterlogging)



Photosynthetic pigments in two diverse waterlogged genotypes under different treatments. (↑= initiation, ↓ = termination of waterlogging)

MH - 1K - 24 (susceptible to waterlogging) was conducted. Exposure of blue light and foliar application of urea enhanced the level of photosynthetic pigments and photosynthesis rate under both normal (non-waterlogged) and waterlogged conditions. Foliar spray of urea effectively enhanced the plant height, leaf area and total dry matter accumulation and accelerated the recovery rate. However, dithiothreitol (DTT),

an inhibitor of de-epoxidation of violoaxanthin significantly reduced the level of chlorophylls and carotenoids, photosynthesis rate, membrane stability index, and growth parameters under waterlogged conditions in both genotypes. This in turn indicated the involvement and protective role of carotenoids in waterlogging tolerance. This view is also supported by tolerant genotype, which had higher level of carotenoids compared to that of susceptible genotypes under waterlogging. Further, the level of carotenoids and carotenoids/chlorophyll ratio showed significant relationship with photosynthesis, photosynthetic pigments and waterlogging tolerance during waterlogging and after waterlogging termination.

Photosynthetic pigment profiles developed using the TLC technique revealed various bands, which were very clear particularly in non-waterlogged treatments except non-waterlogged DTT. Poor bands of major photosynthetic pigments and non-traceable minor pigments were noted in waterlogged control, particularly in susceptible genotype and waterlogged DTT treatment. Foliar application of urea and blue light exposed plants exhibited sharp bands of all thirteen pigments under both non-waterlogged and waterlogged conditions.

***Cloning of abiotic stress responsive genes encoding transcription factor and signaling proteins (MAPK, PP2C) from wheat (Triticum aestivum* L.).** A study was undertaken to clone drought stress responsive genes that encode signaling proteins Mitogen Activated Protein Kinase (MAPK) and Protein Phosphatase 2C (PP2C) and a transcription factor (Zinc finger protein). Wheat cultivar C306 (drought and heat stress resistant) and Kharchia 65 (salinity stress resistant) plants were grown in small pots of 6 inches diameter at the National Phytotron Facility, IARI, New Delhi during the *rabi* season, 2006-07. One-month-old wheat plants were subjected to water-deficit stress by withholding irrigation for 7-8 days. Another set of plants was regularly irrigated (Control).

RNA was extracted and reverse transcription polymerase chain reactions (RTPCR) were conducted. Expression analysis showed that wheat *TaMAPK*, *TaPP2C* and *TaZF* genes were induced only under water deficit stress conditions, but not under irrigated conditions. Further, sequence analysis of these genes revealed that the wheat *TaMAPK* encoded protein differed from a previously reported elicitor induced wheat WCK-1 protein only at a single amino acid indicating that both of these mRNAs are encoded by the same gene. The *PP2C* gene isolated from wheat cultivars C306 and Kharchia-65 was found to show 99% identity at the nucleotide level. At the protein level, a single amino acid change was observed (K104 in C306 to E in Kharchia-65). The *ZF* gene isolated from wheat was found to encode a PHD type zinc finger protein and showed 66% sequence similarity at the protein level to a previously reported Alfin1 ZF transcription factor from alfalfa. Thus, in this study drought stress responsive genes encoding *MAPK*, *PP2C* and *ZF* have been cloned from abiotic stress resistant wheat cultivars.

Drought induced expression of these wheat genes suggests a potential role of these genes in drought stress signaling and gene regulation. Functional characterization of these genes through transgenic development or genetic approaches will significantly enhance our understanding of drought stress tolerance in wheat.

5.3.2.3 Oxidative stress metabolism in leaves of wheat cultivars differing in senescence under heat stress

Two wheat genotypes, Hindi 62 (heat tolerant) and PBW 343 (heat susceptible) were analyzed for antioxidant defense in the flag leaf under high temperature. The parameters studied include H_2O_2 estimation, lipid peroxidation, antioxidant metabolites and antioxidant enzymes. The first and foremost visible effect of heat induced oxidative stress was to increase the membrane damage. The extent of membrane damage in terms of lipid peroxidation was considerably higher in PBW 343 than that in Hindi 62 under heat stress**.** The lower level of ROS production, lower lipid peroxidation with less altered and well coordinated antioxidant system during heat stress enabled Hindi 62 to cope with heat stress more efficiently than PBW 343. The ROS scavenging system of heat susceptible genotype PBW 343 was affected more under heat stress and contributed to the faster rate of leaf senescence.

5.3.2.4 Isolation and characterization of chloroplastic Cu/Zn superoxide dismutase gene from *Chenopodium murale*

The Chl Cu/Zn superoxide dismutase gene (*Cm*CSV) was isolated from *Chenopodium murale* using RT-PCR and RACE techniques. The 445 bp amplicon obtained by 5´ RACE PCR contained the N-terminus region of the Chl Cu/Zn SOD. The full length cDNA sequence obtained was 672 bp and had the putative conserved domain of the Cu/Zn SOD with the chloroplast transit peptide. The N-terminal sequence

of the purified SOD protein showed 70% homology with the N-terminal region of the cloned full length cDNA. This is the first report on cloning of chloroplastic Cu/Zn SOD cDNA from *C. murale*. The expression pattern of the chloroplastic Cu/Zn SOD V (*Cm*CSV) of *C. murale* was examined under various abiotic stresses like high temperature (45 °C) either with or without prior acclimation at 35 °C, high light intensitiy (900 ± 50 µmol m^{-2} s^{-1}), and water stress followed by recovery. The Northern blot analysis clearly indicated that transcript levels of *Cm*CSV were more under high light intensity, high temperature stress after acclimation and water stress recovery in the leaves compared to those of control plants. However, no change in the protein level of chloroplastic Cu/Zn SOD was observed in the western blot using the antibody raised against the thermostable SOD.

5.3.3 Post-harvest Physiology of Fruits, Vegetables and Flowers

5.3.3.1 Regulation of ripening in climacteric fruits

Role of stem scar region of tomato fruit in regulating the process of ripening. In harvested tomato fruit, major gaseous exchange and loss of moisture is through the stem scar region. For study purpose, this region of the tomato fruits was sealed by silicone grease in two varieties with contrasting ripening behaviour, i.e., Pusa Ruby (fast ripening) and Pusa Gaurav (slow ripening). This would allow the gaseous exchange and loss of moisture only through the lenticels present on the surface of the tomato fruit. Treatment was given at two different stages of harvest : (1). Green mature, and (2). Breaker. Fruits were stored at room conditions (temperature of 28 ±1 ^{0}C and relative humidity 35 ±6%). The effect of the treatment was studied on the rate of respiration.

The results indicated the role of stem scar region on the rate of respiration. Varietal variations in the rates of respiration and ripening (as reported earlier) appeared to be correlated.

Effect of blocking the stem scar region of tomato fruit by silicone grease (SG) for 10 days on the rate of respiration (µmole CO_2 g^{-1} fr. wt. h^{-1}) in comparison with control (C)

Variety	Pusa Ruby			Pusa Gaurav		
Treatments (T)/ Stage (S)	Control	Silicone grease	Mean	Control	Silicone grease	Mean
Green mature, 3 DAH	20.38a	8.99^{c}	14.68^{a}	11.63^{b}	3.08^{c}	7.36^{b}
Green mature, 10 DAH	15.23^{b}	4.77^{d}	9.99^{b}	3.79^{c}	2.78^{cd}	3.29^{c}
Breaker, 3 DAH	18.68^{ab}	9.39^{c}	14.04^{a}	20.62^{a}	1.66^{d}	11.14^{a}
Breaker, 10 DAH	5.34^{cd}	3.62^{d}	4.48^{c}	4.09^{c}	3.30^{c}	3.69^{c}
Mean	14.91^{a}	6.69^{b}		10.03^{a}	2.71^{b}	
CD value at P=0.01	**S: 2.839, T: 2.008, S x T: 4.015 S: 0.928, T: 0.656, Sx T: 1.313**					

Note : Fruits were harvested at 'green mature' and 'breaker stages' and kept at room temperature of 28 ±1^{0}C and RH of 35.0±6%.

5.3.3.2 Physiological and molecular bases of regulation of flower senescence

Nitric oxide (NO) regulate the flower senescence in gladiolus. The aim of this study was to assess the impact of nitric oxide (NO) on the vase life of cut flowers of *Gladiolus grandiflora* cultivar Snow Princess. Effects of two sources of NO, viz., 2,2'-(hydroxynitrosohydrazino)-bisethanamine, (DETA/NO) and sodium nitroprusside (SNP) were examined on the post harvest life of gladiolus cut flowers. The vase solution having SNP and DETA/NO significantly increased the vase life of gladiolus flowers compared to that of the controls (DW). Spikes kept in vase solution containing SNP and DETA/NO also exhibited lower lipid peroxidation and lipoxygenase (LOX) activity, and higher membrane stability, soluble protein concentration, and activity of antioxidant enzymes such as superoxide dismutase (SOD) and catalase. Results suggest that NO increases vase life by increasing the reactive oxygen species (ROS) scavenging activity of the gladiolus cut flowers.

Lipoxygenase activity, membrane injury index, vase life and vase pH of gladiolus florets during post harvest life (four days after treatments) as influenced by NO releasing compounds

Treatments	MII (%)	LOX (Ä A_{234} min^{-1} mg^{-1} protein)	Vase life (days)	Vase pH
Control (DW)	57.18±2.37	64.45±1.76	4.8±1.08	4.79±0.71
Sodium nitroprusside (10 ppm)	49.23±3.08	57.87±2.99	6.1±0.66	4.23±0.89
DETA/NO (10 ppm)	43.72±3.22	52.33±3.09	7.9±1.05	3.97±0.42

Studies revealed that nitric oxide was effective on ethylene insensitive gladiolus flower in delaying the flower

senescence by 2-3 days suggesting that the mode of action of NO differs from current commercial treatment protocols such as silver thiosulfate (STS) and 1-methylcyclopropene (1-MCP) that exclusively target the effects of endogenous and exogenous ethylene.

5.3.4 Characterization of Crop Responses to Global Climate Change

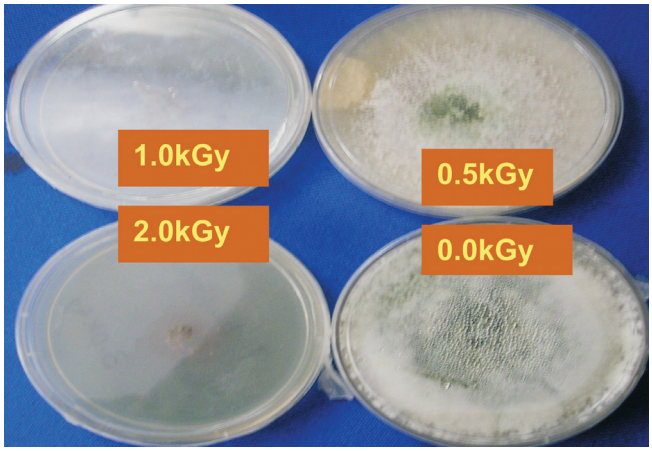
Effect of elevated CO_2 and temperature on growth and yield of chickpea genotypes. Two genotypes of chickpea, Pusa 256 and Pusa 212, were grown in the open top chambers to study the interactive effects of elevated CO_2 and temperature. Four treatments consisting of two temperature levels and two CO_2 concentrations were maintained in the open top chambers as follows – Chamber 1: Elevated Temperature + Elevated CO_2, Chamber 2: Ambient Temperature + Elevated CO_2, Chamber 3: Elevated Temperature + Ambient CO_2 and Chamber 4: Ambient Temperature + Ambient CO_2. Elevated temperature was provided by increasing the temperature by 2-4 °C. Higher temperature resulted in decrease in total dry matter production, photosynthesis and nodulation both under elevated CO_2 and ambient conditions. Partitioning of photo-assimilates to seeds increased at higher temperature, thereby increasing the harvest index. The chickpea genotype Pusa 256 responded better in terms of dry matter production to the elevated CO_2 as well as to the ambient temperature. Elevated CO_2 conditions increased the respiration rate of the leaves. Therefore, an increase of temperature by 2-4 °C can override the beneficial effect of elevated CO_2 depending upon the genotype.

Effect of elevated CO_2 and temperature on dry matter production and partitioning in chickpea varieties Pusa 256 and Pusa 212 (EC: elevated CO_2; ET: elevated temperature, AC: ambient CO_2; AT: ambient temperature)

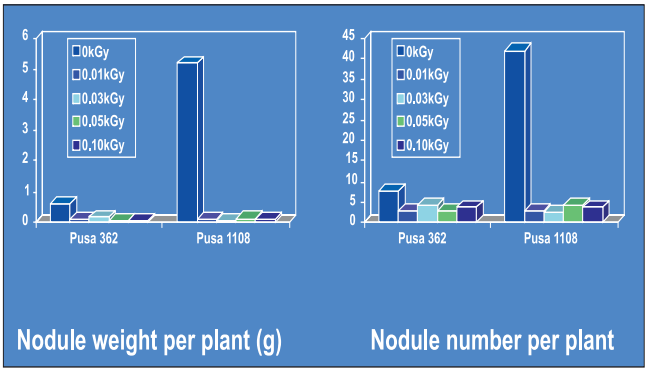
Treatment	Total dry matter(g plant^{-1})		Seed weight (g plant^{-1})		Harvest index (HI) (%)	
	Pusa 256	Pusa 212	Pusa 256	Pusa 212	Pusa 256	Pusa 212
EC+ET	32.737	26.940	14.602	8.831	0.446	0.328
EC+AT	52.397	24.170	20.475	7.665	0.391	0.317
AC+ET	29.563	22.740	12.042	8.908	0.407	0.392
AC+AT	38.787	26.007	15.867	6.657	0.409	0.256

5.3.5 *Gamma* Irradiation for Altering Plant Responses, Microbial Growth and Nutritional Quality of Agri-produce

Rhizobium strain SP-4 gram 31-8 and *Trichoderma harzanium* T-5230 irradiated at 0.5, 1, 2, 3 kGy showed significant inhibition in colony count and colony diameter after 24 hours of incubation and per cent inhibition increased with dose. In another experiment conducted with two chickpea lines, Pusa 362 (*desi*) and Pusa 1108 (*Kabuli*) to investigate the effect of *gamma* irradiation (0.01, 0.03, 0.05 and 0.1 kGy) on growth, nodulation and yield characteristics, showed that, in general, *Kabuli* type produced more plant-root and shoot mass, nodule number, nodule mass as compared to *desi* type. Irradiation inhibited not only the growth but also the nodule number and nodule mass per plant and weight of a single nodule. The inhibition was, however, less pronounced for the *desi* chickpea type. F_2 population of wheat with high ear bearing tillers was developed using *gamma* irradiation to stabilize the trait.



Effect of *gamma* irradiation on the growth of *Trichoderma harzanium* (T-5230)



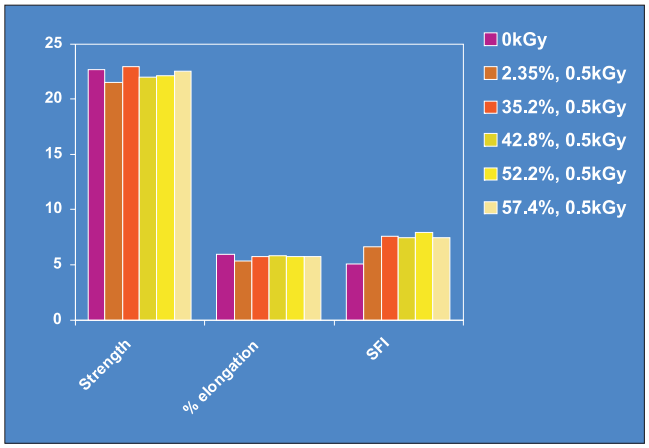
Nodulation attributes of *desi* and *Kabuli* type chickpea as affected by *gamma* irradiation

5.3.6 Effects of Exposure of Wheat Seeds to Gamma Irradiation on the Physiological and Morphological Traits

A field experiment was conducted to study the effect of *gamma* radiation on a promising wheat plant type to improve the plant type by reducing the height and increase the ear bearing tillers. The adaptive response was observed on the development of plants in M1 stage. The irradiation doses, viz., 0.01, 0.03, 0.05, 0.07, and 0.1 kGy not only improved the wheat plant growth behaviour but also did not affect the active metabolism in plants under normal conditions. The wheat plant type appeared to be adapted to *gamma* irradiation even at a dose over 0.5 kGy. Total number of tillers and number of ear bearing tillers increased significantly with *gamma* radiation, maximum effect being evident at around 0.05 kGy. Overall plant vigour and area of flag leaf also increased significantly; flag leaf area at 0.05 kGy was about five times higher than that of unirradiated control. Number of spikelets per ear also increased with a reduction in shoot length particularly at 1.0 kGy. Shoot length and number of internodes per mother shoot decreased with increasing dose of *gamma* irradiation. Further efforts are being made to examine the relationship of these physiological and morphological attributes with irradiation induced changes in growth hormones. The investigation offers newer scope of research towards useful utilization of *gamma* radiation for improving yield attributes in wheat.

5.3.7 *Gamma* Irradiation Effect on Cotton Fiber Strength

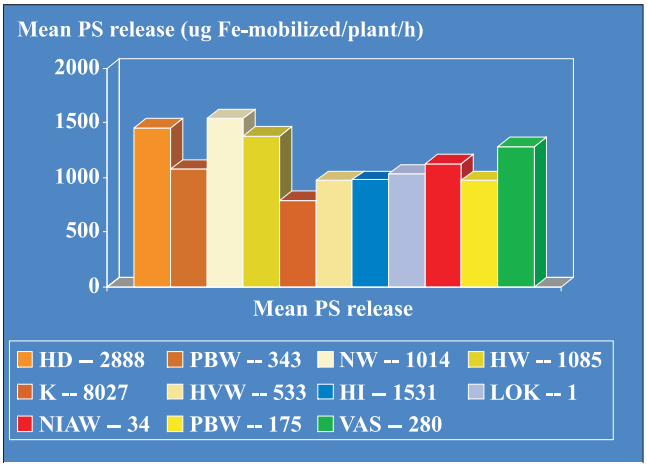
Five cotton lines, viz., P 514, F 2086, H 1287, CNH 1101 and P 576 were examined with 0, 0.25, 0.5, 1.0, 3.0 kGy dose treatments. Irradiation of cotton fiber after soaking in water was found to improve fiber strength. This could be possibly due to redistribution of otherwise unevenly distributed cellulose over the fiber pre-soaked and sun dried. The increase in cotton fiber quality attributes is shown in the following figure.



Effect of gamma irradiation and water soaking of cotton fiber on fiber strength (g/tex), per cent elongation and short fiber index

5.3.8 Phytosiderophore as Possible Tool for Biofortification of Wheat with Zinc and Iron

Release of phytosiderophores (µg Fe-mobilized/plant/h) measured in 11 diverse wheat lines, viz., HD 2888, PBW 343, NW 1014, HW 1085, K 8027, HVW 533, HI 1531, Lok 1, NIAW 34, PBW 175 and UAS 280, from 9th to 15th day after transfer to Fe deficient nutrient solution culture showed an increase from day



Phytosiderophore release efficiency of diverse wheat genotypes (mean across 9-15 days after transplanting into iron deficient nutrient solution)

9 until day 13 followed by a decline. Across genotypes, PS release was the highest for HD 2888, NW 1014, HW 1085 and UAS 280, while the least was observed in K 8027. Micronutrient concentration of Mn, Zn, Cu in shoots was the highest for HD 2888 followed by HW 1085. The latter line also showed the highest shoot iron. Least micronutrient levels were observed for K 8097, which also showed the least release of PS. A similar pattern was observed for various micronutrients when computed on per plant basis and followed the variation among the genotypes for the release of PS. Incidentally, the roots of the above-mentioned lines showing high shoot micronutrients had better translocation as evident from their relatively low levels in the root.

5.4 GENETICS

5.4.1 Wheat

5.4.1.1 Genetics of morpho-physiological traits and seedling survivability

To understand the genetic basis of relative water content, excised leaf water retention capacity and mode of inheritance of seedling survivability, several morpho-physiological traits like number of grains/main spike, grain yield/main spike, excised leaf water retention capacity were studied in the crosses, HW 3081/HD 2839 and HW 3081/C 306 and seedling survivability in Kundan/HD 2329 and HW 3081/HD 2839. Relative water content was studied in 4 crosses including the above three and MP1136/ HW 2044. The results indicated the presence of duplicate type of epistatic gene interaction for relative water content. However, the dominance component was found predominant over additive component in determining the number of grain/main spike, whereas additive component is more important for grain yield/main spike. The overall trend indicated that epistasis is the integral part of the genetic architecture of the parental material used in the study. Significant positive correlations were observed between number of grains/main spike and relative water content and grain yield/main spike. The study on seedling survivability under artificial moisture stress conditions in the greenhouse indicated that this trait is controlled by a single dominant gene. Both relative water content and seedling survivability could be used as selection criteria for drought tolerance.

5.4.1.2 Detection of an additional adult plant resistance gene *Lr48* in the near-isogenic line of Thatcher possessing seedling resistance gene *Lr25* for leaf rust resistance in wheat

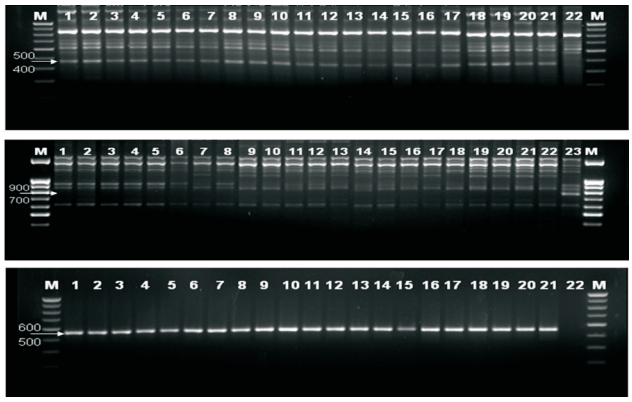
In a genetic stock documented as near isogenic line (NIL) of the cultivar Thatcher carrying the gene *Lr25* (Tc + *Lr25*), validation studies with newly developed molecular markers linked to the recessive APR gene *Lr48*, detected the presence of the additional gene *Lr48*. The NIL was documented to carry only one seedling resistant gene *Lr25* for its leaf rust resistance. The gene *Lr25* is a seedling resistance gene which operated till maturity imparting resistance to leaf rust and gene *Lr48* is an APR gene operating only at boot leaf and later stages. The local land race of wheat Agra Local was leaf rust susceptible with no resistance to any known pathotypes of leaf rust in India. Two populations were developed with the above as parental lines. One population was F_2 from the cross Tc + *Lr25* × CSP44 made for test of allelism for leaf rust resistant loci and the other was involving Tc + *Lr25* × Agra Local for inheritance of resistance in Tc + *Lr25*.

5.4.1.3 Genetics of resistance against stripe rust

Inheritance of stripe rust resistance in Avocet *Yr15* was analysed against 46S119 pathotype. The F_2 seedlings derived from the cross Agra Local x Avst *Yr15* segregated into 142 resistant and 47 susceptible ones, which fitted well in the expected ratio of 3:1 indicating the presence of monogenic dominant control of inheritance against the pathotype.

5.4.1.4 Molecular breeding: Molecular analysis of the F_3 progeny selections in F_4 generation for pyramiding of *Lr28* + *Lr48* and *Lr24* + *Lr48*

In two populations from the crosses PBW343/ HD2329+*Lr24*/ *4//CSP44 and PBW343/HD2329+ *Lr28*/*3/



An example of MAS identified homozygous F_4 family which did not segregate for (a) RAPD marker $S3_{450}$, (b) RAPD marker $S336_{775}$ linked to the gene *Lr48*, and (c) SCAR marker $SCS421_{570}$ linked to the gene *Lr28* in the cross(PBW343+*Lr28*) x (CSP44). M: molecular marker; lanes 1-21 in (a); and lanes 1-20 in (b) and (c) indicate the presence (a & c) or absence (b) of the linked marker fragment (arrow); lane 21: b (CSP44) and c (PBW343+*Lr28*), lane 22: a & c (CSP44) and b (PBW343+*Lr28*), and lane 23: a (PBW343+*Lr28*)

/CSP44, employing MAS, it was possible to select 48 F_4 sub-families for the genes *Lr28* + *Lr48* and *Lr24* + *Lr48* showing homozygosity for the two gene combinations in F_3 families. The non-segregating leaf rust resistant families were selected and used for molecular analysis to confirm the presence of the two genes in each combination, i.e., *Lr28* + *Lr48* and *Lr24* + *Lr48*.

Field analysis and molecular marker analysis of the F_4 lines. The selected F_3 families from the harvest of last summer were forwarded as F_4 sub-families in *rabi* 2006-2007. Individual plants within a family were tested with related markers for the presence of gene combinations *Lr28* + *Lr48* and *Lr24* + *Lr48* to confirm the fixation of the pyramided *Lr* genes. In the case of population bred for *Lr 28* + *Lr48*, a total of 26 single plants were tagged for generating the F_5 generation for bulking and yield trials in the next season. In the second population, 35 single plants were selected on the basis of their expression for desirable plant height, number of tillers per plant, number of seeds per spike and single plant yield. These plants which remained resistant would be tested for agronomic suitability and yield trial in the forthcoming generations for produce development purpose.

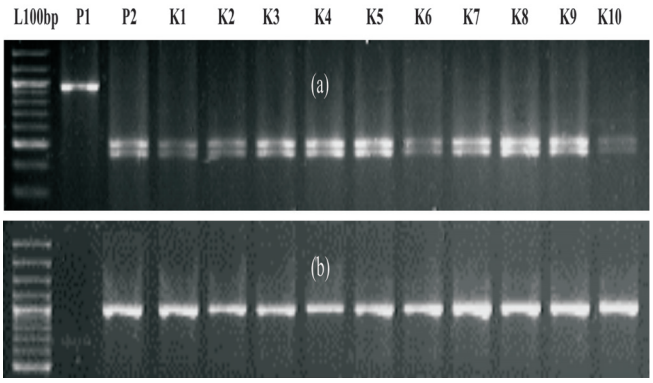
5.4.2 Rice

5.4.2.1 Marker aided improvement of parental lines of Pusa RH 10 for resistance to bacterial blight (BB) and blast diseases

A marker assisted back cross breeding programme was initiated for incorporating genes *xa 13* and *Xa21* conferring resistance to BB and genes *Piz-5* and *Pi k*^{h} conferring resistance to blast diseases in the parental lines of Pusa RH 10, namely, Pusa 6A and PRR 78. Improved Pusa Basmati 1 (Pusa 1460) was used as donor for genes *xa13* and *Xa21* while C101A51 and Tetep were used as donor for *Piz-5* and *Pi k*^{h}, respectively. Marker assisted foreground and background selections were used to compress the breeding cycle. A total of 150 BC_2F_2, BC_2F_3 and BC_1F_3 families involving crosses Pusa 6B and PRR78 with Pusa 1460, C10151A and Tetep were evaluated for agronomic performance, disease reaction and grain and cooking quality traits during *kharif* 2007.

5.4.2.2 Marker assisted maintenance breeding in Improved Pusa Basmati 1

Panicle-to-progeny rows of Improved Pusa Basmati 1 were grown during *kharif* 2007 at IARI Regional Station,



Molecular profile of recurrent parent Pusa Basmati 1 (P1), resistant donor parent IRBB55(P2) and 10 panicle-to-progeny rows of Improved Pusa Basmati 1 (K1-K10) for genes xa13 using CAPS marker (a) and Xa 21 using STS marker (b).Lanes K1-K10 show resistant donor parent specific bands for both the markers

Data on quality traits of promising pyramided lines of Pusa 6B and PRR 78

Line	Gene	KLBC (mm)	KBBC (mm)	KLAC (mm)	KBAC (mm)	ER	ASV	Aroma
Backcross derivatives of PRR 78 with resistance to BB and blast diseases								
Pusa1601-05-25-5	*xa13 & Xa21*	8.41	1.60	15.01	2.00	1.78	7	3
Pusa1601-05-27-9	*xa13 & Xa21*	8.33	1.60	13.00	2.00	1.56	7	2
Pusa1602-05-20-5	*Piz-5*	8.33	1.66	11.75	2.00	1.41	7	2
Pusa1602-05-23-4	*Piz-5*	8.00	1.66	11.50	2.40	1.43	4/7	2
Pusa1603-05-74-7	*Pi k*^{h}	8.83	1.66	12.00	2.00	1.35	7/3	3
Pusa1603-05-73-1	*Pi k*^{h}	8.50	1.91	12.25	2.50	1.44	7	3
PRR 78	–	7.98	1.68	14.13	2.07	1.77	6	2
Backcross derivatives of Pusa 6B with resistance to BB and blast diseases								
Pusa1605-05-26-2	*xa13 & Xa21*	8.16	1.66	13.25	2.00	1.47	7	2
Pusa1606-05-238-2	*Piz-5*	8.50	1.66	13.50	2.70	1.58	7/5	3
Pusa1606-05-238-3	*Piz-5*	7.91	1.66	12.50	2.40	1.58	7/5	3
Pusa1604-05-148-2	*Pi k*^{h}	7.00	1.83	11.50	2.13	1.64	7	2
Pusa 6B		7.51	1.50	10.60	3.53	1.41	6	2

Karnal for its nucleus seed production to consolidate on the basis of field performance and cooking quality traits as well as molecular marker based verification to confirm the purity status and true to type inheritance of the variety.

5.4.2.3 Development of provitamin A rich *indica* rice lines through marker assisted backcross breeding

The main objective of the project was to introgress provitamin A trait from transgenic Golden Rice lines (pCaCar, GR1 and GR2) into widely grown Indian rice varieties Swarna and Jaya. During the period under report, the following progress was made:

BC_2F_2 and BC_3F_2 plants homozygous for transgenes (*Psy+CrtI*) having 87-94% recovery of recurrent parent (Swarna) were developed through marker assisted background selection using pCaCar events in the background of Taipei 309 and IR 64 as donor.

In the case of GR1, transgene positive BC_2F_2 plants in the background of rice varieties Swarna and Jaya were developed.

In GR 2, BC_1F_2 seeds from six events using Swarna as recurrent parent were produced which will be used for event selection. In addition, BC_2F_1 seeds using two selected events were generated. BC_2F_1 plants are currently growing in phytotron.

5.4.2.4 Mapping QTLs for yield and yield components by the use of immortal mapping population in rice

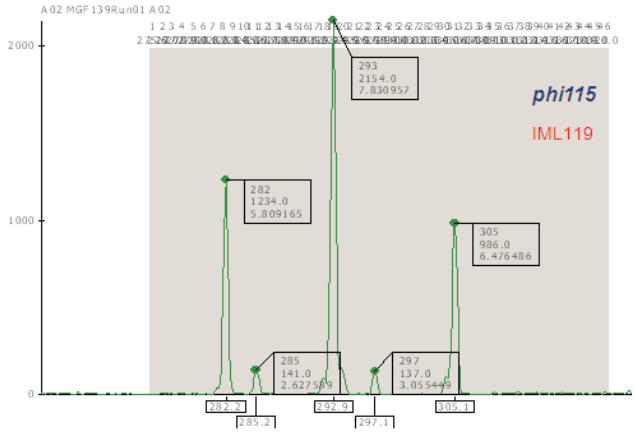
A recombinant inbred line population consisting of 310 F_8 RILs developed from the cross of an inter sub-specific derivative NPT 11 with national check rice variety Jaya was genotyped with 100 polymorphic markers. Genotyping with additional 60 polymorphic markers is in progress. The data on yield and yield components of these lines were already generated through a multilocation trial, which will be used for identifying QTLs.

5.4.3 Maize

5.4.3.1 Phenotypic and molecular analyses of maize landrace accessions in India

Evaluation of agronomic performance of a set of 125 landrace accessions of maize from diverse agroecologies in India was undertaken through multi-location trials at Tadong (Sikkim), Almora (Uttarakhand), Bajaura (HP), Delhi and Hyderabad (AP) during the last two years (2006 and 2007). The biplot analysis demonstrated that landrace accessions could exhibit both location-specific and broader adaptation. Twenty highly promising accessions were identified based on their performance for yield attributes and flowering behaviour.

Molecular characterization of 91 landrace accessions of maize in India was completed using 42 fluorescent-labeled SSR markers with allele resolution through MegaBACE DNA Sequencer, and estimation of allele frequencies using FreqsR.



DNA sequencer image of SSR alleles (reflected as distinct peaks) in a specific accession

Analysis using POWERMARKER revealed a total of 656 alleles, with a mean of 16 alleles per locus, and high mean PIC value of 0.61.

Identification of 187 unique/private SSR alleles led to clear differentiation of the accessions. The study also revealed six highly frequent/major SSR alleles at seven loci (*phi062, umc1266, umc1367, phi090*, *phi014*, *phi112* and *umc2250*) with individual frequencies >0.70. These SSR loci were reported to tag specific genes/QTLs associated with some important traits such as disease resistance, anthesis-silking interval (ASI) and nutritional quality. Thus, it is clear that the chromosomal regions harboring these specific SSRs are not selectively neutral in landraces.

Analysis of various population genetic parameters revealed significant population substructure in the Indian maize landraces. Variation within populations was the highest (61.63%), followed by variation among the populations (37.51%) and variation among the groups (0.86%).

Cluster analysis of SSR allele data showed eight clusters, which largely matched with the patterns derived through analysis of performance data. A 'core set' of 15 landrace accessions was identified using 'advanced M (Maximation) strategy' that captured the phenotypic and molecular diversity among 91 accessions.

The study led to the clear differentiation of 'Sikkim Primitives' (distributed mainly in Sikkim with a few accessions from neighbouring NEH states) from the rest of the accessions, even within Sikkim. Eight 'pools', including

three based on promising NEH and non-NEH accessions (for yield traits) and five 'Specialty corn' pools (including baby corn, pop corn, and high carotenoid) were constituted (presently in C_3/C_4 stage).

5.4.3.2 Analysis of genetic structure of diverse maize inbred lines in India

A detailed analysis of genetic structure in a panel of 69 maize inbred lines, including 58 lines developed under the All-India Coordinated Maize Improvement Project (since 1960s) and 11 genotypes from CIMMYT, was undertaken using microsatellite marker dataset. The inbred lines were subdivided into five genetic clusters (highly congruent with the pedigree data) using a model-based approach with the software package STRUCTURE; some inbred lines showed high genetic sub-structure.

To aid the breeders in choosing a diverse and representative collection, a 'core set' of inbred lines that captured the maximal SSR allelic diversity was identified. This is the first study in India providing a comprehensive understanding of the genetic sub-structure within maize inbred lines that have been used by various breeding programmes across the country.

5.4.3.3 Allele mining in important genes controlling prolificacy and nutritional quality in maize

Allele mining for *teosinte branched-1* (*tb1*) gene that controls prolificacy was undertaken on seven genotypes from a panel of 48 genotypes (including 'Sikkim Primitives' and a set of *teosinte* accessions). Preliminary analysis indicated significant nucleotide diversity in the *tb1* alleles of the prolific 'Sikkim Primitives' compared to that in the *tb1* alleles of normal maize.

Allele mining for *Yellow1* (*Y1*) gene influencing carotenoid biosynthesis in the maize endosperm was undertaken on 20 genotypes (in three replicates) from a panel of 48 maize genotypes (including 14 promising lines identified for carotenoid content by CIMMYT, Mexico). Two gene-specific primer pairs for amplifying overlapping target regions of the 5′ UTR of the *Y1* gene were successfully designed, and the PCR-amplified products were purified and sequenced.

5.4.3.4 Molecular marker-assisted breeding for maize improvement

Gene pyramiding. Gene pyramiding for resistance to *Turcicum* leaf blight (TLB) and *Polysora* rust (PR) is being undertaken in eight recurrent parents (CM137, CM138, CM139, CM140, CM145, CM212, CM150, CM151).

Evaluation of disease reaction responses of BC_2F_1 at UAS-ARS, Nagenahalli (against TLB and PR) and VPKAS, Almora (against TLB) during *kharif* 2007 led to the identification of highly promising genotypes. These were simultaneously screened using molecular markers, and selected plants were selfed to generate BC_2F_2 families.

Promising BC_2F_2 progenies are being advanced to BC_2F_3 at the Maize Winter Nursery, Hyderabad (*rabi* 2007-08) after MAS, for fixation of resistance genes

Marker assisted transfer of opaque2. The objective of the project was to transfer of *opaque2* (*o2*) gene into the six inbred lines (CM137, CM138, CM139, CM140, CM150, CM151) through molecular marker-assisted backcrossing, coupled with phenotypic selection for endosperm modifiers.

MAS (both foreground and background selections using SSR markers) was undertaken on BC_2F_1 populations, and BC_2F_2 progenies were generated during *kharif* 2007 at IARI, New Delhi.

Besides phenotypic selection for the recurrent parent phenotype, biochemical analysis of the BC_2F_2 progenies was also undertaken; the results clearly revealed the nutritional superiority (3-5-fold improvement in tryptophan content) in the lines generated.

MAS for *o2/o2* homozygotes was undertaken on BC_2F_2 progenies during *rabi* 2007-08 (Maize Winter Nursery, Hyderabad) and the identified plants were selfed for deriving BC_2F_3 lines.

Transgenics in crop plants. Analysis of drought stress responses of 24 selected CIMMYT-DTP inbred lines was undertaken during *kharif* 2007 at DMR rain-out shelter, New Delhi, leading to the identification of promising drought tolerant genotypes.

RNA isolations were done from different tissues (silk, ear leaf and tassel leaf) of five genotypes from 'control' and 'drought stress blocks' during *kharif* 2007 at IARI, New Delhi. The experiment was repeated at ICRISAT, Hyderabad, during *rabi* 2007-08. The isolated RNA is being used for transcriptome profiling using maize gene chips.

In silico mining of 40,083 drought stress responsive maize ESTs in GenBank database led to the identification of 1162 EST-SSR markers. The EST sequences were further clustered to reduce redundancy, and consensus sequences were identified through sequence cleaning, repeat masking, vector masking and organelle masking. The consensus sequences were then sorted out based on the microsatellite

repeat motif and sequence length, and primers were designed for an initial set of ~70 EST-SSRs**.**

Transcriptome profiling for downy mildew stress resistance in maize was undertaken for NAI 116, a highly resistant maize inbred line using maize gene chips; for this, RNA was isolated from a field experiment undertaken at UAS-RRS, Mandya during *kharif* 2007.

Allele mining is being undertaken for several genes, including *tb1*, *Y1* and *su1*, which includes both phenotyping for specific target traits and sequencing of PCR-amplified alleles for SNP/haplotype detection.

Characterization of global maize populations: Tracking the maize migration routes from the centre of origin. Molecular characterization of the 288 global maize landraces (including accessions of the wild relative of maize, teosintes) were completed using five fluorescent-labelled microsatellite/SSR markers (*phi076*, *phi075*, *phi299852*, *phi014* and *umc2047*).

The study has led to the identification of several unique alleles among the Indian maize landraces as compared to those among populations/landraces from other Asian countries.

Teosinte is the closest related species of maize and includes maize's progenitor, *Zea mays ssp. parviglumus*.

Maize biofortification. For analysis of kernel micronutrients (Fe and Zn) content, a set of 60 maize genotypes was evaluated at IARI, New Delhi, during *kharif* 2007. Data analyses (for kernel Fe and Zn), led to the identification of a set of highly promising maize genotypes (including HP 2, BAJIM 19, V 336, IML 119, IML 288, IML 434 and IML 467).

Twenty-four phenotypically contrasting inbred lines were analysed using 40 microsatellite/SSR markers covering the maize genome leading to the detection of 178 SSR alleles, at an average of 4.45 alleles per locus. The SSR analysis aided in the selection of specific crosses for generation of different mapping populations for undertaking QTL mapping of kernel Fe and Zn concentrations in maize.

Determining EDVs in maize. Twenty-one maize lines, including different initial varieties (IVs), putative essentially derived varieties (EDVs) and independently derived checks, were genotyped using 40 fluorecent-labelled SSR markers (with allele resolution using MegaBACE DNA Sequencer 1000) during the reported period. The data will be statistically analyzed for determination of thresholds for ascertaining EDVs in maize.

5.4.3.5 Molecular breeding for crop improvement in maize

Three promising NEH and non-NEH pools were constituted and advanced to Cycle 4 during *rabi* 2007-08 from a set of landrace accessions of these regions, through multi-location trials during 2006-2007.

NEH semi-flint pool (Cycle 3) (left), and representative ears (right)

Five specialty corn pools of baby corn, popcorn and high carotenoid genotypes were advanced to Cycle 3 during *rabi* 2007-08 at the Winter Maize Nursery, Hyderabad. Two baby corn pools, one of early maturity and the other of full-season maturity group, are presently in Cycle 3. Also, one highly promising pop corn pool and two high carotenoid pools are at Cycle 3/Cycle 4.

Non-NEH high carotenoid pool (Cycle 3) and selected ears from the pool

Synthesis of a set of specialty corn inbred lines (S3) was also undertaken during the reported period. Eleven promising pop corn inbred lines, four baby corn and five high carotenoid inbred lines were identified during *rabi* 2007-08. These are being advanced. A set of other specialty corn inbred lines (S2) was also advanced during *kharif* 2007.

A set of promising baby corn, pop corn, high carotenoid, sugary inbred lines/populations and QPM genotypes obtained from CIMMYT, Mexico and different breeding centres in India for utilization in the breeding programmes were maintained.

Field views of a pop corn inbred, white seeded baby corn inbred, and an yellow seeded baby corn inbred (left to right)

5.4.3.6 Fingerprinting and molecular diversity analysis

Sixteen popular inbred lines, 8 released and 8 experimental, were analyzed using 24 microsatellites or Simple Sequence Repeats (SSR) markers. The study revealed 28 rare alleles, out of which 9 were unique to some of the inbred lines. The average polymorphism information content (PIC) and discrimination rate (DR) were 0.39 and 0.61, respectively. Genetic similarity expressed as Jaccard's coefficient varied from 0.23 to 0.68 with an average of 0.41. Cluster analysis using unweighted pair group method with arithmetic averages (UPGMA) suggested five clusters. All the genotypes studied could be clearly distinguished with a minimum set of three markers with high PIC and DR.

5.4.3.7 Efforts towards characterization, utilization and introgression of sweet corn trait

Development of experimental hybrids involving 12 sweet corn parental lines was initiated involving parental lines with wider genetic base, including from the crosses between normal x sweet corn combinations. The introgression of sweetness trait into elite field corn inbred lines was taken up in a total of 32 crosses from four sources of sweet corn.

5.4.3.8 Characterization and transfer of disease resistance

Banded leaf and sheath blight (BLSB). On the basis of multiple screening against BLSB pathogen, seven maize inbred lines showing a range of response from 2.5 to 4.5 in a rating of 1-5 were identified.

5.4.3.9 Screening and genetic analysis against biotic stresses

Response of different maize genotypes and their crosses was analyzed against BLSB (banded leaf and sheath blight) under artificial inoculation conditions. Eight elite parental lines were crossed with the registered genetic stocks carrying resistance to MLB (*Maydis* leaf blight) for the purpose of introgression of resistance.

5.4.4 Pearl millet

5.4.4.1 Screening of pearl millet inbreds for nutritional quality (zinc and iron)

Forty-five inbred lines, namely, PPMI 162, PPMI 190, PPMI 295, PPMI 338, PPMI 362, PPMI 479, PPMI 484, PPMI 493, PPMI 560, PPMI 572, PPMI 575, PPMI 603, PPMI 605, PPMI 641, PPMI 653, PPMI 654, PPMI 657, PPMI 712, PPMI 721, PPMI 739, PPMI 741, PPMI 752, PPMI 761, PPMI 767, PPMI 801, PPMI 807, PPMI 808, PPMI 809, PPMI 812, PPMI 823, PPMI 834, PPMI 845, PPMI 862, PPMI 872, PPMI 893, PPMI 981, PPMI 983, PPMI 989, PPMI 990, PPMI 992, PPMI 994, PPMI 997, PPMI 999, PPMI 1000 and PPMI 1003 which showed high zinc and iron contents during 2006 were again evaluated for these traits during 2007.

Fourteen lines, namely, PPMI 295,PPMI 493,PPMI 560, PPMI 575,PPMI 603, PPMI 605,PPMI 641,PPMI 739,PPMI 761,PPMI 767,PPMI 823,PPMI 994,PPMI 997 and PPMI 999 showed higher iron content (range 1.117 ppm to 1.791 ppm).

Another fourteen lines, namely, PPMI 295, PPMI 575, PPMI 657, PPMI 712, PPMI 761, PPMI 767, PPMI 845, PPMI 872, PPMI 981, PPMI 983, PPMI 994, PPMI 997, PPMI 999 and PPMI 1003 exhibited higher zinc content (range 0.673 ppm to 1.111 ppm).

Seven other lines, namely, PPMI 295, PPMI 575, PPMI 761, PPMI 767, PPMI 994, PPMI 997 and PPMI 999 showed higher iron and zinc contents. These seven lines would be utilized in the breeding programme and also to develop mapping population for molecular breeding.

5.4.5 Chickpea

5.4.5.1 Development of a molecular marker based linkage map of chickpea

F_3 population of the cross BGD 112 x FLIP 90-166 was grown at IARI, New Delhi main campus. The data for seven qualitative and quantitative characters were recorded for the F_3 generation of the populations BGD 112 x Flip 90- 166. The data indicated the presence of a considerable amount of genetic variation in the population that is being used for the development of RILs. Such populations are

highly suitable for linkage map construction. F_4 generation was grown at IARI regional Centre, Dharwad (Karnataka) for its off-season advancement. F_5 population of this cross is being grown at New Delhi main campus. Parental polymorphism analysis has provided 18 polymorphic STMS markers.

5.4.5.2 Evaluation of candidate genes for drought tolerance in chickpea

The progress of work is shown as under:

- Concentration of EMS and protocol for EMS treatment for development of TILLING population were standardized.
- ICC 4958 was treated with 0.2% EMS as per the standardized protocol and M1 was sown in the field. Quitea lot of leaf mutants were seen in the field indicating the soundness of EMS treatment.
- Observations on leaf morphology, flowering time, etc. are being taken up
- The parents of the population developed are being screened for RWC, MSI, SLW.
- F_5 generation of the mapping population SBD 377 x BGD 112 are being grown in the field.
- The parents of this population are being screened with 750 primers sent by ICRISAT.

5.4.5.3 Molecular studies

DNA isolation and other microbial biotechnological aspects related to the BNF traits are being carried out at NRCPB. *Rhizobacteria* were collected from root nodules of 99 different samples belonging to parents and mutant types of eight varieties. RAPD marker analysis with the genomic DNA of these bacteria identified variation at genomic level of the *Rhizobacteria*.

5.4.5.4 Basic studies

Forty-seven recombinant lines of chickpea were isolated for different morphological traits (double pods, double compound leaves, etc.) in *desi* and *Kabuli* background from F_5 generation and grown for further evaluation. Similarly, 116 recombinant plants were isolated from F_3 and F_4 generation hybridized materials and sown in *rabi* 2007-08 for further evaluation.

5.4.6 Lentil and Fieldpea

5.4.6.1 Genetic studies in lentil and fieldpea

To generate mapping population for wilt and rust resistance, seed size and maturity duration crosses were made. F_1s will be raised in offseason for advancing the generation. To identify new genes, lentil varieties L 4076 and L 4147 were exposed to 35 kr. Inheritance of yield and related agronomic traits (using Joint Scaling test) in fieldpea was also initiated along with molecular characterization of *Pisum* species by RAPD and SSR markers.

5.4.7 Pigeonpea

5.4.7.1 Breeding for 'A', 'B' and 'R' lines

Four 'A' lines (Pusa 33A, Pusa 2008 A, GPL 100A and GPL 290A) with sterile cytoplasm from GT 288A were maintained. Two 'A' lines (Pusa 9 and Pusa 855) of BC_3 stage were backcrossed for BC_4 stage and two varieties (Pusa 992 and Pusa 991) were advanced to BC_1 stage. Two 'A' lines ICPA-2089A and ICPA-2039A were crossed with early group of genotypes for diversification. In order to develop additional sources of CMS and restorer lines, 310 F_5 progenies of inter-specific cross *C. scarabaeoides* x Pusa 33 were screened for male sterility. Crosses between male fertile and male sterile F_4 genotypes were evaluated. Maintainer genotypes for male sterile genotypes were identified.

5.4.7.2 Evaluation of bold seeded progenies

Forty-three bold seeded (100 seed weight > 9 g) F_5 progenies of inter-specific cross *C. scarabaeoides* x Pusa 33 were evaluated along with 2 checks (Pusa 991 and Pusa 855) in RBD with 2 replications in order to identify restorer genotypes. Bold seeded entries with earliness, erect compact plant type, more primary branches and high yield were identified.

5.4.7.3 Population improvement approach

Single plant progenies of superior recombinants (having semi-determinate growth habit with medium dwarfness and indeterminate growth habit with high basal branching), selected from the fixed population developed through population improvement programme, were evaluated and genotypes with more number of primary branches, earliness, compact plant type, bold seededness and dwarf stature were selected.

5.4.7.4 Wide hybridization in pigeonpea

Wide hybridization study has outlined crossability barriers as non-coincidence of flowering and pre zygotic in crosses with no success in seed formation, and compatibility barriers as post zygotic may be associated with seed development and seed viability, F_1s sterility related to no floral induction and pollen sterility.

Parental wild species involved in wide hybridization were identified as morphologically and genetically diverse genetic stocks based on desirable morphological traits and biochemical parameters of nutritive value, e.g., high seed protein content of >25% (ICP 15603 of *C. acutifolius* and ICP 15685 of *C. scarabaeoides*). Wide variations were observed in banding patterns of total seed proteins (tris soluble) using SDS-PAGE with number of bands resolved ranging from 5 to 10 in wild species and to 10 in cultivated species, with different Rm values, forming one cluster with exceptions of *C. platycarpus* (ICP 15665 and ICP 15670) based on UPGMA analysis. Three parental accessions of *C. scarabaeoides* (ICP 15685, ICP 15692 and ICP 15707) analysed further for another molecular marker, esterase isozymes, resolved a range of number of bands from 3 to 5 with different Rm values, forming one cluster based on similarity values using similarity matching coefficients.

5.4.8 Genes from Landraces to Improve Grain Yield and Other Traits in Cowpea

Landraces are genetically diverse populations adapted to the local environment that provide unique variability for crop improvement programmes. DWDCC 016 (a landrace) is an identified source for more number of pods per peduncle (1 to 6) and high seed index (1.2 to 1.3) for which not much variability exists in the world collection. It was utilized to improve C 152, the most popular cowpea variety in India. Evaluation of tansgressive segregants in F_6 showed that the landrace contained genes capable of improving grain yield, pods per peduncle, seed index, seed size and rust resistance. Some of them out yielded both the parents and standard cultivars.

5.4.9 *Brassicas*

5.4.9.1 Identification of informative markers

Fingerprinting of ten parental lines of *Brassica juncea* was carried out and genotyping was performed on a subset of three F_2 populations, corresponding to a total of 500 F_2 individual plants.

A total of 100 RAPD primers and 48 SSR primer pairs were used to screen polymorphisms between parental stocks and F_2 bulks. The parental genotypes of *Brassica juncea* were fingerprinted. Parental polymorphism was found to be high with 97% primers generating reproducible and easily recognizable bands. One marker by RAPD primer S2083 discriminated between the parental pairs and in the progeny of the cross between Bio YSR (R) and Bio 902 (S).

More than 90% of the SSR markers successfully amplified the corresponding microsatellite regions in *Brassica juncea.* Some SSR primer pairs so far located on *B. rapa* as well as *Brassica nigra* have a high potential for the development of DNA markers that could contribute to the genetic analysis of other *Brassica juncea* and other Cruciferae. Genotyping of parental and F_2 population with 48 SSR primer pairs yielded two putative markers BRMS 001 and BRMS 006 in the progeny of the cross between Bio YSR and Laxmi. Analysis of the bulk revealed the presence of both heterozygous and homozygous individuals in the components of the bulk with about 20% recombination frequency in the F_2 progenies.

White rust resistance, a trait known to be governed by a single dominant gene can be effectively mobilized through the molecular breeding programmes using these three markers,i.e., RAPDS 2083, SSRBRMS 001, BRMS 006 and BN9A.

5.4.9.2 Mapping and marker assisted selection for new genes for resistance to white rust (*Albugo candida*) in Indian mustard

The following mapping populations involving one exotic and two indigenous sources of resistance were developed:

Varuna x BEC 144 (Exotic resistant source), Varuna x Bio YSR (Indigenous resistant source), Varuna x RC 781 (Indigenous resistant source); and Bio-902 x BEC 144 (Exotic resistant source), and Bio-902 x Bio YSR (Indigenous resistant source) Bio-902 x RC 781 (Indigenous resistant source).

The backcrosses of above crosses were attempted and the F_1s selfed to advance them to F_2. More SSR and RAPD markers are being used for the polymorphic studies.

5.4.10 Cotton

5.4.10.1 Screening of material for *Cotton leaf curl virus* (CLCV)

Twenty-six progenies of the variety Pusa 8-6 were evaluated for cotton leaf curl virus disease using RS 9 and

RS 921 as infector lines. Three progenies P16-6, P 40-3 and P 67-3 were found from CLCuV. Five progenies, namely, P 22-3, P 34-3, P 40-1, P 40-5 and P 55-1 showed 1 to 3 infected plants out of 20 plants.

5.4.11 Diversity Analysis in Mustard and Soybean

5.4.11.1 Diversity analysis

A strategy for the selection of diversity from the populations was standardized for soybean and *Brassica* based on 270 accessions of soybean and 268 of *Brassica* germplasm. For developing and verifying the strategy, 11 quantitative descriptors for soybean and 12 descriptors for *Brassica* were included in the study. The suggested procedure results in higher pooled evenness (diversity) as well as allelic richness in the sample. The diversity efficient procedure is computationally convenient and straight forward for selecting distinct accessions for breeding as well as germplasm core-set formation purposes. The procedure can be easily adopted for large collections as it is convenient to generate clusters using *k – means* clustering method. Selection of entries from the non-hierarchical groups are not optional but logical as the entry with the highest inertia is included in the sample.

5.4.12 *Drosophila melanogaster*

5.4.12.1 Molecular genetic analysis of *stambhA*

Overexpressed DWnt 4 in the background of RF1, AL7. A normal copy of the *DWnt4* sequence was over expressed in the *DWnt4* defective genetic backgrounds of $DWnt4^{AL7}$ and $DWnt4^{RF1}$ under the influence of the transcription factor Gal4. The Gal4 transcription factor was driven by the following promoters:

(i) Heat inducible *hsp70,* (ii) ubiquitous *daughterless* (*da*), and (iii) transcription factor β catenin (*Armadillo)*.

The combinations of *hsp70* Gal4: UAS~*DWnt4*, *da* Gal4: UAS~*DWnt4* were able to correct the defects observed in *AL7* and *RF1*. *arm* Gal4: UAS~*DWnt4* was unable to correct the defect.

Overexpressed DWnt 6 and DWnt10 in other complon 6 members. UAS~*DWnt6* and UAS~*DWnt10* were over expressed using *hsp70* Gal4, *da* Gal4 and *arm* Gal4 drivers in the *DWnt4* (complon 6) alleles RF2, RF3, RF4, HL11, and HL34. Interestingly *Wnt6* and *Wnt10* could rescue the defects of *DWnt4* in all these alleles. This demonstrates that *Wnt6* and *Wnt10* have distinct functions and are not redundant.

Functional analysis of dINO80, a chromatin remodeling protein through P element excision and RNAi mediated gene silencing using transgenic approach. RNA expression pattern of INO80 during embryonic development was studied. A P element insertion into INO80 was obtained from the Bloomington *drosophila* collection. The P element was excised out to generate 2 P excision lethals.

5.5 AGRICULTURAL PHYSICS, REMOTE SENSING AND GIS

5.5.1 Soil Physics

5.5.1.1 Development of soil quality indices for quantification of soil quality under cropping systems and tillage management

The assessment of soil quality for evaluating the sustainability of soil and crop management practices has become one of the important issues. Soil quality indices (SQI) were developed and evaluated for quantifying the changes in soil quality under two different cropping systems, viz., maize-wheat and rice-wheat, and two tillage practices in each cropping system. Twelve soil indicators consisting of five soil physical indicators, namely, bulk density, total porosity, mean weight diameter, available water capacity and saturated hydraulic conductivity, five soil chemical indicators, namely, pH, EC, soil nitrate-N, soil ammonium-N and organic carbon, and two soil biological indicators, namely, microbial biomass carbon and dehydrogenase activity, were measured which constituted the minimum data set for estimation of SQI. A total of eight indices were determined for all the treatments, which were Linear Simple Additive SQI (LSASQI), Linear Weighted Additive SQI (LWASQI), Linear Simple Multiplicative SQI (LSMSQI), Linear Weighted Multiplicative SQI (LWMSQI) (for linear approach) and Non-Linear Simple Additive SQI (NLSASQI), Non-Linear Weighted Additive SQI (NLWASQI), Non-Linear Simple Multiplicative SQI (NLSMSQI), and Non-Linear Weighted Multiplicative SQI (NLWMSQI) (for non-linear approach).

Comparison of eight indices for cropping systems

	LSASQI	LWASQI	LSMSQI	LWMSQI	NLSASQI	NLWASQI	NLSMSQI	NLWMSQI
M-W	60.19	3.36	36.42	91.83	64.13	11.47	38.04	91.68
R-W	49.69	0.98	28.40	82.77	51.80	8.8	29.16	82.35
CV	13.5	77.5	17.5	7.3	15.0	18.6	18.7	7.5
% Change	17.4	70.8	22.0	9.9	19.2	23.3	23.4	10.2
	Significant	Significant	Significant	Significant	Significant	Significant	Significant	Significant

Among all the eight indices developed, the 'Linear Weighted Additive Soil Quality Index (LWASQI)' showed maximum sensitivity to represent soil quality changes due to cropping systems. LWASQI is also most responsive to soil quality changes due to tillage practices of conventional planting and bed planting in M-W and puddling and non-puddling in R-W cropping systems. The investigations with measured values indicate that the degree of sensitivity to reflect soil quality changes was higher in Linear than in Non-linear approach for all the treatments.

5.5.1.2 Mapping of soil physical properties for assessing cropping sequences by the use of crop simulation technique in GIS environment

Soil physical properties, namely, moisture content, bulk density (BD), hydraulic conductivity (HC) and available water capacity (AWC) were mapped on grid basis in the farmers' fields of Shikohpur watershed. Bulk density, saturated hydraulic conductivity and moisture contents at 0.1 bar, 0.3 bar, 0.5 bar, 1 bar, 5 bar and 15 bar were determined for three depth layers (0-15 cm, 15-30 cm and 30-60 cm) for each of the 26 grids of the study area. It was found that the average value of BD of soil of Shikohpur watershed significantly varied from 1.54 Mg m^{-3} to 1.60 Mg m^{-3} between surface layer (0-15 cm) and lower layer (30-60 cm). A significant variation of 20 per cent was found in the HC of surface layer and lower layer, and for available water capacity, no difference was observed at different depths. Spatially, all the properties varied significantly. Yields of crops grown in the watershed were simulated for each grid with these soil properties as inputs and yield maps were prepared for the study area. These yield maps were able to identify the areas producing low yields due to spatial variability in the soil physical properties.

5.5.1.3 Soil hydrothermal regimes and root growth under conventional, bed planted wheat and mustard

A field study was conducted to monitor the soil hydrothermal environment under bed and conventionally planted wheat and mustard crops. Temperatures at 0 cm, 5 cm, 10 cm, 15 cm and 20 cm depth were observed at hourly interval from 10 A.M. to 7 P.M. for variable soil water contents, aerial temperatures and relative humidity (RH) conditions. The results revealed that for similar frequency of irrigation, soil water content (SWC, w/w) of 0-20 cm of soil under bed was always lower by 2-3% after irrigation (SWC>10%) and temperatures were higher by 2-3 °C, but the differences in SWC and temperatures reduced to 0.5% and 1-2 °C, respectively, for drier soil (SWC<4%). Depending on atmospheric conditions, soil temperature peak arrived between 2 to 3 P.M. at surface, whereas the time of arrival of peaks at 5 cm, 10 cm and 15 cm depended on soil water status and varied between 3 and 4 P.M., 4.30 and 5.30 P.M. and 5.30 and 6.30 P.M., respectively. For drier soils, the peak of soil temperature wave at bed surface was higher than aerial maximum by 1-2 °C. However, under high RH and high SWC, it became lower than aerial maximum by 2-3 °C. Computation of thermal parameters of heat transport equation showed that most of the time, thermal diffusivity, thermal conductivity and heat capacity values were lower and hence damping depth was also less under bed than under conventional system.

Computed thermal parameters were used for simulating diurnal soil temperature fluctuations under both systems by solving heat transport equation by using the finite difference method. Simulated and observed data showed close agreement.

5.5.1.4 Pedotransfer functions for soil penetration resistance

Pedotransfer functions for soil penetration resistance were developed for soils belonging to soil orders, inceptisol and alfisol. Results suggested that at lower SWC, for most bulk densities, penetration resistance (PR) was higher under alfisol than under inceptisol but the trend was reversed at relatively higher SWC. The higher PR at lower SWC in alfisols was mainly due to hardsetting behaviour of red Chalka soils. For both soil types, value of SWC at 2MPa soil strength (lower limit of LLWR/water availability) at maturity (i.e., at higher compaction level) increased by 4-5% in comparison to its value at the initial stage with less compaction.

5.5.1.5 Effect of tillage and residue management on soil and plant in maize-mustard system

Field experiments were carried out on a sandy loam soil (*Typic Haplustept*) in semi-arid region of India to evaluate the effect of tillage (conventional and zero) and residue management (incorporation/retention/removal) on soil physical properties vis-à-vis plant growth in maize-mustard cropping system. Residue incorporation significantly (*P=0.01*) lowered the bulk density of surface (0-0.15 m) soil layer. Zero tillage with residue retention recorded significantly higher soil organic carbon (SOC) and microbial biomass carbon (MBC) and also significantly greater mean weight and geometric mean diameter of soil aggregates. Though a compact zone between 0.3 m and 0.4 m in the profile was observed in all the plots, residue incorporation reduced the soil resistance to penetration at surface (0-0.15 m). Zero tillage resulted in higher infiltration rates, both at initial and steady state. Emergence rates of seedlings were faster in zero tilled plots without residue for both maize and mustard crops, but the quick emergence could not be effectively transformed in producing more biomass or yield. However, increase in leaf area was faster under conventionally tilled plots with residue incorporation, and the peak leaf area index was also the maximum. Biomass at maturity differed significantly between conventional and zero tillage, but no difference was observed between residue management practices within same tillage system. Root weight density in maize was significantly higher in conventional tillage with residue incorporation, though at deeper depths, the differences were mostly insignificant. In mustard also, maximum root biomass was obtained under conventional tillage with residue incorporation. Although zero tillage optimized water use by both maize and mustard in comparison with conventional tillage, maximum water use efficiency was obtained in conventional tillage with residue incorporation, mainly because of maximum yield obtained under the treatment.

5.5.1.6 Effect of mulching on soil and plant water status, growth and yield in wheat (*Triticum aestivum* L.) in a semi-arid environment

Field experiments were conducted during winter seasons in a sandy loam soil to evaluate the soil and plant water status in wheat under synthetic (transparent and black polyethylene) and organic (rice husk) mulches with limited irrigation practices as against adequate irrigation with no mulch (conventional practices by the farmers). Though all the mulch treatments improved the soil moisture status, rice husk was found to be better in maintaining the optimum soil moisture condition for use by the crop. The residual soil moisture was also minimum, indicating effective utilization of moisture by the crop under rice husk. The plant water status, as evaluated by relative water content and water potential of the leaves was found to be more favourable under the rice husk mulch. Specific leaf weight, root length density and dry biomass were also higher with rice husk. Optimum soil and canopy thermal environment of wheat with limited fluctuations were observed under rice husk, even during dry periods. This also produced comparable yield with less water use, enhancing the water use efficiency. Therefore, under limited irrigation condition, rice husk mulching will be beneficial for wheat as it is able to maintain better soil and plant water status, leading to higher grain yield and enhanced water use efficiency.

5.5.1.7 Pedotransfer functions for predicting the hydraulic properties of Indian soils

Most of the data pertaining to Indian soils, is limited to only the major soil separates, viz., sand, silt and clay. Therefore, an attempt was made to explore the possibilities of using these parameters to relate to the hydraulic characteristics of the soils of India. The final or steady state infiltration rate, which is mainly profile controlled, showed power function relationship with minimum and average clay content in the soil profile. The saturated hydraulic conductivity also showed similar relationship with silt+clay content. The soil water content at a given suction could be satisfactorily predicted using per cent of major soil separates, sand, silt and clay. The coefficients in the soil water function $\psi(\theta)$ were linearly related to the sand content of soil. Non-linear regression equations were developed to predict these coefficients using sand and clay per cent of soils. The equations prove to be quite satisfactory for a wide range of textures and provide reasonably accurate estimates of the soil water characteristic curve with a minimum of readily available data set.

5.5.1.8 Canopy hydro-thermal environment of wheat under long-term fertilization

A field experiment was conducted under long-term fertility trial in a sandy loam (Typic Halpustept) soil at IARI during *rabi* with wheat (cultivar HD 2329). Treatments were 50% NPK (T_1), 100% NPK (T_2), 150% NPK (T_3), 100% NPK + FYM @ 15 t ha^{-1} yr^{-1} (T_4), and control (T_5). Cumulative stress degree day (ΣSDD) was computed from canopy air temperature difference (CATD). Considerable higher transpiration rate was recorded with 100% NPK along with application of FYM @ 15 t ha^{-1} yr^{-1} compared to that of control, which also increased with crop growth. It increased from 4.5 µg cm^{-2} sec^{-1} to 13.6 µg cm^{-2} sec^{-1} in T_4 and 2.6 µg cm^{-2} sec^{-1} to 8.6 µg cm^{-2} sec^{-1} in control during growing season, leading to significant higher grain (5.48 t ha^{-1}) and straw (4.79 t ha^{-1}) yields in T_4 compared to those of control. At flowering stage, significantly lower CATD (-6.5 °C) was observed in T_4 compared to that in other treatments, which might be due to that in higher transpirational cooling. A linear relationship was found between CATD and transpiration rate at different growth stages, which was poor at initial stages, but at fully developed canopy significantly higher inverse relationship (r = -0.82) was found. A negative correlation (r = -0.76) was found between ΣSDD and grain yield of wheat. From this study, it can be concluded that remote sensing can be used as a potential tool for assessing leaf water status and yield of wheat.

5.5.2 Remote Sensing and GIS

5.5.2.1 Identifying potential zones for adoption of resource conserving technologies

Mau district of Uttar Pradesh and Patna district of Bihar were taken for identifying potential zones of RCTs. These districts, which have inherent problems of salinity, waterlogging and flood, were found to be the potential area for optimizing the agricultural land use through Resource Conserving Technologies. Time series multispectral remote sensing satellite data could be used to characterize the areas. Late harvested rice followed by fallow or late sown crop in both the districts, saline areas in Mau district, and excessive moisture and flood in Patna district could be characterized through remote sensing data analysis, thereby identifying potential zones for adoption of different RCTs.

5.5.2.2 Land use cover change analysis with multi-temporal remote sensing data

In India, cities are usually surrounded by agricultural area, and changes, in particular, are harmful when urban expansion occurs against surrounding agricultural areas. In the National Capital Territory of Delhi, urban expansion has been rapid at the cost of highly productive agricultural lands in its surroundings. Satellite remote sensing has been found to be a potential tool for quantification of such change in spatial-temporal scale. Land use cover change analysis of the NCR-Delhi was done using satellite data of 1977 and 2001, respectively, and different change detection techniques were evaluated. Spectral change detection techniques, except multi-date principal component (PC) can be used for identifying the temporal direction of changes. But they could not help find the type of land use change, for which post classification methods were found to be useful. Result of multi-date principal component analysis approach was comparable to that of direct multi-date classification approach. The major changing classes were built up area, vegetation (crop), and bare lands. There was 59.98% of growth in built-up area at the cost of vegetation (crop)/agriculture lands and bare lands.

5.5.3 Agricultural Meteorology

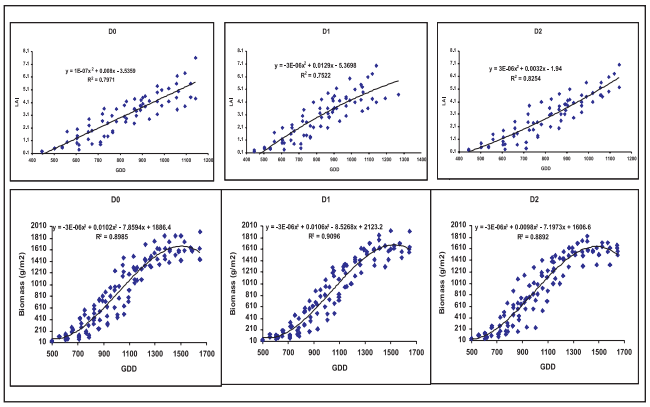
5.5.3.1 Modification in micro-meteorology of *Brassica* through de-branching and its effect on crop growth parameters

The de-branching in two *Brassica* varieties Pusa Jaikisan and Bio-169-96 facilitated higher radiation penetration to the ground which resulted in reducing the chances of occurrence of white rust and *Alternaria* blight diseases to a considerable extent. Apart from this beneficial effect, it was also observed that the radiation use efficiency, water use efficiency and heat use efficiency in the de-branched plots were relatively higher as compared to those of the control plots. The leaf area index in Bio-169-96 was observed to be higher than that of Pusa Jaikisan irrespective of the treatment. Moreover, the leaf area index in the de-branched plots was found to be marginally higher than that of the control plots.

Effect of debranching on ground shading inhibiting the radiation penetration to the ground level (left: control, right:debranched plots)

5.5.3.2 Assessing the leaf area index and biomass production in mustard varieties by the use of thermal time

Based on the field experiments with two *Brassica* varieties (Pusa Jaikisan and Bio-169-96), thermal response curves were developed using thermal time as a base. The best-fit polynomial second order regression equations were developed taking LAI as a dependable variable with the thermal time, viz., growing degree days (GDD) as an independent variable. The growing degree days could explain 96% to 99% variation in LAI in different treatments in Pusa Jaikisan and Bio-169-96 in October 15 sowings and 95% to 98% in October 30 sowing. When the 2006-07 season data were pooled with the previous crop season data (two varieties and two seasons), the correlation coefficients were highly significant (at 1 per cent). Hence, the regression equations were developed which will be of immense use in assessing the leaf area index by the use of the thermal time, without destroying the plant samples. Similarly, by the use of thermal response curves of biomass production, regression equations were developed to assess the biomass production at different intervals of time, without destroying the plants. However, caution is required when the data over varieties are pooled, as they might lead to considerable errors. It would be worthwhile to develop equations, which are variety and location specific. These types of quantitative relationships would go a long way in dynamic crop simulation modeling studies.



Thermal response curves: (top) for leaf area index (LAI), and (bottom) for biomass in mustard under control(D0), and debranched at 50 DAS(D1) and at 60 DAS(D2)

5.6 PHYTOTRON FACILITY

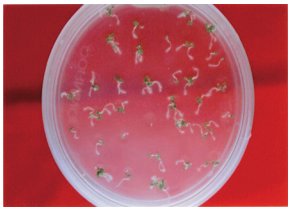
The studies conducted at the National Phytotron Facility during the year are listed below:

Studies conducted at the National Phytotron Facility

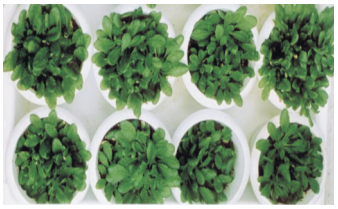
Sl. No.	Topic
1.	Crossing work in soybean between poor storer and good storer (Division of Seed Science & Technology)
2.	Study of water logging tolerance in greengram genotypes (Division of Plant Physiology)
3.	Pathogencity test of *R. solani* isolates on rice plants (Division of Plant Pathology)
4.	Aluminum organic acids interaction in rice rhizosphere in acid soil (Division of Soil Science & Agricultural Chemistry)
5.	Interaction among plant pathogen and bio-control agents in pigeonpea (Division of Microbiology)
6.	Drought tolerance studies in wheat (NRC on Plant Biotechnology)
7.	Genetical and molecular analyses of new plant type wheat for yield components and grain quality (Division of Genetics)
8.	Gene pyramiding for resistance to leaf stripe rust in wheat (Division of Genetics)
9.	Suitability of environmental conditions for growing *petunia* healthy seedlings (Landscape Development Pvt.)
10.	Transgenic mustard for abiotic stress (NRC on Plant Biotechnology)
11.	Transgenic in crops – Drought tolerance in tomato (NRC on Plant Biotechnology)
12.	Physiological and biochemical bases of heat tolerance in chickpea genotypes (Division of Plant Physiology)
13.	Temperature dependent regulation of oleate desaturase gene from *Brassica juncea* (Division of Biochemistry)
14.	Raised nursery of transgenic tomato for field trail (NRC on Plant Biotechnology)
15.	Transgenic tomato plants (T_0) Bt gene for seed collection (NRC on Plant Biotechnology)

16.	Functional genomics for chickpea – for drought screening (NRC on Plant Biotechnology)
17.	Evaluation of transgenic cucumber lines against CMV-CP virus (Division of Plant Pathology)
18.	Agroinoculation of tomato leaf curl virus clones on *N. benthaminana* and tomato (Centre for Virology)
19.	Transgenic tomato for post harvest (NRC on Plant Biotechnology)
20.	Molecular characterization of Indian wheat germplasms for quality (Division of Genetics)
21.	Transgenic cotton (cocker 310 F12) with *Cry 1Ac* gene for resistance to *H. armigera* (Delhi University, South Campus)
22.	Growing T_1 plants of transgenic brinjal (var. PPL)with Bt gene for insect resistance (NRC on Plant Biotechnology)
23.	Whole genome characterization of Indian *Citrus ring spot virus* (Division of Plant Pathology)
24.	Growing of break fern for phytoremediation of contaminated soil (Division of Soil Science & Agricultural Chemistry)
25.	Functional genomics of chickpea – NFBSRA Project (NRC on Plant Biotechnology)
26.	Effect of Arbuscular Mycorrhiza Fungi and water stress in citrus (Division of Fruits & Horticultural Technology)
27.	Screening of wheat genotypes for phosphorus use efficiency (Division of Plant Physiology)
28.	Biofortification of wheat land races by molecular and conventional plant breeding methods (Division of Genetics)
29.	Evaluation of PGPR-*Cyanobacteria* for wheat and paddy crops (Division of Microbiology)
30.	Marker assisted selection for seedling and adult plant leaf rust resistance in wheat (National Phytotron Facility)
31.	Study on heat stress in *Chenopodium album* (Water Technology Centre)
32.	Inheritance and mapping of disease resistance genes in lentil (Division of Genetics)
33.	Use of molecular markers in wheat quality breeding (CCS University, Meerut)
34.	Study of drought resistance in wheat (WL 711 x C 306) RILs (Water Technology Centre)
35.	Grown T_0 plant of Bt transgenic tomato cv. Pusa Ruby (NRC on Plant Biotechnology)
36.	Development of transgenic maize for stem borer resistance (Directorate of Maize Research)
37.	Physiological and biochemical bases of high temperature tolerance studies in chickpea genotypes (Division of Plant Physiology)
38.	Transferred blast resistant transgenic rice plants from the net-house to Phytotron for molecular and functional analyses (NRC on Plant Biotechnology)
39.	Salt stress study on rice (NRC on Plant Biotechnology)
40.	Pathogenic and molecular variability of *Bipolaris maydis* incitant of *maydis* leaf blight of maize (Division of Plant Pathology)
41.	Rice crossing for F_1 (NPT x PB 1) (NRC on Plant Biotechnology)
42.	Tillering population (N 22) M_2 (NRC on Plant Biotechnology)
43.	Inoculation of bioformulation treated rice seedlings with xoo (Division of Plant Pathology)
44.	Development of pro-vitamin A rich *indica* rice through marker assisted backcross breeding (Division of Genetics)
45.	T_1 generation of tomato cultivar PED, having truncated A-rep gene for tomato leaf curl virus (Division of Plant Pathology)
46.	Identification of promoter location and assessment of promoter strength in *Arabidopsis* (NRC on Plant Biotechnology)
47.	Effect of viral suppressors of RNAi on *Arabidopsis* (Centre for Virology)
48.	Functional analysis of carotenoid biosynthesis genes in tomato (NRC on Plant Biotechnology)
49.	Development of transgenic papaya resistant to spot virus using coat protein gene (Advance Centre for Virology)
50.	Gene pyramiding for multiple biotics stress resistance in crops (wheat) (Division of Genetics)
51.	Physiological experiments in tomato NCPGR, JNU, New Delhi
52.	Characterization and identification of bacterial genes imparting osmo-tolerance and their validation in plants (NRC on Plant Biotechnology)
53.	Mapping of F_2 populations and 21 lines – International Tomato Genome Sequencing Project (NRC on Plant Biotechnology)
54.	Modeling epidemiology of *F. monilifpormae* var. *subglutinans* (Division of Fruits & Horticultural Technology)
55.	Microbial diversity of *Rhizobium* and isolation of genes for symbiosis and biotic resistance (NRC on Plant Biotechnology)
56.	Evaluation of clodinafop, sulfosulfuron and pinoxaden towards cross resistance across *Phalaris minor* Retz. biotypes (Division of Agronomy)
57.	Genetic transformation of wheat for drought tolerance (NRC on Plant Biotechnology)
58.	Screening of transgenic rice plants agains *Magnaportha grisea* (NRC on Plant Biotechnology)
59.	Isolation and characterization of PR genes in *Brassica juncea* against *Alternaria brassicacea* and study of their regulation (NRC on Plant Biotechnology)
60.	Development of procedure and protocol for ascertaining of EDV status of wheat (Division of Genetics)
61.	Transgenic *Arabidopsis* transplanted for tissue specific promoter validation (NRC on Plant Biotechnology)
62.	Temperature dependent regulation of Fad2 gene experssion in *Brassica juncea* (Division of Biochemistry)
63.	Role of signal peptide in aphid resistance of *Brassica* (NRC on Plant Biotechnology)
64.	Effect of silencing of nematode genes on infection on development and reproduction of *Heterodera anenae* - Silencing of nematode genes using RNAi (Division of Nematology)
65.	Evaluation of the salt tolerance mechanism in *Azolla* sp.-*Anabaena* system (CCUBGAC)
66.	Evaluation of fungicidal properties of *Calothrix elukerii* extracts against damping off disease caused by *Pythium apharidermatum* in vegetables (brinjal, chillies and tomato) (Division of Microbiology)
67.	Proteome analysis of heat susceptible and tolerant wheat genotypes (Division of Genetics)
68.	Molecular characterization of tn-5 mutants of *Mesorhizobium ciceri* (NRC on Plant Biotechnology)
69.	Unravelling molecular processes involved in the adventive polyembryony towards genetic engineering for fixation of heterosis – Transfomation of *Arabidopsis thaliana* with promoter trap vector (NRC on Plant Biotechnology)
70.	Senescence: Mechanism in crops in relation to abiotic stress-sink strength and their interaction (Water Technology Centre)

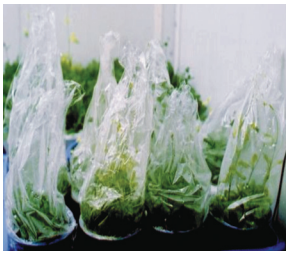
71.	Cloning and characterization of abiotic stress inducible TF gene in rice (NRC on Plant Biotechnology)
72.	Effect of salicylic acid on high temperature stress amelioration on wheat during post flowering period (Division of Plant Physiology)
73.	Genetic analysis of abiotic stress tolerance in *Arabidopsis* (Water Technology Centre)
74.	Double haploid production in wheat (NRC on Plant Biotechnology)
75.	Screening races against 40 A race of stem rust (Division of Genetics)
76.	Treatment for synchronization of flowering in wheat genotypes (Division of Genetics)
77.	Development of abiotic stress tolerant transgenic rice (NRC on Plant Biotechnology)
78.	Testing the packaging material for the storage of *Brocolli* florets (Division of Post Harvest Technology)
79.	Stress treatment at 6 ºC to rice plants (NRC on Plant Biotechnology)
80.	Expression analysis of transcription factors during abiotic stress in wheat (NRC on Plant Biotechnology)
81.	Isolation and characterization of abiotic stress inducible transcription factor (promoters) in response to cold stress in rice (NRC on Plant Biotechnology)
82.	Cloning and characterization of wound inducible promoter from *Arabidopsis thaliana* (NRC on Plant Biotechnology)
83.	Development of mapping population for identification of QTLs – Molecular breeding of PCR based marker for sheath blight resistance gene in rice (NRC on Plant Biotechnology)
84.	Studies on the uptake of K, Co, Na from saline Hoagland solution – Role of SOS pathway in salinity tolerance in wheat (Division of Plant Physiology)
85.	Effect of *Pseudomonas fluroscens* on life cycle of *Meloidogyne incognita* (Division of Nematology)
86.	Genetic transformation studies in pigeonpea with Bt genes (cv. Pusa 855, tall) (NRC on Plant Biotechnology)
87.	Molecular characterization of cryptic root specific promoter isolated from *Arabidopsis thaliana* (NRC on Plant Biotechnology)
88.	Biochemical isolation of defense related signal peptides from rice – Isolation and characterization of defense peptides (Division of Agricultural Chemicals)
89.	Development of transgenic tomatoes for resistance to fruit borer (NRC on Plant Biotechnology)
90.	Molecular characterization of Indian wheat germplasm lines for quality traits – DNA isolation from leaves (Division of Genetics)
91.	Studies on the efficiency of a biocontrol agent against *Fusarium udhum* in *Cajanus cajan* (Division of Microbiology)
92.	Inheritance and mapping of disease resistance genes in lentil – raise F_1 generation (seed to seed) (Division of Genetics)
93.	Multiplication of wild species of lens (Division of Genetics)
94.	Studies on GBNV and TSV on groundnut – Maintenance of GBNV and TSV on cowpea (Division of Plant Pathology)
95.	Comparative molecular analysis of cmds lines of *B. juncea* carrying *D. catholica* cytoplasm – Validation through transgenic expression in *Arabidopsis* (NRC on Plant Biotechnology)
96.	Molecular breeding in wheat improvement (Division of Genetics)
97.	Differential expression profiling and EST development for leaf rust resistance (Division of Genetics)
98.	Infectivity of *Potato apical leaf curl virus* on different hosts (Division of Plant Pathology)
99.	Assessment of genetic vigour between poor and better storers of soybean lines (Division of Seed Science & Technology)



(A)



(B)



(C)

(D)

Development of transgenic *Arabidopsis* through *A. tumefaciens* using floral dip method: (a) Seeds of *Arabidopsis* after 10 days of inoculation on ½ MS, (b) plants of *Arabidopsis* after 30 days of seeds inoculation, (c) plants inoculated with *A. tumefaciens*, and (d) fully matured siliques covered with butter paper

Independent lines of transgenic cotton at the Phytotron facility

6. SOCIAL SCIENCES AND TECHNOLOGY TRANSFER

6.1 AGRICULTURAL ECONOMICS

6.1.1 Adoption and Impact of Resource Conserving Technologies on Farm Economy in Indo-Gangetic Plains of India

Current evidences from various research studies indicate that the growth in rice and wheat yields has started slowing down or stagnating in the high potential agricultural areas of the country. It is, therefore, imperative to now develop and promote alternative technologies that will conserve the much needed and gradually depleting natural resources and also help to maintain a favourable production environment. New resource conserving technologies (RCTs) are being promoted in rice-wheat belt of Indo-Gangetic plains in order to enhance the productivity, profitability and sustainability of rice-wheat cropping system with corresponding benefits to the natural resource base. The present study shows that the farmers are benefited significantly in terms of input saving in the entire transect. It clearly shows that the adopter farmers save a lot of manpower and machine power used in the cultivation of wheat owing to adoption of zero tillage technology. In IGP region, zero tillage reduces overall input costs in cultivation of rice to the extent of 10 per cent. Cost of human and machine labour was brought down to the extent of 22 per cent, plant nutrients up to 10 per cent, cost of irrigation up to 15 per cent and plant protection cost up to 16 per cent. The returns to cost ratio was found to be higher for adopters of zero tillage (up to 18%) compared to non-adopters making farming a much more profitable option. Zero tillage reduces the cost of labour in wheat up to 23 per cent, cost of seeds up to 7 per cent, plant nutrients up to 10 per cent, irrigation up to 17 per cent, weed control up to 21 per cent and plant protection cost up to 37 per cent thus reducing the total input cost of adopters by up to 16 per cent. The returns to cost ratio differential of adopters was as high as 29 per cent as compared to non-adopters. This clearly illustrates the superiority of RCT over conventional planting technique in the IGP region. Considering the input use efficiencies of adopters and non-adopters, it could be seen that the percentage of adopter farmers was much higher in higher efficiency class interval than that of non-adopters. Besides, the returns to investment (project appraisal) worked out for adoption of zero tillage showed that the BC ratio was greater than one, the net present value was positive and the estimated IRR was much greater than opportunity cost i.e., interest given by the commercial banks on deposits. All the project appraisal indicators were found to be desirable indicating that the adoption of RCT was economically viable in the region.

However, to popularise the adoption of RCTs, there is a need to design new technologies to significantly reduce the cost per unit of output produced either through a positive shift in yield or through an increase in input use efficiencies in rice-wheat systems. Popularization of RCT also requires evolving an entirely new set of package of practices including soil, water and nutrient management practices. Extending the adoption of these technologies from crop based approach to system approach would further bring about a sea change in the adoption of RCTs in the entire Indo-Gangetic plains transect.

6.1.2 Labour Migration and its Impact on Rural Economy of Indo-Gangetic Plains of India

Labour migration is prevalent in Indo-Gangetic plains of India with maximum incidence of out-migration from Bihar and eastern Uttar Pradesh, and maximum in-migration into Punjab. The preliminary results of a study have thrown light on the magnitude and determinants of migration and its implications on the structural and socio-economic conditions of agriculture as a whole and rural households in particular. Macro level evidences as evinced in census, 2001 revealed that among females, marriage was cited as the pre-dominant reason for migration. About 42.4 million migrants out of total 65.4 million female migrants cited this reason for migration. Among males, the most important reason for migration was 'Work/Employment' with 12.3 million out of 32.8 million total male migrants revealing this as the reason for migration. The same was corroborated with primary data collected from the states of Bihar and Uttar Pradesh to study the implication of labour migration. It was observed from a field survey that

the annual average work availability in Bihar was around 5 months and that in UP was only around 3 months. This shortage of work during the most part of the year has resulted in accelerated movement of people from the rural and backward areas in search of gainful employment. The average family size of migrant and non-migrant households was 7.15 and 6.29, respectively, indicating a close relationship between the family size and migration among resource poor households in the study area. Among the migrant households, 44.22 per cent members were illiterate while among non-migrant households, 38.48 per cent were illiterate. Thus, poor educational status pushed labourers to move from their native place to other places to generate more income and employment from non-farm activities. Occupational pattern of migrant and non-migrant families showed that labour force is shifting from agricultural labour to non-farm wage labour. Nearly 44 per cent of labour migrated from Bihar to Delhi while 57 per cent of labour from Uttar Pradesh migrated to Mumbai in search of better livelihood. Study of remittance allocation pattern of migrants showed that most (54%) of the migrants belonged to the monthly income group of Rs 2000-4000 per month and around 79 per cent of the migrants send a monthly remittance of Rs 1000 to their homes most of which was spent for food and farm investment. Most of the family members of the migrants felt that migration of the members had contributed to improvement in education, food consumption, healthcare and overall happiness of the family. However, migration of labour did have some implications on the members of the family in terms of increase in work load (as reported by 81 per cent of family members of migrants from Bihar and 54 per cent from U.P.), problem in supervising labour (as reported by 47 per cent respondents from Bihar), inadequacy of remittance for farm purposes (as reported by 69 per cent respondents from Bihar), and difficulty in obtaining loans in times of need (as reported by 88 per cent respondents from Bihar and 73 per cent from U.P.).

6.1.3 Marketing Information System for Horticultural Commodities in India: Status, Constraints and Prospects

The major objective of the project was to study the role of market information and designing efficient market information system. It was found that small markets for fruits and vegetables were unintegrated while metro markets, were comparatively more integrated. The farmers' access to market information was also poor in most of the states. Most of the farmers and traders were not aware of even a single exporter.

About 50 per cent of farmers in Maharashtra and Himachal Pradesh selling grapes, onion and apples get price information daily, but the situation in other states was very poor. Sharing price information by fellow farmers and fellow traders remained the main source of price information. Most of the farmers in all the states claimed 10 to 20 per cent gain through availability of price information in time. But many claimed even above 20 per cent gain in price. However, compared to farmers, more traders claimed receiving price information in time.

The traders are not aware of much information related to exports, especially that related to changing quality standards, the sanitary and phyto-sanitary standards, legal environment and regulations in various developed countries, and need the information on these urgently for increasing exports. It was found that the availability of all needed market information for external marketing will result in 320 per cent of the domestic market price received.

Creation of Village Information Centre/Knowledge Centre having authentic and up-to-date information received from specialists in the region/state authorities will help in providing the desired information to the farmers. A model for efficient marketing information system was also developed.

Traders and other ancillary service agencies that are existing in marketing chain received information either through sources like functionaries in APMCs or through the associations or other sources. Updated detailed intelligence on existing demand and potential demand, both in internal and external marketing and SPS, existing and potential competitors and their strategies as well as facilities/subsidies and other information needed for exports was extremely important.

6.1.4 Impact of Trade Liberalization on Indian Agriculture

Trade liberalization among nations leads to real specialization in production of commodities, multilateral trade opportunities and high welfare under fair play trade field. The increase in quality produce, production efficiency and better institutional framework will increase the agricultural exports from India. However, real export opportunities due to natural competitive advantage in agricultural production would depend on real withdrawl of subsidies by competitors.

The result of Indian agricultural competitiveness in respect of rice and wheat on different time periods was assessed using net protection coefficient (NPC). The value of NPC was 0.38, 0.68, 0.95 and 1.00 for rice and 1.29, 1.11, 3.50 and 2.07 for wheat during 1994, 1998, 2001 and 2004, respectively. It was inferred that Indian coarse rice was competitive in international market with NPC value remaining less than 1.00 except in 2004 when it was just on the edge. India's competitiveness in *basmati* production is obvious from high export of *basmati* rice in terms of quantity and value from India. On the other hand, India seems to be un-competitive in wheat production for which calculated value of the NPC was more than 1.00 in all the above years.

Similarly, NPC value for mango, grapes, banana, potato, onion and tomato was below 1.00 indicating that the country was competitive in their production. Today, quality standards are the main considerations in international market for agricultural commodities export. In fact, phyto-sanitary and SPS measures, by the importing developed countries, serve as ultra non-tariff barriers for imports from developing countries like India. The competitiveness on cost compliance to meet standards of importing countries was also worked out for some fruits and vegetables. The value of NPC with cost compliance was 0.80, 0.96, 0.85, 1.00, 0.94 and 0.85 for mango, grapes, banana, potato, onion and tomato, respectively. Thus, the results indicated that India is competitive in production and export of these fruits and vegetables even after cost compliance.

6.1.5 Study on Peri-urban Agriculture and its Management in Delhi

On examining the socio-economic conditions of the respondents, it was noted that 56 per cent farmers fell in the age group of 18-50 years and about 90 per cent were educated up to matriculation. The number of illiterates and those with graduation and above was observed very less. Production and marketing of agricultural produce have become highly professional.

About 76 per cent farmers have < 2 ha of land. The average family size was 7.34 members, which is quite high. Production and marketing of vegetables is the best opportunity available to small farmers. Most of the small and marginal farmers allocated 60 to 70 per cent area to vegetable crops whereas medium and large farmers allocated 23 to 28 per cent area to vegetables. It was found that 72 per cent of small and marginal farmers contribute towards the total vegetables production.

More than 50 per cent of vegetable produce was sold by farmers at Azadpur market and 20 per cent at Okhla market. None of the farmers practiced grading, and packaging, while selling their produce.

6.1.6 Food Safety Measures and their Implications on India's Horticultural Exports

A survey of mango processing firms was undertaken in the states of Maharashtra and Andhra Pradesh. Hazard Analysis and Critical Control Points (HACCP) is an important certification procedure being mandated by a number of importing countries on the processing firms intending to export the finished goods to them. The survey, therefore, intended to address the issue of adoption of HACCP and the constraints faced by the processing firms.

Benefits and influence of adoption of Hazard Analysis and Critical Control Points (HACCP)

Particulars	Little influence	Moderate influence	Significant influence
Increased market access		✓	
Increased price received	✓		
Reduced price uncertainties		✓	
Increased market demand		✓	
Improved quality of produce			✓
Improved yield		✓	
Reduced yield	✓		
Increased profit		✓	
Improved brand name			✓
Helped to compete with other nations		✓	

The study revealed that the HACCP certification was adopted mainly by medium and large scale firms. It was not adopted by home-scale and cottage scale processing firms as they were catering to the needs of domestic market, and for whom it was not feasible to adopt the same. The adoption of HACCP had a beneficial role in the performance of the processing firms, and in building the brand name and improving the quality of the produce. However, it had little influence on the increase in the price of the output.

Constraints in adoption of HACCP

Particulars	Yes/No	Remarks
Causes increase in the cost of production	Yes	
Unavailability of training facilities	No	Locally it is not there
Quality of training is not adequate	No	
Cost of training is very high	Yes	
Frequent change in standards	Yes	
Non-recognition of standards by the importing countries	No	
Equipment and materials are not present to adopt the desired changes in production system	No	Affordability is not there
Lack of trained consultancy firms	No	
Knowledge about changing standards is not received well in time	Yes	

The firms experienced a number of constraints in the adoption of HACCP. The cost of HACCP adoption was exorbitantly high. It involved both fixed and recurring expenditure. The training facilities are not available locally leading to increase in the cost of training the personnel. The changing standards of HACCP module further adds to the cost and needs up-gradation from time to time.

6.1.7 Co-integration of Horticultural Markets in India

Price fluctuations play a predominant role in creating uncertainty in the income earned by vegetables growers and expenditure borne by consumers. This has been a matter of serious concern for policy makers in India. In addition, an increase in consumer's price is not fully reflected in a matching increase in producer's price and a greater share of the consumer's price is taken away by the intermediaries. The seasonality in production associated with poor marketing facilities exaggerates the adverse movements of arrivals and prices. The prices of a few important vegetables of Delhi APMC market were analysed for intra-year price variation (IPV) and average seasonal price variation (ASPV). It was found that for onion the IPV was 92.7 per cent and the ASPV was 63.3 per cent. The cofficient of variation (CV) of onion price was 23.2% and was greater than the CV of onion arrivals (14.7%). It was also found that major onion markets were integrated but the speed of adjustment of price to achieve equilibrium was slow, i.e., about 5% maximum per week. For potato, the IPV was 163.1 per cent and the ASPV was 89.8 per cent. The CV of potato price was 35.5 per cent. Brinjal had the IPV of 172.3% and an ASPV of 92.6%. The CV of price and arrivals were 30.7% and 23.4%, respectively. The IPV for ginger was 82.5% per year while the ASPV for ginger was 58.4% per year. It was observed that there has been a sharp increase in the arrivals of ginger. The ASPV for cabbage was 116.9% and the CV price was 56.1%. The IPV for garlic was 68.2 per cent and the ASPV was 50.9 per cent. The CV of garlic price was 15.5% while it was 37.3% for arrivals.

6.2 AGRICULTURAL EXTENSION

6.2.1 Farming Systems Research and Extension for Sustainable Development

The aim of the project is to analyse and design appropriate farming systems for sustainable development in selected locations. Selected districts of Gurgaon in Haryana, North Delhi in Delhi, Indore in M.P., Muzaffarpur in Bihar, Katrain (Kullu) in H.P. formed the project locale which included a cluster of four villages out of which, one village was identified for action research. Important farming systems of selected villages were identified. On an average, 2 to 4 sub-systems existed at household levels and crop production and dairying were the important systems commonly found. On-farm demonstrations, training, awareness camp, entrepreneurial motivation and mobilization of farmers were the major interventions.

Important problems were identified for interventions in action research villages. Crop demonstrations, animal health and fertility camps and training of farmers were undertaken to tackle the problem of low productivity of crops and dairy animals. Quality seed production and distribution, use of bio-fertilizers, vermi-compost and bio-pesticides were taken up with the participation of farmers as the farmers voiced the problem of non-availability of quality inputs and their high cost during PRA exercise.

A survey was also conducted that helped to understand the socio-economic advantages and disadvantages of existing systems, their structure and interrelationship, and plan sustainable alternatives and interventions for soil and water management, use of organic/inorganic inputs, new options in agriculture processing and value addition, gender empowerment, entrepreneurship development and SHGs mobilization.

The perceived problems were lack of quality seeds and inputs; poor knowledge of integrated pest management, high value crops, organic means of crop cultivation, management

of micronutrients and post harvest technology; poor on-farm water management and high drudgery of women. The farmers were trained and motivated to handle these problems.

A majority of the farmers preferred land/agriculture based livelihood to other business ventures/opportunities like transport, share capital, etc., based upon large capital gained by selling their land as they believed that agriculture provided sustainable livelihood. They also opined that flourishing of industries will provide marginal benefit to the locals as industries recruit skilled people, and villagers lack industry related skills.

Soil and water tests were undertaken in selected villages. One hundred and seventy-nine demonstrations of improved varieties covering paddy (PB1, PS 4, PRH 10), *jowar* (Pusa chari 9, Pusa chari 23), wheat (PBW 343, PBW 502, HD 2733, HD 2643, HD 2851), *arhar* P 992, mustard (Pusa Jaikisan) and various varieties of vegetable crops of carrot, Tinda, cucumber, sponge-guard, lauki, lady fingers, bitter gourd, chillies, tomato, brinjal, radish, *methi* and *palak* were conducted in the villages of Tiggipur in NCR Delhi and Saidpur in Gurgaon district.

Animal health and fertility camps were also held to take care of dairy animals. The farmers of project villages in Bihar suffered because of the lack of market for their main cash crop-tobacco. Low market returns from vegetable crops further affected their income adversely.

Farmers were mobilized to take up cultivation of high value crops, and form self-interest groups and farmers' organizations for better articulation and bargain power in marketing the produce as well as in the procurement of inputs.

6.2.1.1 Communication behaviour of farmers

In order to develop communication materials for transfer of technology, the communication behaviour of farmers as well the extent of adoption of modern technologies were analysed through Rapid Rural Appraisal.

Communication materials in Hindi were developed on wheat cultivation, mushroom cultivation and nutrition. These materials were evaluated by the farmers for technical content and utility in terms of relevance, physical lay out and help in improving productivity and profitability.

6.2.1.2 Development of entrepreneurial skills among farmers

The project aims at capacity building and inculcation of entrepreneurial skills among farmmen and farmwomen for sustainable livelihood in rural areas. A survey was conducted with a focus on entrepreneurial skill development. Matrix ranking of potential enterprises was conducted. Vegetable and fruit cultivations were the most preferred entrepreneurial ventures perceived by the farmers followed by polyhouse nursery raising, mushroom cultivation, beekeeping, poultry, vermi-composting and fisheries.

During the period under report, 20 potential entrepreneurs were selected and given entrepreneurial motivation training for three days in Tiggipur village, Delhi and two days in Saidpur village, Gurgaon. Motivational levels of youth before and after the training were measured, and the data are being analysed. Organizational support for rural entrepreneurial ventures available was also documented and awareness generation exercise regarding these was conducted in the villages. Project reports in respect of peri-urban agricultural enterprises were developed with the help of farmers. Research data collection from individual farmers is being done.

6.2.2 Assessment of Socio-economic and Environmental Impact of Agricultural Technologies

A survey of villages in Abohar, Bhatinda and Mansa blocks of Punjab revealed an additional benefit in the range of Rs. 3000-5,500/-per acre is being obtained by small farmers with Bt. cotton varieties, particularly RCH 134, when the price was in the range of Rs 1350 and more (per 450 g Bt.cotton seed) during the year 2005.

A survey conducted in the villages of Narwana, Barawala and Sirsa blocks of Haryana revealed that the farmers preferred RCH 134 to other Bt. varieties (NCS 138, MRC 6301, Ankur 651, JK 1947, etc.)

Farmers perceived that the cultivation of Bt. cotton reduced the frequency of spray by 62% and health hazards by 89.6%, and increased the yield by 38.8% and income by 142 %. The use of higher seed rate i.e., 1.5 to 2 times more than the recommended rate (650-900g in stead of 450 g) was a serious limitation in obtaining more profit**.** The constraints in the adoption of Bt.cotton varieties were identified, which included high cost of seeds, lack of knowledge about agro-techniques and lack of technical guidance.

The survey also revealed lack of information about Bt. technology and related issues. Issues of bio-safety,

agro-techniques and risk communication remained unattended. Extension services for Bt. cotton are mainly covered by the seed agency, and the public extension system in which the farmers have enormous faith have very little role. The farmers had a high level of information and training needs (MS 2.76) for successful cultivation of Bt.cotton as revealed by their mean score measured on three point continuum (most needed, somewhat needed and not needed with respective weightage of 3, 2, and 1).

Factors affecting agricultural productivity and household livelihood security were identified during the pilot survey of the villages of Samastipur district of Bihar. Increasing cost of inputs, poor irrigation facilities, low market price of agricultural produce, unavailability of market facilities, large scale unemployment, unavailability of manpower for agricultural activities due to migration of people, lack of awareness about nutritious and balanced diet, vulnerability attributed to flood and poor economic base, hampering of paddy cultivation due to vagaries of monsoon, social problems like dowry and increasing trend of liquor consumption, more expenditure on social customs and rituals, ineffective rural development and employment programmes of the Govt. etc., constituted the major factors affecting the livelihood of rural people.

6.2.3 Enhancing the Efficiency of Extension Organization

The major objective of the project is to develop computer based interactive self-learning modules (SLM) on major functions of development management, entrepreneurship development and training management. During the period under report, programmed text materials were prepared for the modules on leadership and teambuilding, the same were evaluated. The following steps were followed in developing programmed learning materials: 1) development of text materials, 2) conversion of text into small units called frames, 3) development of appropriate cases and practical exercises for each frame, 4) development of questions (to test the learning that had taken place) for each frame, 5) the learner/trainee goes through each frame and answer the question in each frame before he/she goes to the next frame, 6) the learner also compares his answer with the correct answer and get the feed back about his/her performance, 7) each frame introduces new concepts or new ideas, and 8) reinforcement though immediate feed back helps the learner motivated to complete the task until completion.

6.2.3.1 Evaluation of the programmed text on leadership

The programmed text materials for the modules on leadership were evaluated with the help of twenty extension professionals drawn from various KVKs and state agricultural universities.

The study revealed that the extension professionals perceived the overall contents of the programmed text as highly effective with a score of 4.27 out of 5.00.

Evaluation of contents of programmed text on leadership (n = 25)

Items	Average score *	Rank
Adequacy of contents of the text	4.45	1
Appropriateness of sequencing of the contents	4.15	5
Simplicity of language used	4.35	3
Useful and interesting way of presentation	4.15	6
Integration of text with small case-lets to help in understanding the subject	4.40	2
Self-learning without the help of an instructor	4.15	4
Over-all contents (Average score)	4.275	

*Score maximum 5, minimum 1.

The study also revealed that the overall utility of the programmed text on leadership was high with a score of 3.93(out of maximum possible score of 5.00). Thus, it is clear that the extension personnel perceived the programmed text on leadership as a very useful method of learning, which will help them to improve their professional competencies, motivation for learning, and work productivity.

Perceived utility of programmed text on leadership (n = 25)

Items	Average score *	Rank
Usefulness in improving professional capacity	4.20	1
Learning new concepts in leadership	4.05	2
Realization of one's strength and weaknesses	3.75	6
Helping in self-introspection	3.95	3
Increased motivation for learning	3.75	5
Improvement in work productivity	3.90	4
Overall utility of programs text on leadership(average)	3.93	

* Score maximum 5, minimum 1.

Usefulness of "programmed text" in comparison to "conventional text". The extension personnel perceived the programmed text more useful compared to conventional text in all dimensions with a score of 4.057.

Perceived usefulness of "programmed text" in comparison to "conventional text" (n = 25)

Items	Average score*	Rank
In terms of learning taken place	3.90	5
In terms of interest created	4.20	2
In terms of ease in understanding	4.15	3
In terms of cost	3.95	4
In terms of accessibility	3.85	6
Study at one's own pace	4.00	2
Study at ones' own time	4.35	1
Overall usefulness (average)	4.057	

*Score maximum 5, minimum 1.

6.2.4 Development of Participatory Extension Methodology and Intersectoral Micro-plans

6.2.4.1 Developing a model of sustainable extension system through rural institution

The project is being undertaken in selected villages at three locations, namely, Bulandshahar district (U.P.), Alipur block, Delhi, and Sonepat district (Haryana). Farmers were organized to form a cooperative society with a total of 60 members from a cluster of ten villages of Bulandshahar district (U.P.) The modalities and byelaws of the society were discussed and finalized with the participation of farmers.

A methodology for organizing farmers for rural institution (Rural Social Center) was developed. Sustainability attributes were reviewed based on the work done by eminent scientists globally. Based on those attributes, opinion on Rural Social Centers' sustainability was obtained from the scientists of different SAUs, and ICAR research institutes. Sixty farmers in a cluster of 10 villages in Bulandshahar district were organized to form a society and were motivated to produce improved seed varieties of paddy and *mung* for sale to raise their income through seed production.

Amount of seed produced by members of co-operative society

Crop	Variety	Amount of seed (tonnes)
Paddy	P B 1	5 tonnes
Paddy	Pusa Sugandh 4	5.5 tonnes
Paddy	Pusa Sugandh 5	7.0 tonnes
Paddy	Pusa 44	6.5 tonnes
Moong	Pusa Visal	0.3 ton
Moong	K 851	0.1 ton

The already established Rural Social Center in village Palla of Alipur cluster was not only selling seed and agro-chemicals to its 102 members but also to farmers in other states. The non-members also procure quality inputs from this centre. A study of its sustainability is in progress and a number of theories and hypotheses will be tested.

The formation of a third Rural Social Centre in the cluster of ten villages in Rai block, Sonepat district, Haryana, was initiated.

6.2.4.2 Development of micro-plan for empowering the youth

The aim of the sub-project is to develop suitable strategy to empower rural youth. PRA exercise and focus group discussion revealed that youth is brimming over with excellent ideas on micro plans but remorseless lack of infrastructure impacts their motivation and self confidence adversely. Majority of the youth were found to be engaged in agriculture activities either full time or partially. Increase in profitability is making agriculture more lucrative again for them. Analysis of the data from 93 individual farm youth collected from Kamona, Phasi villages, Aligarh district, Aterna village, Sonepat district and Saidpur village, Gurgaon district is in progress.

6.2.4.3 Assessment of performance of development administration in achieving human development

The project aims at assessing the performance of development administration personnel. A prototype index for assessing agricultural and human development was developed and being tested. Individual data collection work from development department staff and farmers is in progress.

6.2.5 Impact Analysis of Training Programmes Conducted under CAS in Agricultural Extension

Post-evaluation of training programmes conducted under CAS revealed that majority of the participants (96%) considered the CAS programmes as excellent and good. Data on content exposure before training showed that only 43% participants had exposure to the content before the training. As regards the method of training, it was found that majority of them perceived the impact of simulation games and role plays (91%) as maximum for improving knowledge, skills and attitude followed by field visits (87%) and demonstrations (86%). Networking, evaluation

studies and seminars were considered by more than 95% of trainees as necessary for improving the impact of the training programmes.

6.2.6 Evaluation Capacity Building in Rural Resource Management: A Pilot Action Research on Program Evaluation

The main objective of this project is to build program evaluation capacity among rural resource management program staff in India through development of a cadre of evaluators who will be willing and able to conduct evaluation of educational and/or developmental programs through "train the trainer approach". A manual on evaluation (along with cases) was prepared and final report of the project submitted.

The project has resulted in the development of a training module on evaluation that can be used as a resource material on evaluation by the trainers. The project has also resulted in the development of 20 cases on evaluation of selected research and developmental projects, which will be resource materials for trainers and planners.

6.2.7 Taking Wheat Cultivation Technology to Remote and Tribal Areas

A total of 155 frontline demonstrations of 11 wheat varieties were conducted during 2006-07 in the farmers' fields in an area of 66 hectares in Jhabua, Indore, Rewa, Sidhi and Mandla districts with special emphasis on remote and tribal areas. Variety-wise increase in yield over respective check/s was 54% for HI 1500, 46% for HW 2004, 61% for HI 1531, 63% for HD 4672, 59% for HI 8627, 52% for HI 8638, 92% for HI 1479, 93% for HI 8381, 88% for HI 8498, 80% for DL 788-2 and 93% for HI 1454.

During 2007-08, a total of 169 FLDs were conducted in the states of Madhya Pradesh, Uttar Pradesh and Rajasthan. Despite severe drought, particularly in eastern M.P., in 84 demonstration fields there has been least effect of drought, generating high enthusiasm among farmers for "Dry Sowing Limited Irrigation Technology" for improving the productivity and profitability of wheat crop. In nearly 75% fields, the crop raised following local method will either force-mature or dry up.

6.2.8 Alleviating Malnutrition through Popularization of Consumption of *Durum* Wheat

An extensive campaign for popularizing the consumption of *durum* wheat through the sale of *durum* products, e.g., *dalia* (porridge), semolina and flour, is being pursued since 2004 to create wide awareness for inclusion of *durum* preparations in the daily diet.

6.3 TECHNOLOGY ASSESSMENT AND TRANSFER

6.3.1 Prospects of New Growth Areas for Application of Agricultural Technologies in Different Agro-eco Regions

6.3.1.1 Semi-arid region - Jhunjhunu and Churu districts, Rajasthan

Management of Orobanchae weed in mustard crop. 1) Aqua plough was used for sowing mustard crop without pre-sowing irrigation. With the use of this plough for sowing mustard, the weed infestation could be reduced by 32-68%, and the yield increased by 25%, 2) Delayed sowing of mustard crop (after 25th October) resulted in 12% higher yield with less weed infestation as compared to that in control plot, and 3) cluster bean, onion, and sesame crops during preceding *kharif* season reduced Orobanchae infestation in mustard crop by about 7 - 15%.

Integrated insect-pest management in gram crop. Integrated insect-pest management which included putting 2 - 3 pheromone traps per acre before or at the time of flower initiation, light traps during night, and spray of nuclear poly hedrosys virus (NPV) when 15-20 adults start entering the Phenormone traps per day were found very effective in controlling pest damage in gram crop, and increasing the yield of gram crop by 40%.

Assessment and promotion of improved crop varieties (rabi 2006-07). Pusa Bold variety of mustard gave the highest increase in yield (17.80%) among all varieties demonstrated. The farmers preferred Pusa Bold and Pusa Jagannath varieties during *rabi* 2006-07. The performance of gram variety BG 372 was very good in terms of yield increase (15%) and disease (wilt) resistance. Among wheat varieties, Kundan gave the highest average yield of 4.80 tonnes/ha followed by WH 711, (4.62 tonnes/ha) in comparison to that given by the local check (4.20 tonnes/ha). In addition, the eating quality of Kundan was found to be better by farmers. *Methi* variety PEB performed well and gave an average yield of 1.80 tonnes/ha against that given by local varieties (1.72 tonnes/ha).

Assessment and promotion of improved crop varieties (*rabi*-2006-07)

Crop	Variety	No. of demonstrations	Area (ha)	Av. yield (tonnes/ha)	Local yield (tonnes/ha)	% increase
Mustard	Pusa Bold	22	20.00	1.72	1.46	17.80
	Pusa Jaikisan	27	20.00	1.66		13.76
	JD 6	34	25.60	1.50		2.74
	Pusa Jagannath	11	8.40	1.68		16.43
Gram	BG 372	19	8.00	1.88	1.60	15.00
	BG 362	21	7.68	1.64		2.50
Pea	AP 1	43	2.40	3.20	New introduction	
Wheat	Raj 3675	9	2.40	4.55	4.20	5.95
	Kundan	29	11.20	4.80		11.90
	WH 711	3	1.20	4.62		10.00
Methi	PEB	10	1.88	1.80	1.72	4.60
Tomato	PH1	5	1.00	12.50	New introduction	

Assessment and promotion of improved crop varieties (kharif 2007). *Bajra* variety Proagro 9444, *Guar* variety HG 365, *Bhindi* variety Varsha Uphar, *moong* variety Pusa Vishal, and Cowpea variety RJ 19 gave an average yield of 2 tonnes, 1.03 tonnes, 10.90 tonnes, 0.53 tonne, and 7.87 tonnes per ha, respectively. *Arhar* varieties (P 992, P 991, P 2002, P 855 and P 2001) were introduced as new crop/ varieties to the area and among these P 992 gave the highest average yield (0.78 tonne/ha) followed by P 2001 (0.73 tonne/ha).

6.3.1.2 Agri-horti system in peri-urban areas of Ghaziabad and Baghpat districts

Promotion of improved varieties in Baghpat and Ghaziabad districts. In Baghpat district, wheat varieties HD 2329 gave the highest yield (5.33 tonnes/ha) followed by HD 2428 (5.25 tonnes /ha) as compared to that given by the local check (3.62 tonnes /ha). Mustard varieties Pusa Jaikisan and JD 6 gave 39.03% and 38.20% higher yield in comparison to that given by local varieties (1.45 tonnes /ha).

In Ghaziabad district, among wheat varieties HD 2824 gave the highest average yield followed by HD 2329. These varieties gave 47% and 46% more yields that local checks. Among mustard varieties, Pusa Bold (53.87%) and Pusa Jaikisan (43.16%) yielded higher than the local check. The gram variety BG 362 was the new introduction in the area.

Kharif 2007. In Ghaziabad district, the demonstrations on paddy varieties PRH 10, PB1 and PS 4 yielded on an average 7.61 tonnes, 5.41 tonnes and 4.66 tonnes per hectare, respectively in comparison to the yield of local check (3.78 tonnes). Demonstrations on *arhar* (Pusa 992) resulted in an average yield of 2.61 tonnes/ha. The average yield of bottle gourd (Pusa Samridhi) and *bhindi* (Arkanamika) was to the tune of 28.22 tonnes and 13.20 tonnes per hectare, respectively.

In Baghpat district, 65 demonstrations on paddy varieties, PRH 10, PB1 and PS 4 yielded on an average 6.64 tonnes, 4.82 tonnes and 4.52 tonnes per hectare, respectively. Bottle gourd (Pusa Samriddhi) gave an average yield of 25.55 tonnes/ha.

Yield performance of different crops in Ghaziabad district (U.P.), during *kharif* 2007

Crop (variety)	Area (ha)	Yield (tonnes per hectare)			% increase over local / control
		Max	Ave.	Local	
Bhindi (Arkanamica)	4.0	13.92	13.20	10.55	25.15
Bottle gourd (Pusa Samridhi)	2.8	28.87	28.22	22.12	33.03
Arhar (P 992)	5.0	2.35	2.10	1.20	71.75
Moong (Pusa Vishal)	1.2	0.92	0.81	0.56	46.25
Paddy					
PRH 10	6.0	8.25	7.61		101.48
PB 1	8.0	5.51	5.14		36.0
PS 4	10.0	5.32	4.66	3.78	23.49
Over all	24.0	8.25	5.56		47.14

6.3.1.3 Sustainable rice-wheat based production system in irrigated areas (Patiala district - Punjab, Gautam Budh Nagar and Bulandshahr districts, U.P.)

Under varietal diversification through seeds production programme of improved IARI varieties, wheat seeds of HD 2733 (10.00 tonnes), HD 2851 (12.90 tonnes) and WR 544 (8.00 tonnes) and paddy seeds of Pusa 44 (30.0 tonnes) and Pusa 1121 (9.22 tonnes) were produced at the farm of Young Farmers' Association at Rakhra, Patiala. Hybrid seed of paddy PRH 10 (0.29 tonne) was also produced at Badshahpur village, Faridabad district.

All the six wheat varieties under demonstration in Gautam Budh Nagar (U.P.) performed better than the local

check. HD 2733 was the top yielder with an average yield of 5.63 tonnes /ha. Wheat varieties, HD 2824, HD 2733, PBW 343, HD 2285, PBW 502 and HD 2643 gave an average yield of 5.44 tonnes, 5.63 tonnes, 5.47 tonnes., 4.75 tonnes, 5.00 tonnes and 4.30 tonnes per hectare, respectively against 4.10 tonnes/ha of local check (UP 2338). The ear head of HD 2824 variety is long. This is very popular among the farmers. More tillering and no lodging was observed in HD 2733 variety of wheat.

Yield performance of different crops in Gautam Budh Nagar : *rabi* 2006-07

Crop	Variety	No. of demon-strations	Area (ha)	Av. yield tonnes/ha	Local yield	% increase in av. yield
Wheat	HD 2824	8	3.20	5.44	4.10	32.78
	HD 2733	10	4.00	5.63		37.32
	PBW 343	3	1.20	5.47		33.41
	HD 2285	2	0.80	4.75		15.85
	PBW 502	1	0.40	5.00		21.95
	HD 2643	3	1.20	4.30		04.88
Mustard	JD 6	9	3.60	1.99	1.50	32.93
	Pusa Bold	4	1.60	1.97		31.67
	Pusa Jaikisan	1	0.40	2.00		33.33

Mustard varieties, JD 6, Pusa Bold and Pusa Jaikisan gave average yields of 1.99 tonnes, 1.97 tonnes, and 2. 0 tonnes/ha, respectively against 1.50 tonnes/ha of local check (Rohini). Fourteen kg oil from 40 kg mustard (cv. Pusa Jaikisan) was obtained against 11 kg of oil from local variety.

During *kharif* 2007 demonstrations, paddy varieties P 1121, P 2511 and PRH 10 gave an average yield of 5.24 tonnes, 5.47 tonnes and 6.5 tonnes, respectively, in comparison to 4.7 tonnes/ha of local check variety (Sarbati). The market value of paddy P 1121 was the highest. It has good cooking quality. The yield of PRH 10 was the highest compared to the yields of other varieties of paddy. Farmers like PRH 10 variety because of its early maturity and low incidence of pests and diseases. *Jowar* (PC 9) gave an average fodder yield of 78.37 tonnes in comparison to 62.5 tonnes/ha of local check variety (Hari Ganga). Four demonstrations of *moong* (Pusa Vishal) gave an average yield of 1.12 tonnes in comparison to 0.87 tonne/ha of local check variety (PS 10).

6.3.2 Farmer Participatory Seed Production in Different Villages

Farmers' participatory seed production programme in major crops like rice, wheat, *arhar* and gram initiated by CATAT was useful to the farmers of Sonepat, Faridabad and Gurgaon districts in Haryana, Bulandshahr and Mathura districts in UP, Patiala district in Punjab, and Jhunjhunu district in Rajasthan. The total seed production was 58.64 tonnes of wheat, 8.23 tonnes of gram, 65.12 tonnes of paddy and 11.45 tonnes of *arhar*.

This programme helped the farmers not only in saving the money and time for procuring HYV seeds but also timely sowing of their crops. The seeds of these crops were produced by farmers themselves under the guidance of scientists of the Institute, and made available to other farmers through farmer-to- farmer seed exchange programme. Part of seed produced was sold back to IARI or to farmers at Pusa Krishi Vigyan Mela for increased income.

6.3.3 Joint Bio-fertilizer Extension Programme (IARI - NFL)

During *rabi* 2006-07, a total of 58 demonstrations on use of bio-fertilisers for seed treatment with Azotobacter + PSB (in mustard and wheat) and with Rhizobium + PSB (in gram and pea) were also laid. These were for: mustard (17), wheat (23), pea (12) and gram (6) conducted in Gurgaon district (Haryana), Jhunjhunu district (Rajasthan) and Sonepat district (Haryana).

In all the demonstrations, the yield under treatment plots was higher than that of the control. Farmers liked these biofertilizers and showed keen interest to use them in future.

Performance of bio-fertilizer demonstrations in Jhunjhunu district (Rajasthan), Sonepat and Gurgaon districts in Haryana (*rabi* 2006-07)

Crop	Variety	No. of demon-strations	Area (acre)	Av. yield (tonnes/ha)	Control yield (tonnes/ha)	% increase
Mustard	Pusa Jagannath	15	6.0	1.82	1.65	10.05
	Pusa Bold	2	1.2	2.17		31.74
Pea (vegetable)	Azad Pea 1	12	4.8	6.23	5.54	12.45
Gram	BG 372	6	2.4	1.93	1.73	11.56
Wheat	WH 711	16	6.4	4.94	4.59	7.58
	HD 2733	7	3.2	5.14		11.82

During *kharif* 2007, sixty demonstrations on the use of bio-fertilizers in *bajra*, paddy, green gram, sorghum and cowpea were conducted. Farmers rated (*Azotobactor/ Rhizobium* +PSB) treatment high as the crop growth was much better than that of the local control. Maximum gain in term of yield was observed in the case of *bajra* where *Azotobactor*+PSB was used. The use of liquid bio-agents gave 8.59% higher yield compared to that of control.

One training programme was organized at each site on the importance and scope of bio-fertilizer in crop production. Two field days were also organized at each site at flowering and seed setting stages.

6.3.4 Front Line Demonstrations (FLDs)

Twenty five FLDs on wheat were conduced in 13 villages of Bulandshahr and Gautam Budh Nagar districts in UP and Faridabad district in Haryana covering an area of 14 ha. Seventeen demonstrations were conducted on newly released varieties of wheat, PBW 502, HD 2851 and WR 544. Four demonstrations each on zero tillage and use of biofertilizer (*Azotobacter* + PSB) were also conducted. While the average yield of PBW 502 was the highest (5.01 tonnes/ ha) among all the wheat varieties demonstrated, the B:C ratio of HD 2851 was the highest (2.65) followed by WR 544 (2.45). The demonstrations on the use of biofertilizers resulted in 4.10% increase in the yield. The zero tillage practice resulted in 6.39% increase in yield over that of the control plot.

To reduce the technological and yield gaps of the farmers' fields, 37 frontline demonstrations were laid out during the year in Samastipur, Muzaffarpur, Darbhanga, and Vaishali districts of Bihar. The demonstrations related to the use of bio-fertilizers–*Azatobacter* and PSB (14), zero-tillage technology (06), and new improved wheat varieties (17). The size of each FLD was of 1 hectare.

The first tropical wheat, CoW (W)1 developed at IARI, Regional Station, Wellington matures in just 90 days under the conditions obtaining in the areas adjoining Southern hills and still yields 2.5 – 3.0 t/ha. To popularize this variety, the front line demonstrations were carried out by the Directorate of Wheat Research. The resource poor farmers from non–traditional areas are adopting this wheat as an alternate choice crop during *rabi* for their lively-hood security.

Front line demonstrations on wheat and barley were conducted the by Tutikandi Centre of IARI Regional Station, Amartara Cottage, Shimla in 4 villages under Shimla, Bilaspur and Kinnaur districts of Himachal Pradesh. The performance of the new wheat variety Shivalik was very good under late sown condition with a mean yield of 2.3 t/ha with 15% increase over that of the local checks. Barley variety BHS 352 gave an average yield of 2.0 t/ha with an increase of 17 - 25% over that of the local checks.

Front line demonstrations on wheat-*rabi* 2006-07

Name of the demonstration	No. of demon-strations	Av. yield (tonnes/ha)	% increase in av. yield of variety	Gross return (Rs/ha)	Net return over operational cost (Rs/ha)	B : C ratio
Latest variety	**17**					
Control (PBW 343, PBW 159, WH 711)		4.02	-	48190	27315	2.31
PBW 502	8	5.01	24.52	60057	34897	2.38
HD 2851	4	4.87	21.14	58265	36307	2.65
WR 544	5	4.70	17.01	56438	33418	2.45
Application of biofertilizer	**4**					
Control		4.26	-	50999	27811	2.20
Use of *Azatobacter* and PSB		4.44	4.10	53161	30231	2.32
Zero tillage	**4**					
Control		4.01	-	48057	24792	2.06
Use of zero tillage		4.26	6.39	50989	31471	2.61
Total no. of demonstrations	**25**					

Area covered : 14.0 ha.

During *kharif* 2007, 100 FLDs were conduced on maize in Bulandshahr and Gautam Budh Nagar, Ghaziabad and Aligarh districts in U.P. and Delhi covering an area of 25 ha. Demonstartions were conducted on the latest varieties of maize: 32A-09, HQPM 1, 32T-25, NMH 589, 30V-92 and HM 4. Five demonstrations were destroyed due to water logging. Among the varieties, NMH 589 gave the highest grain yield of 3.31 tonnes/ha. Farmers in NCR region found maize more remunerative if they sell the cob. For cob, variety 32T-25 gave the highest cob yield of 13.32 tonnes/ha.

6.3.5 Collaborative Extension Programme with SAUs/ICAR Institutes

The National Extension Programme in far off northern, southern, eastern and western parts of the country has recently been taken up by the Centre from *rabi* 2007-08 in collaboration with selected SAUs/ICAR institutes. A cluster of 2-4 villages was selected at each project site in different locations to carry out the project activities. The progressive farmers in project locations were linked and utilized for technology transfer. Under this programme, IARI has provided improved varieties of gram (BG 1088, BGD 72, BG 1103 and BG 256) and mustard (Pusa Bold, Pusa Jaggannath and Pusa Jaikisan) to collaborative SAUs/ICAR institutes. Results of these demonstrations are awaited.

6.3.6 Transfer of Technology Programme

During *rabi* 2006-07, a total number of 142 demonstrations on mustard, wheat, gram, vegetable pea, in 5 districts of Haryana, namely, Sonepat, Jhajjar, Rohtak, Mahendergarh, Faridabad, and in Bulandshahr district of U.P. were conducted.

Among 4 mustard varieties, Pusa Bold gave highest yield (2.02 tonnes/ha), which was 31.68% higher than that of local variety followed by Pusa Jaikisan with 23.73 % increase in yield over control. In case of wheat, yield performance of HD 2733 was best (5.17 tonnes/ha) which was 26.36% higher than the yield of local variety followed by HD 2329 with 4.90 tonnes/ha against 4.09 tonnes/ha of control plot. In gram, variety BG 362 gave an increase of 19.5% over local check. Increase in yield of vegetable pea (Azad P 1) was to the tune of 12.63% over control.

Dr. Michael Keenum, Under Secretary for Farm and Foreign Agriculture Service, USDA meeting farmers at a village in Sonepat district, Haryana

During *kharif* 2007, a total of 165 demonstrations were conducted in Sonepat and Faridabad (Haryana) and Bulandshahr districts (U.P.) on improved varieties of Paddy (P 1121, PRH 10, P 2511 and Pusa 44), *Jowar* (PC 9), *Arhar* (P 992, P2001 and P 2002), and, *Bhindi* (Versha Uphar and Arka Anamika). Among paddy varieties PRH 10 gave the highest yield of 6.47 tonnes per ha. The average yield of *Jowar* variety, PC 9 was 42.85 tonnes/ha and P 992, P2001 and P 2002 varieties of *Arhar* yielded 1.17, 1.02 and 1.05 tonnes/ha, respectively. The average yields of *Bhindi*, vars. Versha Uphar and Arka Anamika was 19.35 tonnes and 15.58 tonnes/ha, respectively.

Farmers and IARI officials at Badshapur village of Faridabad district, Haryana under the seed production programme of rice hybrid PRH 10

Fifteen demonstrations in *rabi* and 10 demonstrations in *kharif* on different vegetables were laid out in five villages by IARI Regional Station, Katrain. To popularise the latest vegetable production technology, an exhibition was arranged at Kullu Dussehra from October 21 to 27,2007.

The Regional Station, Pusa, also participated in the *kisan mela* organized by the Indian Institute of Vegetable Research, Varanasi in Harsidhipur village, Motihari district (East Champaran).

6.3.7 Pusa Krishi Vigyan Mela 2007

A three-day *krishi vigyan mela* (February 24-26, 2007) on the theme "IARI - In the Service of Farmers" was inaugurated by Shri Sharad Pawar, Hon'ble Union Minister of Agriculture, Consumer Affairs, Food and Public Distribution on February 24, 2007 at IARI. Dr. Mangala Rai, Secretary, DARE and DG, ICAR presided over the function and Dr. S.A. Patil, Director, IARI gave the welcome address. On this occasion, a thematic publication of the *mela* and four technical publications,namely, *Prasar Doot (Mela*

Visheshank), *Kharif Fasalon Ki Unnat Kheti*, *Gehun Ka Utpadan Badhane Mein Bharatiya Krishi Anusandhan Sansthan Dwara Vikasit Gehun ki Kismon Ka Yogdan* and *Uttar Bharatiya Paristhitiyon Mein Sankar Dhan Ki Beej Utpadan Prodyogiki* were released by the Hon'ble Agriculture Minister.

Technologies developed by IARI, were displayed in the thematic pandal, where some progressive farmers also shared their experiences of IARI technologies with the visiting farmers. Different Project Directorates, Divisions and Units of the Institute demonstrated/displayed their technologies in their respective stalls. Besides IARI, four State Agricultural Universities, eleven ICAR Institutes, including some livestock based research institutes, twenty four Private Companies, five Public Sector Undertakings and seventeen NGOs/Societies put up their stalls and participated in the *mela*. Ten progressive farmers from Outreach Extension Areas of the Institute also put-up their stalls to display and sell their farm produce.

Shri Sharad Pawar, Hon'ble Union Minister of Agriculture, Consumer Affairs, and Food and Public Distribution (centre) arriving for the inauguration of the *Pusa Krishi Vigyan Mela*. He is accompanied by Dr. S.A. Patil, Director, IARI (extreme right), and other senior officials of IARI

About 35,000 visitors comprising farmers, farmwomen, students, extension workers, entrepreneurs and others from different parts of the country visited the *mela*. Organised visits of farmers to various live crop demonstrations, the Centre for Protected Cultivation Technology, and other experimental plots on IARI farm, were conducted during the *mela* period.

The Women Empowerment Workshop of the *krishi vigyan mela* was inaugurated by Mrs. Renuka Chawdhury, Hon'ble Minister of State for Child and Women Welfare, Government of India on February 25, 2007. More than 1000 farmwomen and farmmen from different parts of the country participated in the workshop, deliberating on the latest issues/schemes of the Govt. for empowerment of women and interacted with the scientists of the Institute.

Farmers visiting the live demonstrations of *rabi* crops during *Pusa Krishi Vigyan Mela*

A farmers-agro-industry personnel -scientists interface was also organised from 11.00 am to 1.00 pm on February 26, 2007 in which farmers, representatives of agro-based industries and scientists exchanged their thoughts and experiences for increased agricultural productivity in the overall interest of the Nation. Dr. S.P. Tiwari, Deputy Director General (Crops) was the chief guest of the interface which was presided over by the Director, IARI.

Kisan goshthies were organised every day in the evening where farmers discussed their agriculture related problems with the scientists of IARI/ SAUs/ other ICAR institutes. Dr. Mangala Rai, Secretary, DARE and DG, ICAR was the chief guest of the *kisan goshthi* on February 24 and Dr. C.D. Mayee, Chairman, ASRB was the chief guest of the *kisan goshthi* on February 25. After the *kisan goshthi* on February 26, the valedictory function of the *krishi vigyan mela* was graced by Shri Kanti Lal Bhuria, Hon'ble Minister of State for Agriculture, Government of India who addressed the farmers and distributed prizes and certificates to various participating organisations/progressive farmmen/ farmwomen.

6.3.8 *Kisan Mela* organized at Regional Station, Pusa

For popularization and wider dissemination of IARI technologies and varieties, a *kisan mela* was organized at IARI Regional Station, Pusa on March 18, 2007. The major attractions of the *mela* were: quiz competition for the farmers; fruit, vegetables and flower exhibitions; and face-to-face farmers-scientists' interaction during *kisan goshthi*.

6.3.9 Off-campus Exhibitions/Field Day/ Farmer's Day

The Institute participated in several agricultural exhibitions for display/sale of IARI technologies, products, services, and publications.

The Division of Soil Science and Agricultural Chemistry of the Institute organized a field day on September 16, 2007 at Lohtaki village, Gurgoan district, Haryana. More than 200 farmers from Lohtaki and neighbouring villages participated in this event. Farmers were taken to the experimental fields, wherein they interacted with the scientists and gained knowledge about the benefits of soil testing and soil test based site specific nutrient management (SSNM) in augmenting the crop yields.

Scientists of the Indian Agricultural Research Institute and the International Plant Nutrition Institute interacting with the farmers at the on-farm experiments on SSNM at Lohtaki village, Gurgoan district, Haryana

Participation of IARI in off-campus events

S. No.	Name of event	Place	Period
1.	Exhibition during Delhi University Seminar	Delhi University, Delhi	January 19-20, 2007
2.	Krishi Expo 2007	Pragati Maidan, New Delhi	February 21-25, 2007
3.	KVK *KisanMela*	KVK, Shikohpur, Gurgaon	March 1, 2007
4.	YFA *Kisan Mela*	Rakhra, Patiala, Punjab	March 24, 2007
5.	Krishi Vigyan Mela	Khammam, Andhra Pradesh	March 25-26, 2007
6.	Northern Regional Agricultural Fair cum Mango Show	Lucknow (UP)	June 15 -17, 2007
7.	Regional Level Science Exhibition of CBSE	Bal Bharti School, New Delhi.	August 17-18, 2007
8.	Nineteenth Mango Festival 2007 organised by Delhi Tourism & Transportation Development Corporation Ltd	Talkatora Stadium, New Delhi	July 7-8, 2007
9.	Exhibition on Agro-food and Value Added Products of ICAR	NASC, New Delhi	July 16, 2007
10.	National level Kisan Sammelan	Utsav Maidan, Pilani (Raj.)	September 9, 2007
11.	*Kisan Mela*	YFA campus, Rakhra	September 19, 2007
12.	*Kisan Mela* and *Pashu Vigyan Pradarshani*	IVRI, Izzatnagar	November 1-3, 2007
13.	Eleventh IITF-2007	Pragati Maidan, New Delhi	November 14-27, 2007

A farmer's day was organized on July 7, 2007 at the Dhanda Farm of IARI Regional Station, Amartara Cottage, Shimla. More than 100 farmers, vegetable growers and apple orchardists participated and took keen interest in the cultivation of newly evolved varieties of temperate fruits.

6.3.10 Training Programmes Organised for Farmers and Extension Workers

Several training programmes were organized by the CATAT/ATIC on different topics during the period under report.

Trainings organized by CATAT/ATIC

S.No	Topic of training	Date(s)
1.	Importance of bio-fertilizers in crop production in Ureeka village (Jhunjhunu district)	July 5, 2007
2.	Importance of bio-fertilizers in crop production in Sandhal village (Sonepat district)	July 10, 2007
3.	Importance of bio-technology in agriculture	August 3, 2007
4.	Pre-seasonal *kharif* crops	August 9-10, 2007
5.	Water harvesting and water conservation	August 17, 2007
6.	Integrated pest management in vegetable crops	August 24,2007
7.	Dryland farming	August 31,2007
8.	Training on mushroom cultivation	November 6, 2007
9.	Training programme on *rabi* crops	November 26-27, 2007
10.	Integrated nutrient management	December 7, 2007
11.	Post harvest technology and animal health care in Sandhal Khurd village, Sonepat district	December 17, 2007
12.	Post harvest technology and animal health care in Galibpur village, Najafgarh block, Delhi	December 18, 2007
13.	Post harvest technology and animal health care in Asanda village, Jhajjar district	December 19, 2007
14.	Post harvest management	December 27, 2007

6.3.11 Technology Dissemination through Agricultural Technology Information Centre (ATIC) - A Single Window Delivery System

ATIC is effectively providing products, services, technologies and information to the different stakeholders through a 'Single Window Delivery System'. The farmers and other stakeholders visiting ATIC are provided farm advisory services and other related information. Farmers are also given farm advice through Pusa Helpline (011-25841670), exhibitions, farm literature and letters. A IInd Level of Kisan Call Centre (1551) was established at ATIC for ready solution to the problems/queries of farmers of Delhi and Haryana states. To educate the farmers about IARI varieties, live demonstrations of *Dhaincha* as green manure crop in *kharif* and mustard vars. Pusa Jai Kisan, JD 6, Pusa Krishma, Pusa Bold, Pusa Vijay and LES 1-27, Wheat vars. HD 2687, HD 2851, HD 2824 and HD 2643 in *rabi* 2007-08 were conducted for the benefit of the visitors. High density fruit trees orchard planted with lemon (Kagzi Kalan), mango (Amrapali), guava (Allahabadi Safeda), *ber* (Banarasi Karaka), and a new plantation of *aonla* (Vars. NA 7, NA 10, Krishna, Lakshmi 52, Chakaiya) and *Jatropha* are catering to the growing information needs of farmers. Medicinal plants such as aloe vera, *sataver* and *aswagendha* were also planted for the benefit of visitors. Information and advisory needs of the visitors are also being catered through information museum, plant clinic, farm library, and exhibits related to agriculture implements, seed samples, bio-fertilizers, etc., displayed in the Centre.

More than 12,000 farmers/entrepreneurs, development department officials, students, NGO representatives, etc. from 22 states of India visited ATIC during the year for farm advice, diagnostic services, purchase of technological inputs/ products and trainings. Purpose-wise maximum number of farmers visited ATIC to purchase/enquire about seeds/ varieties (6452). The rest of the visits related to information on horticultural and medicinal plants (4588), plant protection (1248), agro-based enterprises (894), farm literature (2642), dairy (536), agricultural implement (755) and others (965). State-wise, out of the total farmers visited ATIC, U.P.(28%) ranked the first followed by Haryana (24%), Delhi (18 %), and Rajasthan (15 %). Two thousand one hundred and sixty eight farmers/entrepreneurs from 16 states were able to get information on various aspects of agriculture through Pusa Help-line and Kisan Call Centre (IInd level). Purpose-wise, maximum calls were made by the farmers related to seed availability (1125) followed by production technology (870), plant protection (815), agro-based enterprises (268), literature (398), biofertilizer (296) and others (478). Seeds of improved varieties, worth Rs. 405611 and various publications worth Rs. 14506 were sold by ATIC during the period.

Two bulletins, "*Fal Fool Evam Sabjiyon Ki Utpadan Takniki*" and "*Krishi Evam Gramin Vikas - Yojanayen Aur Suvidhayen*", and two issues of six monthly magazine "Prasar Doot" were published during the year. Fourteen pamphlets on cereals, pulses, vegetables and fruit crops were also printed and distributed free to visiting farmers. Besides this, more than 98 farmers were given farm advisory services through letters during the period. ATIC also participated in 10 exhibitions and 3 farmers' field days where IARI products, services and technologies were displayed. Visitors took a lot of interest in IARI products and technologies.

The demand for IARI products, technology and services is increasing day by day in the market. Besides

farmers, industry has shown a lot of interest in IARI research products. The ATIC is providing a mechanism for getting direct feedback from the technology users to the technology generators. The feedback strengthened the ATIC activities and provided a ground for need based technologies. The ATIC also developed functional linkages with various agencies working for the farming community to effectively cater to the information needs of various kinds of visitors.

6.3.12 Krishi Vigyan Kendra (KVK), Shikohpur, Gurgaon

The Institute's Krishi Vigyan Kendra (IARI) at Shikohpur, Gurgaon is playing a significant role in combating unemployment of rural youth through technological empowerment, and improving the farmers' awareness and farm productivity through various TOT programmes.

6.3.12.1 Front line demonstration (FLD) programme

FLDs on oilseeds, pulses and cereal crops are playing a catalytic role in the transfer and dissemination of location specific crop technologies in the area. During *rabi* 2006-07 and *kharif* 2007, 80 demonstrations (covering 39.00 ha) on oilseeds, pulses and cereal crops were organized in the farmers' fields in 7 villages of 4 blocks of Gurgaon district. Out of 80 demonstrations, 48 demonstrations on mustard (var. Pusa Jagannath), 16 demonstrations on gram (var. Pusa 1103), 8 demonstrations on lentil (var. K 75), 5 demonstrations on *arhar* (var. Pusa 992) and 3 demonstrations on *moong* (var. Pusa.Vishal) were laid out in the farmers' fields.

An average yield of 1.38, 1.46, 0.94, 1.82, and 1.05 tonnes per hectare in respect of mustard, gram, lentil, *arhar* and *moong* crops was obtained, respectively. The comparative results revealed that the average yield of mustard, gram, *arhar*, and *moong* increased by 14.85%, 10.24%, 12.26%, and 66%, respectively, over that obtained with the farmer's existing practices. The lentil crop was introduced first time in the FLD programme of KVK.

Sponsored front line demonstrations. During *rabi* 2006-07, the KVK organized 26 FLDs (covering 8.00 ha) sponsored by the National Fertilizers Limited, Noida (UP) on the use of bio-fertilizer, and 4 FLDs (covering 2.40 ha) sponsored by the National Centre for Organic Farming, Ghaziabad (UP) on organic farming in farmers' fields in different villages of Gurgaon district.

6.3.12.2 Trainings for different target groups : achievements

The major objectives of on-campus and off-campus trainings were to generate opportunities for income and employment, to provide technical know–how and to update the knowledge of in-service personnel of agriculture departments.

Demonstrations on bio-fertilizers and organic farming

Sponsoring agency	Season/ year	Crop	Variety	No. of demonst-rations	Area (ha)	Av. yield of demonstrations(t /ha)			Yield of local check (t/ha)	Increase in yield over local check(%)
						Highest	Lowest	Average		
National Fertilizers Limited (NFL), Noida (UP)	*Rabi* 2006-07	Mustard	Pusa Jagannath	08	3.20	2.21	1.75	1.95	1.91 (Luxmi)	2.09
		Pea*	Azad P1	06	2.40	8.00	6.20	7.00	6.80 (P.Pragati)	2.94
		Wheat	WH 711	06	2.40	5.40	4.25	4.79	4.71 (HD 2824)	1.69
Theme (Use of bio-fertilizers)		Total	—	20	8.00	—	—	—	—	—
	Kharif 2007	*Bajra*	Hyb 9444	08	3.20	3.03	2.62	2.81	2.60	8.07
		*Jowar***	Hyb PSJ 9999	12	2.40	49.00	40.50	43.80	38.00	15.26
		Paddy	Pusa Sugandh 5	06	2.40	5.47	5.02	5.21	4.90	6.32
		Total	—	26	8.00	——	—	—	—	—
National Centre for Organic Farming, Ghaziabad Theme (Organic farming)	*Rabi* 2006-07	Pea	Azad P 1	02	1.20	1.23	1.18	1.20	1.55	(-) 22.58
		Wheat	WH 711	02	1.20	1.44	1.26	1.35	1.88	(-) 28.19
		Total	—	04	2.40	—	—	—	—	—

*Application of bio-fertilizers under FLDs
- Mustard – Azotobactor + PSB
- Peas – Rhizobium + PSB
- Wheat – Azotobactor + PSB

Bajra – Azotobactor + PSB
Jowar – Azotobactor + PSB
Paddy – Azotobactor + PSB + Azospirillum

* Green pods sold as vegetable
** Sold and used as green fodder
Note: Low yield was obtained because of the use of organic inputs under organic farming

The details of trainings organized for different target groups during 2007 are as follows.

Vocational trainings for rural youth including girls. During the year, 12 vocational training courses on the subjects, viz., bee-keeping (1), dairy farming (2) dress designing & tailoring (2), landscaping & beautification (1), motor winding (1) Custom service in plant protection (1), establishment and management of orchards (1), vermi-compost technology (1), preservation of seasonal fruits and vegetables (1) and raising of plant nursery under poly-net house (1) were organized. Through these trainings, 224 youth (99 male and 125 female) were benefited.

Skill training on motor winding

In-service (refresher course) trainings. Two in-service trainings (refresher course) – one on integrated pest management (IPM) and the other on integrated plant nutrient management (IPNM) – were organized for Agriculture Development Officers (ADOs) of Haryana Agriculture Department, Gurgaon during the year 2007. Through these training courses, 31 ADOs were benefited.

Day-long trainings. During the period, 58 day- long training programmes for the practicing farmers and farm women were organized in different disciplines to update the knowledge about production and protection technologies of oilseeds, pulses, vegetables and cereal crops, and other allied areas. Through these trainings, 1537 farmers (1101 male and 436 female) were benefited.

Discipline-wise on/off-campus trainings organized during the year 2007

Training areas	No. of trainings	No. of beneficiaries		
		Male	Female	Total
Crop production	12	240	15	255
Plant protection	16	465	34	499
Horticulture	13	112	61	173
Dairy farming	14	250	300	550
Agril. engineering	02	30	—	30
Home management	01	04	26	30
Total	**58**	**1101**	**436**	**1537**

6.3.12.3 Agricultural extension activities and farm advisory services

For speedy dissemination of technologies among the farming community, the KVK organized various extension activities in the villages and at KVK campus. During the period under report, 426 such activities were organized. Out of 426, 1 *kisan mela*, 11 field days on different crops,1 women in agriculture day, 6 animal health day-cum-clinical camps, 1 honey day, 42 method demonstrations, 48 group discussions, 3 camps/campaigns on plant protection, water saving and soil testing, 45 lectures by the subject matter specialist (SMS)on various occasions, 15 programmes on TV/ radio, 106 field visits of scientists/SMS in farmers' fields, 120 visits of farmers at KVK for farm advisory services, 22 media coverage of different activities and 5 exhibitions were the important activities to mention. Eight hundred sixty five (865) animals were also treated for different types of ailments through animal health camps.

The *Krishi Vigyan Patrika,* a quarterly Newsletter of KVK in Hindi, continues to provide the latest technologies to the farmers at proper time at their doorsteps. It provides relevant technical know-how related to the production technologies of field crops, fruits, vegetables, home and dairy management. During the period, 5641 (4137male and 1504 female) members of different farming communities were benefited through these programmes. Among the beneficiaries, 68% belonged to OBC, 11% to SC and 21% to other categories.

6.3.12.4 On-farm testing

During the year 2007, 24 on-farm trials (covering 6.50 ha) were conducted on different field/farm problems, and one trial (covering 20 calves) was conducted on calf mortality. By adopting the tested technologies and recommendations in their farming, the farmers received more profit compared to that obtained with the farmers' practices. The direct beneficiaries of this programme are playing a catalytic role for other fellow farmers of the village and neighbouring villages.

Three deworming drugs, namely, Albandazole, Morentel citrate and Piprazine were tested on buffalo calves to check calf mortality. Albandazole drug was found to be most effective as compared to other drugs.

Major OFTs, and their comparative yield performance

Sl. No.	Field problem/ title of OFT	Technology tested			Control (farmer's practice)			Increase in yield over farmer's practice(%)
		No. of trials	Treatments	Av. yield (t/ha)	No. of trials	Treatments	Av. yield (t/ha)	
***Rabi* 2006-07**								
1.	Evaluation of new herbicide molecule for weed control in wheat	04	Clodinofop @ 60 g /ha	3.72	04	Hand weeding / no use of any chemical	3.35	11.04 %
2.	Application of zinc sulphate in wheat crops	04	Zinc sulphatre @25 kg/ha at the time of sowing	3.56	04	No use of zinc sulphate	2.96	20.27%
3.	Management of nematode in wheat crops	04	Soil treatment with carbofuran (3G) @ 33 kg /ha & neem cake @500 kg /ha	5.22	04	No use of any chemical	4.78	9.20%
4.	Management of pod borer in gram	04	i.) Pheromone trap ii.) Use of NPV, @ 1ml/l of water iii.) Neem seed extract @ 5 ml/l of water iv.) Use of wooden T sticks for the bird predatory birds	1.69	04	- One spray of endosulphan @ 2ml/l of water- One spray of dichlorovas @ 1ml/l of water	.1.40	20.71%
***Kharif* 2007**								
5.	Management of pod borer in *arhar*	05	i.) Use of Pheromone trap ii.) One spray of endosulphan and one spray of quinolphos @ 2 ml/l of water	1.85	05	One spray of endosulphan @ 2ml/l of water	1.63	13.50%
6.	Management of nematode in chillies	03	Soil treatment with carbofuran (3G) @ 33 kg/ha -Seedling treatment by dipping of roots for ½ h in trizophos (40 EC) solution @ 2.5 ml /l water	1.93	03	Two sprays of dimethoate (30 EC) 2 1ml /l of water at 30 and 40 days after transplanting	1.50	28.66%

7. EMPOWERMENT OF WOMEN AND MAINSTREAMING OF GENDER ISSUES

7.1 EMPOWERMENT OF FARMWOMEN

Rural women play a significant role not only in homestead activities but also in agricultural development and allied fields. However, the status of rural women has not improved commensurate with their role. Women have proven that they can be good entrepreneurs and development managers in any kind of activities.

The Institute's Centre for Technology Assessment and Transfer (CATAT) and Krishi Vigyan Kendra (KVK) at Shikohpur organized several training programmes oriented towards empowerment of women.

Three capacity building training programmes on post harvest technology were organized by CATAT in Sandhal Khurd village, Sonepat district (Haryana), Galibpur village, Najafgarh Block, Delhi, and Asanda village, Jhajjhar district (Haryana). Women were trained to improve their skills in the preparation of preserves using *aonla* and tomatoes. The other objective was to make women aware of the importance of nutritive preserves and enable them to improve the nutrition of the family and save money by preparing preserves at home. Seventy women participated and were benefited through these training programmes.

School girls taking skill training on preparation of *aonla* pickles

Three training programmes on improved breeding, feeding, management and health care practices for milch animals were also organized by CATAT for farmwomen of OEP areas in Sonepat and Jhajjhar districts of Haryana, and Najafgarh block of Delhi. More than 100 farmwomen were benefited through awareness generation on improved management practices like navel treatments, control of gut acting endoparasites, control of ectoparasites of their animals, and feeding practices for growing stock, pregnant and milch animals for increased milk production. Three animal health care camps were also organized on these days in which 128 (54+24+50) dairy animals were attended for treatment against various ailments including gynecological problems of sub-fertility, ectoparasites and endoparasites, etc.

Dr. H.S. Gaur, Dean and Joint Director (Education), IARI giving away prizes and certificates to the participants at a function on "Women in Agriculture Day" organized by the KVK, Shikohpur, Gurgaon

The CATAT also organized a 'Women Empowerment Workshop' during Pusa Krishi Vigyan Mela, which was inaugurated by Mrs. Renuka Chawdhury, Hon'ble Minister of State for Child and Women Welfare, Government of India on February 25, 2007. On this occasion, progressive farmwomen, Smt. Versha Tomar, President of a women self help group (SHG), Smt. Rajwati of Tatesar village and Smt.

Sarvesh Yadav of Shikohpur village, Gurgaon shared their success stories and experiences with other participating women. Scientific deliberations on women empowerment and care of milch animals were conducted by the scientists of the Institute. A large number of farmwomen from different parts of the country participated in the workshop and shared their views on latest issues/schemes of the government for empowerment of women.

The Institute's KVK, Shikohpur launched a programme for empowerment of women to enable them to realize their full identity and power in all spheres of life.

The objectives of the programme at KVK are as follows:

- To increase women's employment opportunities
- To increase women's work efficiency
- To increase women's energy input/output ratio
- To ensure efficient use of available resources
- To raise women's socio-economic status
- To reduce farmwomen's dependence on skills of men folk
- To enable farmwomen to take equal part in decision-making process
- To generate self-confidence among farm women
- To strengthen farmwomen's participation in national development

Based on a need assessment, the KVK organized 25 training courses on dress designing and stitching, preservation of seasonal fruits and vegetables, dairy farming, and beekeeping for empowering women at village level. Through these trainings, 542 rural women were trained.

Other important programmes and activities organized by the Institute's KVK, Shikohpur for the rural women are as under:

- Organization of vocational courses for income generation
- Trainings in villages for updating the farm knowledge/ skill
- Method demonstration and organized visit of rural women in agricultural fairs and exhibitions
- Celebration of farmwomen in agriculture day

During 2007, a total number of 28 activities were organized at campus and in the villages. Through these activities, 792 rural women were benefited. Out of these participants, 115 (14.42%) belonged to SC, 510 (64.39%) to OBC, and 167 (21.09%) to other castes.

7.1.1 Socio-economic Impact Programmes and Activities Organized for Rural Women

- After getting vocational trainings, the rural women were able to save Rs. 2500-3000/- per annum by stitching garments for their family members and other needy neighbours.
- Some rural women started their own training centres and provided trainings to needy girls/women on tailoring in their villages.
- A few women took up processing as a part time vocational activity to generate additional income by locally selling pickles.
- Dairy farmers obtained comparatively more net profit from dairy enterprises by the adoption of low cost dairy management practices.
- Through village trainings and method demonstrations, the farmwomen were able to do farm work (including dairy farming) with the application of improved technologies, and obtained more profit.
- Organized visits of rural women to agricultural fairs and exhibitions, and participation in functions for farmwomen played an important role in orienting them towards scientific farming.

A veterinary specialist of the KVK training women on dairy farming

7.2 GENDER EMPOWERMENT AND FARMING SYSTEM DEVELOPMENT: AN ACTION RESEARCH STUDY

7.2.1 Farming System Development

Introduction of improved crop varieties and hybrids for higher productivity. A number of demonstrations (138) with unit area of one acre were conducted for improved varieties/ hybrids of wheat (54), mustard (20), gram (3), pea (13), paddy (23) and pigeonpea (25) developed by IARI to show the potential of these varieties and develop conviction among the farmers of the project villages, namely, Mumtajpur, Banspadamka, Safedarnagar and Lokra of Pataudi block and Sampka and Johari of Farookhnagar block of Gurgaon district, Haryana during *kharif* and *rabi* seasons. Emphasis was laid on integration of pulse crops in their cropping pattern as over the years they avoided cultivation of pulse crops owing to pest incidence (particularly gram) and low yield. Farmers were satisfied with the performance of paddy variety Pusa 1121 and hybrid PRH 10, which yielded 2.1 tonnes/acre and 2.6 tonnes/ acre, respectively, against 2.0 tonnes/acre from a traditional variety (*Muchhal*). Cultivation of PRH 10 was also favoured because of its short duration. Harvest of PRH 10, fifteen to twenty days earlier than traditional paddy, facilitated early land preparation and sowing of next crop.

Capacity building for hybrid seed production. Interventions were made through trainings and on-farm trials on hybrid seed production of paddy (PRH 10). As a result, the farmers gained knowledge and skills in the following areas:

- Principles of hybrid seed production
- Staggered sowing of male and female parental lines
- Transplanting of male and female plants in alternate rows (2:6)
- Managing synchronization of flowering and facilitating pollination with mechanical process ofsweeping with rope or chemical treatment with GA_3
- Managing genetic purity with isolation distance, physical barrier, staggered planting time, and recurrent rogueing
- Harvesting with caution to ensure seed purity
- Sharing of knowledge and lessons learnt among fellow farmers
- Farmer-to-farmer seed exchange

As a result of the interventions, a farmer named Shri Bhura Singh, and his family from Mumtajpur village could secure a harvest 0.24 tonne of PRH 10 seed from 0.30 hactare plot and sold it @ Rs. 180/- per kg seed. Then, he earned Rs. 43200/- besides Rs. 4200/- from produce of male plants. Satisfied with the success, a group of five farmers decided to take up seed production programme in their village.

Capacity building of vegetable growers in net house nursery and IPM. A group of 15 farmers were provided trainings in net house nursery raising and use of IPM practices in vegetable cultivation. As a result, the seedlings of cauliflower were developed 15 days earlier with minimal mortality as compared to those developed in open field nursery which benefited the farmers to the tune of Rs. 15-20 thousand extra per acre.

Farmers learnt about the management of major insect pests and diseases of vegetable crops through integrated cultural and chemical practices. They also learnt about the economic threshold level based pest management, judicious use of pesticide and the measures (avoiding pesticide application at bloom stage and the use of synthetic pyrethroids) to safeguard pollinators and bio-agents. They also learnt about the trap crops and the use of *Trichoderma*. Root dip treatment of the saplings with *Trichoderma* helped in managing the problem of root rot.

Trainings organized for gender empowerment

Training area	Date	No. of participants
Hybrid seed production in paddy and pest management	21.6.07 & 7.10.07	50
Improved cultivation of vegetables with IPM practices	21.6.07	50
Nursery raising with net house and IPM practices	2.8.07	15
Management of animal nutrition and diseases	7.10.07	200

Animal camp. The Institute organized a training camp on management of animal nutrition and diseases to educate the farmmen and farmwomen about healthy and hygienic care of cattle at Mumtajpur village on October 10, 2007. Two hundred farmers brought their buffaloes and cows for check up. Remedies were suggested, and treatments were given on the spot by veterinary doctors. Women learned about safe practices in milking and balanced nutrition for their cattle.

7.2.2 Gender Empowerment

Formation of self help groups (SHGs). Women were motivated for group action. Initially, they were educated about the modalities of formation of SHG; its structure and function; process of money collection, deposition in bank, loaning and recovery; and monthly meeting, and record keeping. Four groups were formed and registered with the Grameen Bank at Pataudi.

Dr. S.A. Patil, Director, IARI giving away an appreciation certificate and a trophy to a member of the self help group (SHG) for her contribution to the creation of self employment, and income activities for other rural women of the area at a function organized by the KVK, Shikohpur, Gurgaon

Training for self-enterprise. Based on the assessment of the need of women, trainings on candle making, *dal* making and value addition (preparation of sweet products of *bajra*, *dalia* of wheat, etc.) were given to women. One group undertook *dal* making, and another group candle making as enterprises for additional income. The Institute organized several training programmes for women of Sampka village.

Trainings organized for farmmen and farmwomen

Training area	Date	No. of participants
Capacity building of SHGs of women in non-farm enterprises for employment and income generation (candle making)	21.5.07	30
Stitching and embroidery	24.5.07	25
Gender empowerment and food security	16.8.07	50
Mobilizing women for SHG formation and management	8.9.07	30

Sensitization of women about food and nutritional security. Women were sensitized about food and nutritional security through an interface of rural women and scientists on World Food Day (October 16, 2007). On this day, a debate was organized for school children on the topic "Contribution of Women in Food and Nutritional Security" to promote awareness among rural women. A quiz was also held for rural women about nutrition deficiency diseases, and their management, health and hygiene, hygienic cattle keeping, safe storage of agricultural produce and food. The winners were encouraged with certificates and prizes.

8. POST-GRADUATE EDUCATION AND INFORMATION SYSTEM

8.1 POST-GRADUATE EDUCATION

8.1.1 Admission during the Academic Session 2007-2008

The Post Graduate School of IARI continues to attract a large number of students seeking admission to various PG courses. The admissions to the Ph.D. programme are made on the basis of candidates' performance in a national level entrance examination conducted in different parts of the country followed by an interview and academic records, while the admissions to the M.Sc. programme are made on the basis of a combined all India competitive examination for Junior Research Fellowship and Master's degree programme of deemed universities of ICAR and state agricultural universities conducted by the Indian Council of Agricultural Research (ICAR). The foreign students are admitted through DARE, Ministry of Agriculture, Govt of India. Foreign students are exempted from appearing in the written test and interview.

During the academic year, 2007-2008, 187 students were selected for admission to various M.Sc. and Ph.D courses.

Category- wise number of students admitted to M.Sc. and Ph.D.

Category	M.Sc.	Ph.D	Total
Open competition	78	99	177
Foreign students	2	8	10
Total	80	107	187

* Foreign students admitted were from the countries, namely, Egypt, Ethiopia, Iran and Libya

The total number of students on roll were 531 (166 M.Sc. and 365 Ph.D.) which includes 30 students from foreign countries, namely, Egypt, Ethiopia, Iran, Libya, Srilanka and Vietnam.

8.1.2 Convocation 2007

The 45th convocation of the Indian Agricultural Research Institute (IARI) was held on February 9, 2007. Dr. Mangala Rai, Secretary, Department of Agricultural Research & Education (DARE) and Director-General, Indian Council of Agricultural Research (ICAR), who was the chief guest, delivered the convocation address. In his address, the chief guest highlighted the priorities and issues in the development of agriculture in the changing national and international scenarios.

Dr. S.A. Patil, Director, IARI, in his report, presented the significant research achievements of the Institute during the year 2006. Dr. H.S. Gaur, Dean & Joint Director (Education), IARI, highlighted the important role being played by the Institute in human resource development in terms of post-graduate teaching, short-term training courses and modernization of post-graduate students' laboratories, lecture halls, hostels, dispensary, etc.

A Ph.D. student receiving her degree certificate from Dr. Mangala Rai, Secretary, DARE and Director-General, ICAR at the convocation. Also seen in the picture are: Dr. S.A. Patil, Director, IARI (centre), Dr. S. Nagarajan, Chairperson, Protection of Plant Varieties and Farmers' Rights Authority, Government of India (left), and Prof. V.L. Chopra, Member, Planning Commission, Government of India (right)

A series of IARI publications, including volume 29 of the Journal of IARI Post Graduate School, 2006 (renamed 'Pusa AgriScience'), and 12 IARI crop varieties were released during the convocation.

At this convocation, 75 M.Sc. and 73 Ph.D. students were awarded degrees. Mr. P.N. Sivalingam (Plant Pathology) and Mr. Mridul Chakraborti (Genetics) were awarded the 'Best Student of the Year 2006' award for Ph.D. and M.Sc., respectively. Five recipients of Ph.D. degrees, namely, Ms.

Dipanwita Haldar (Agricultural Physics), Mr. Berin Pathrose (Entomology), Ms. Malathi Priya M. (Environmental Sciences), Mr. Mahesh Yandigeri (Microbiology) and Mr. Satya Pal Kumar (Molecular Biology & Biotechnology); and five recipients of M.Sc. degrees, namely, Mr. Manoj V.B. (Agricultural Chemicals), Mr. C.Y.M. Kanhaiya (Agricultural Extension), Mr. Anees K (Biochemistry), Mr. N. Karthikeyan (Microbiology) and Mr. Aashish Ranjan (Molecular Biology & Biotechnology), were awarded the 'IARI Merit Medal' for their outstanding academic performance.

Five faculty members, namely, Dr. D.V.K. Samuel (Post Harvest Technology), Dr. Indra Mani (Agricultural Engineering), Dr. K.D. Srivastava (Plant Pathology), Dr. (Ms.) K. Annapurna (Microbiology) and Dr. V.K. Sharma (Agricultural Statistics) were awarded the 'Best Teacher Award' for their outstanding contribution to teaching.

The 2nd Rao Bahadur Dr. B. Viswanath Award for the Biennium 2004-2005 consisting of a cash prize of Rs. 1,00,000/-, a gold medal and commendation certificate was awarded to Dr. B.S. Parmar, former Joint Director (Research), IARI (presently Emeritus Scientist, Division of Agricultural Chemicals, IARI), for his outstanding research contributions to eco-friendly agro-chemicals.

The 7th Hari Krishna Shastri Memorial Award for the year 2006 consisting of a cash prize of Rs. 25,000/- and a commendation certificate was awarded to Dr. G.R. Patel, Joint Director (Academic), National Dairy Research Institute, Karnal, for his outstanding research contribution to dairy technology.

The 19th Hooker Award for the biennium 2004-05 consisting of a cash prize of Rs. 15,000/- and a commendation certificate was awarded to Dr. R.K. Sairam, Principal Scientist, Division of Plant Physiology, IARI, for his outstanding research contributions to the field of plant physiology.

The 11th B.P. Pal Memorial Award for the year 2006 consisting of a cash prize of Rs. 10,000/-, a gold medal and a commendation certificate was awarded to Dr. B.M. Prasanna, National Fellow, Division of Genetics, IARI, for his outstanding research contribution to application of molecular breeding approaches for improvement of maize.

The 37th Lal Bahadur Shastri Memorial Lecture was delivered on February 8, 2007 by Dr. M.V. Rao, Chairman, BPC-APNL Biotechnology Programme, Hyderabad, on the topic, "Green Revolution — Lessons Learnt and Strategies for Future." The function was presided over by Dr. Asis Datta, Director, National Centre for Plant Genome Research, New Delhi.

8.1.3 Training Programmes

Several training programmes were organized by the Institute during the year 2007.

Training programmes organized

Training programme	Period
Division of Agricultural Chemicals	
• Pesticide residues extraction and analysis procedures	December 1 – 31, 2007
Division of Agricultural Engineering	
• Motor winding for rural youths	October 26 – November 5, 2007
Division of Agricultural Extension	
• Advances in extension research • Empowerment of rural youths through participatory extension methodology	November 19 – December 19, 2007 November 29 – December 19, 2007
Division of Agricultural Physics	
• Remote sensing application in agriculture with special emphasis on crop growth monitoring system	December 1 – 24, 2007
Division of Agronomy	
• Resource conserving techniques for improving input use efficiency and crop productivity	September 4 – 24, 2007
Division of Biochemistry	
• Advanced biochemical and molecular techniques	September 18 – October 8, 2007
Division of Fruits & Horticultural Technology	
• *Nursery prabandhan tatha adhunick phal utpadan* • *Audyanik phasalon ki nursery avam adhunik nursery pravardhan tatha phal utpadan*	July 18 – 24, 2007 September 25 – October 1, 2007

Division of Nematology	
• Workshop on nematology in India: achievements and opportunities	March 3 – 7, 2007
Division of Plant Pathology	
• Biocontrol of plant pathogens • Mushroom cultivation	August 1 – 21, 2007 September 23 – 27, 2007
Division of Post Harvest Technology	
• Farmers' training on post harvest management of horticultural produce	March 19 – 24, 2007
Division of Seed Science & Technology	
• Seed quality control • Plant variety protection and related issues • *Kaddoo jatiya sabji faslon mein sankar beej utpadan takneek* • Seed production and marketing • Seed laboratory analysis and technology • Seed quality evaluation (for officials from Iraq) • DUS testing for plant variety protection – principles and procedures	March 15 – 22, 2007 August 21 – October 27, 2007 August 31 – September 1, 2007 September 31 – October 25, 2007 November 13 – December 11, 2007 November 15 – December 26, 2007 December 18, 2007 – January 7, 2008
Division of Soil Science & Agricultural Chemistry	
• Soil testing, plant analysis and water quality assessment	September 6 – 26, 2007
Division of Vegetable Science	
• Improved production technology of vegetable crops	March 28 – 29, 2007
Water Technology Centre	
• Micro-irrigation system and water conservation technology	January 2 – 9, 2007
Centre for Protected Cultivation Technology	
• Drip irrigation and protected cultivation technology • Protected cultivation of horticultural crops • Advances in protected cultivation of vegetables	April 23 – 28, 2007 April 30 – May 5, 2007 May 10 – 15, 2007 November 19 – 25, 2007 November 26 – December 1, 2007 December 3 – 8, 2007 December 10 – 21, 2007
Unit of Simulation and Informatics	
• Computer basics with application in office automation	January 27 – 31, 2007

8.2 INFORMATION AND DATABASE

8.2.1 Agri-Informatics

A case study of Orissa was done for the development of crops and cropping system database for the application of agri-simulation models and decision support systems for assessing the productivity of crops under various biotic and abiotic stresses and suggesting the optimal use of inputs for sustained productivity of major crops. The agro-climatic zones-wise crop and cropping system information was collated and parameterization for commonly used rice was done. The potential yield of the rice crop was worked out with crop models INFOCROP and ORYZA using 25-year daily data of Cuttack. The information generated is important to make decisions for the adoption of suitable agronomic and management options to sustain crop productivity.

Spatial maps for the derived soil parameters were prepared on a district level scale. For two districts, namely, Bolangir and Nuwapara in Orissa, spatial soil information such as soil class, surface texture, soil depth, soil reactions including salinity/alkalinity, flooding, etc., was collated and processed using GIS tool. Soil quality quotient is under process for one district. This information system would be used to access site-specific information for soil quality quotients of the agro-ecological zones (AEZ) and districts.

It was reviewed that most of the crop growth models have limitations in terms of phosphorus. An attempt was made to incorporate a phosphorus module for INFOCROP. Phosphorus module once developed, calibrated and validated may have potential in its use in Infocrop crop-simulator. This module will account for various stages of crop growth and their impacts such as nutrient P uptake, transpiration, and soil residue. The

phosphorus cycle is simulated by the processes that include mineralization, immobilization, and mineral cycling.

During November, 2007 a research project on "Consortium for e-Resources in Agriculture (CeRA)" was sanctioned under NAIP with IARI as the Nodal Agency. The project aims to facilitate on-line accessibility of some of the foreign journals to 123 users under NARS (comprising ICAR institutes, SAUs, and NRCs).

8.2.2 Bioinformatics

8.2.2.1 In-silco prediction of structure and function of hypothetical proteins

An attempt was made to predict the structure and function of the protein (acc, no AAG 52239) of *Arabidopsis thaliana* which is hypothetical in nature. *Arabidopsis thaliana* is a mustard weed which contains 27,029 protein coding genes (TAIR7). Majority of proteins are still unannotated and have been termed as unknown or putative or hypothetical. The difficulty in the prediction of structure and function of hypothetical protein is due to its low similarity with other known proteins. Therefore, more emphasis was given on fold recognition and domain identification. In this study, a number of online and offline tools were used. It was found that our query sequence is quite similar to 2bw3A sequence and this template has the same domain, i.e., hATC dimerisation domain.

8.2.2.2 Novel gene identification in *Medicago truncatula* using in-silico approaches

The present study was carried out on completed sequences of *Medicago truncatula*, which is a forage legume. Genes from *M.truncatula* share identity to legumes and established symbiotic relationships with nitrogen fixing *Rhizobia* and are colonized by mycorrhizal fungi. In this study, several gene finding programs were used to find genes in the sequences, which utilized one or the other gene-finding algorithmic strategies. For increasing gene prediction accuracy both intrinsic and extrinsic approaches were included by using ab-initio programs and blast search. TWINSCAN which uses a combination of both the approaches for prediction enhancement was also used. The novel genes as predicted by most of the softwares were composed of single exons; hence there were no splice results when NNSplice and NetPlantGene were used on gene again validating our results. Some of the gene finding programs used were GENSCAN, GeneID, GrailEXP, GenMark.hmm and Augustus. BLAST analysis was performed on the genes predicted by these programs to infer homology. WU-BLAST was also executed against the EST sequences of *M.Truncatula* to enhance the validity of the gene. Further confirmation of the result was done through splice-site detection programs and gene prediction program well trained on dicotyledons databasets (Diogenes, TWIMSCAN). From the study, nineteen new genes were predicted from seven sequences. Of the 19 sequences, 10 had a function, 8 were of unknown function, and 1 sequence was a novel gene.

8.2.3 Internet Activities

During the year, the Unit of Simulations and Informatics (USI) maintained and monitored the functioning of internet activities of the entire Institute. In order to minimize, if not completely stop, spam, viruses and unsolicited emails, a unified threat management system (Cyberroam) was installed successfully for stopping infected files/data at the gate end of the internet. In addition to this, antivirus protection from the user end was installed using the 'trend microsystems' software.

8.3 LIBRARY SERVICES

IARI Library is one of the largest and the finest agrobiological libraries in South East Asia housing a total of 6 lakh publications including 1 lakh books/monographs, 3,50,000 journal volumes, 45,000 bulletins, 15,000 post graduate theses, 10,000 pamphlets, 30,000 news clippings, 30,000 reports, and other reference materials. The Library has, on its role, 2000 members, viz., students, scientists and technical staff. It also serves about 8,000 visitors every year. The Library functions as the depository of FAO, IDRC and AVRDC publications and also as the National Depository for CGIAR institutes' publications.

8.3.1 Acquisition Programme

8.3.1.1 Books

During the year, the Library procured 516 publications, which included 258 in Hindi and 258 in English costing Rs. 20,44,893. The Library also acquired 217 gift publications, 156 IARI theses, 5 ICAR/RFT theses, and 173 ICAR award winning theses documents.

8.3.1.2 Serials

The Library procured 806 journals/serials through subscription, gifts and exchanges. It subscribed to 106 foreign journals (out of which 45 had online access) and 252 Indian journals and 54 advances/annual reviews. Exchange relationship was maintained with 185 institutions/parties

globally and nationally by sending annual reports/ Indian journals and society publications.

One hundred seventy-four (174) annual/scientific/ technical reports of different institutions and 152 bulletins were received in the Library. The expenditure on Serial Acquisition Programme from Plan and Post Graduate Strengthening Grant was Rs.77,07,346.

8.3.2 Documentation Activities

8.3.2.1 AGRIS project

IARI Library was declared an input centre for national agricultural research database (NARD) under AGRIS Project. The Library was assigned the job of scanning articles from 10 most important Indian journals. The input was done in ISO format using AGRIN methodology. During the period under report, 392 articles were scanned, processed and sent to DIPA, ICAR for inclusion in AGRIS Index.

8.3.2.2 Development news in agriculture

Four thousand six hundred eighty (4680) news papers were scanned and 35 news items pertaining to IARI as well as ICAR were sent to the Director, IARI and the Principal Scientist (ITMU).

8.3.2.3 Document processing

In all, 1597 documents consisting of books, bulletins, IARI post-graduate theses and Hindi books were processed (classifying and cataloguing).

8.3.3 Resource Management

8.3.3.1 Binding of publications

In all, 2751 volumes consisting of 20,000 loose issues of journals, reports and bulletins were bound and 2751 volumes were accessioned.

8.3.3.2 Reference, circulation and stack maintenance

Apart from approximately 2000 registered members, the Library served approximately 125-130 users, who consulted approximately 2000-2500 documents everyday. During the period under report, 10550 publications were issued to its members. In all, 95 documents were issued under Inter Library Loan System to various institutions including NISCAIR. Three hundred and sixteen No Due Certificates were issued to staff, including scientists, after checking the relevant record.

8.3.3.3 Reprography services

During the period, the Library provided 89,513 pages of photocopies of scientific and technical literature officially. One key cord counter for updating of Resograph GR 1750, one Toshiba Color Photocopier Model Studio 351C and one Toshiba Studio 452 digital photocopier were purchased.

8.3.3.4 CD-ROM workstation

In all, 11,0484 references were downloaded to the users consisting of scientists, and students of IARI, and visitors from all over India. The cost based references downloaded were 8801, which generated revenues amounting to Rs. 7,050. The scientists of IARI were provided access through the Intranet (Local Area Network).

8.3.3.5 C-DAC Project

A memorandum was signed with C-DAC (Ministry of Information Technology) on 4th September 2004 to digitize old documents. During the period, 43,00000 pages of 6250 publications published before 1950 and not covered under Copyright Act were scanned. They can be accessed through the software developed by C-DAC. The first phase of the above project ended on 31st March, 2007.

8.3.4 National Agricultural Library Activities under Agricultural Knowledge Initiative (AKI) Programme

8.3.4.1 Indo-US- AKI workshop on Indian libraries and information system

Indian Agricultural Research Institute, New Delhi organized an Indo-US AKI workshop on Indian Library and Information System under the bi-lateral programme of India and USA. The workshop was held for 2 days from May 16 to 17, 2007 at NAAS complex, New Delhi. The AKI (Agricultural Knowledge Initiative) Programme is a collaborative programme of India and the USA, and is based upon partnership in four major components, viz., biotechnology, curriculum development, food processing and human resources development.

The introductory session was inaugurated by Dr. S.P. Tiwari, DDG (Edn. & CS), who was the Chief Guest. Dr. S.A. Patil, Director, IARI chaired the session. Prominent among others who graced the occasion were Dr. Geral S. Smith, Agricultural Attache, US Embassy, New Delhi, Mr. Janet McCue, Cornell University, and Dr. H.S. Gaur, Dean and Jt. Director (Education), IARI. Mr. N.S. Pakhale, Organizing Secretary, and Head, Library Services, IARI, proposed the vote of thanks.

The library partnership between the National Agricultural Library (India), i.e., IARI Library, and the

National Agricultural Library (USA) comes under the human resources development component. In the said workshop, more than 60 officials participated. The workshop, after the introductory session, had a total 5 technical sessions, namely, 1. Library and Information Systems in USA, 2. Indian Library Resources-Status and Linkages, 3. Library and Information System at Some Leading Institutions/DUs/SAUs, 4. Group discussion : Modernisation of National Agricultural Library, and 5. Group Discussion : Networking of NARS Libraries and NAL, USA.

The technical session 1 was chaired by Dr. S.A. Patil, Director, IARI, session 2 was chaired by Dr. Mruthyunjaya, National Coordinator, NAIP, session 3 was chaired by Dr. Sushil Kumar, Director, NDRI, Karnal, session 4 was chaired by Dr. S.A. Patil, Director, IARI, and session 5 was chaired by Dr. S.L. Mehta, Vice Chancellor, MPUAT, Udaipur.

The concluding session was chaired by Dr. S.L. Mehta, Vice Chancellor, MPUAT, Udaipur with Dr. Janet McCue as Co-Chair person. In this session, the reports on the presentations of the technical sessions were produced by the respective chairpersons.

The major recommendations were as follows:

1. Declare the IARI Library as the National Agricultural Library to be headed by a Joint Director (Library and Information Services)
2. Fill up vacant library positions
3. Fill up the position of Information Scientist with IT background in NAL, SAUs and DUs
4. Compile the e-Resources and databases/journals and book acquisitions
5. Modernise library infrastructure
6. Augment library automation
7. Network with Indian and US libraries
8. Develop human resources
9. Give due attention to disaster management

8.3.5 Training Activities

The following trainings/demonstrations were arranged/ organized by the Training Cell of the Library during the period under report:

1. Basic training about IT sensitisation for F & AO and AF & AO	January 9-11, 2007
2. Basic training about IT sensitisation for Audit Staff	January 15 to February 8, 2007
3. Demo of DODIG for LIS	January 17, 2007
4. Hindi Karyashala for APS 2000 +	January 18-19, 2007
5. Hindi training	June 16, 2007
5. Hindi competition test	August 18, 2007
6. Lecture on E-resources for 25 participants of Summer School	September 9, 2007
7. OVID database training for LIS	September 17, 2007

8.3.6 Bibliography of IARI Theses, 1923-2005 (In CD-Form)

A bibliography of 7364 references comprising theses of 883 Associateships, 2812 M.Sc's. and 3669 Ph.Ds. was released by Shri Rajsekharan, Honourable Minister of State for Planning, Government of India on May 26, 2007 on the occasion of Dr. B.P. Pal Memorial Lecture.

9. PUBLICATION ACTIVITIES

An important mandate of the Institute is to develop an information system, add value to information and share the information nationally and internationally. Publications are an important component of the information system. During the year, the Institute brought out several regular and *ad hoc* publications both in English and Hindi. The details of the publications brought out during the year are given below:

Regular Publications (English)

- IARI Annual Report 2006-2007 (ISSN: 0972-6136)
- IARI News (Quarterly) (ISSN: 0972-6144) - 4 issues
- IARI Current Events (Monthly) - 12 issues

Ad hoc Publications (English)

- Soil Testing for Balanced and Integrated Use of Fertilizers (ISBN: 81-88708-19-4)
- Testing of Distinctness, Uniformity and Stability for Plant Variety Protection (ISBN: 81-88708-20-8)
- Micro Irrigation Manual (ISBN: 81-88708-21-6)
- A Practical Manual of Field Crops Management (ISBN: 978-81-88708-23-9)
- Detection and Management of Loose Smut Disease of Wheat (TB-ICN:45/2007)
- Detection and Identification of Designate-Seed Borne Diseases (TB-ICN:46/2007)
- STCR Approach for Fertilizer Recommendations Based on Targeted Yield Concept (TB-ICN:47/2007)

Regular Publications (Hindi)

- *Pusa Samachar* (Quarterly) (ISSN 0972-7280) -4 issues
- *Prasar Doot* (Half Yearly)-2 issues
- *Samyiki* (Monthly) - 12 issues

Ad hoc Publications (Hindi)

- *Sinchai Jal Ke Daksh Upyog avam Utpadakta Vroddhi Ki Nai Taknikiyan* (ISBN: 81-88708-22-2)
- *Kharpatvar Mukt Beej Utpadan* (ICN: H-48/2007)
- *Beej Bhandar Mein Keet evam Chuha Niyantran* (ICN: H-49/2007)
- *Beej Fasaloin Main Ekaeekrit Rog Prabandhan* (ICN:H-50/2007)
- *Beej Fasaloin Main Paragan Evam Usake Liye Mon Paalan* (ICN:H-51/2007)
- *Subjee Fasaloin Hetu Beejon Ka Safal Utpaadan* (ICN: H-52/2007)
- *Narsury Parbandhan Tatha Aadhunik Fal Utpadan* (ICN:H-53/2007)
- *Kaddu Jatiye Sabziyoin Kee Sanker Beej Utpadan Takneek* (ICN:H-54/2007)

10. COMMERCIALIZATION AND IPR ACTIVITIES

The mandate of the Institute Technology Management Unit (ITMU) relates to registration of patents, facilitation of contract research projects and consultancies by the Institute scientists, intellectual property rights, and interaction with the agri-business industry.

The following activities were organized by the ITMU during the year:

Patents Filed

- Decision support system for on-farm water management – Farm Wat
- Improvement in pesticidal neem preparations with Oxime Esters
- Precision seeder for plug tray nursery
- Development of entomopathogenic nematode–based termite bait and a technique to disseminate the bait for attracting and killing subterranean termites
- Solid-state digesters for anaerobic fermentation of organic wastes for biogas and manure

MoUs Signed

- A Memorandum of Understanding (MoU) between IARI and M/s J.K. Agri Genetics Ltd., Hyderabad signed on coat protein gene construct of *Tobacco streak virus* (TSV) for the gene/promoter of TSV
- Two MoUs between IARI and M/s Krishidhan Seeds Ltd., Jalna signed on: (i) licensing of gene construct with *Cry1Fal* gene and transgenic brinjal seed material, and (ii) licensing of *Cry1Aabc* gene
- An MoU between IARI and M/s Ankur Seeds Pvt. Ltd., Nagpur signed on licensing of gene construct with *Cry1Fal* gene

Technologies Assigned to NRDC for Commercialization

- Process for production of formulation of reduced azadirachtin
- Improvement of end use efficiency through nitrification inhibitors
- Development of novel high absorbent hydrogel
- *Trichoderma virescens*
- Biopesticidal NemaGel

A farmer signing a memorandum of understanding with the Institute under the seed production programme at the Institute's regional station at Karnal in the presence of Dr. K.R. Koundal, Joint Director (Research), IARI, and Dr. S.N. Sinha, Head, IARI Regional Station, Karnal (extreme right)

11. LINKAGES AND COLLABORATION

Given the national leadership in almost all major agricultural research areas, the Institute has close linkages with almost all annual crop and horticultural crop research institutes, centres, project directorates, coordinated projects as well as a few selected institutes of the ICAR. Similar linkages exist for natural resources and socio-economic research institutions. Collaboration exists with almost all the state agricultural universities (SAUs), selected conventional universities, several of the institutes of the CSIR and the departments of Ministry of Science and Technology such as the Departments of Biotechnology, Space Research, Meteorology and Information and several other ministries/departments/organisations of the Government of India.

At the international level, the Institute has close linkages with several of the CGIAR's international agricultural research centres (IARCs), more particularly with ICRISAT, CIMMYT, IRRI, IFPRI, INSAR, IIMI, ICARDA and IPGRI and CABI. Among other international organizations, FAO, IAEA, USAID, UNDP, WMO, UNIDO (through ICGEB) and UNEP have been the closest allies. Several bilateral research linkages involving developed and developing countries exist. These include linkages with USDA, selected universities in USA, Rockefeller Foundation, European Commission, ODA, DANIDA, IDRC, SIDA, JAICA, JIRC, CSIRO, ACIAR, MASHAV (Israel), IRRDB, AVRDC (Taiwan), etc. The details of externally funded projects in operation during 2007 are given in the following table:

Name of funding agency	No. of projects
Within India	
DBT, DST, ICAR, CICR, CSIR, NCPA, Ministry of Environment & Forest, DOAC, DRDE, NAAS, CPCB, NFBSRA (ICAR), NAIP (ICAR), etc.	92
AP Cess Fund, National Fellow Scheme of ICAR	37
Outside India	
PPIC, USAID, IDRC, CGIAR, CIMMYT, VKIERI, UNEPRRC	11

12. BUDGET ESTIMATES

(Rs. In lakh)

Subhead	Budget estimates 2006-2007		Revised estimates 2006-2007		Budget estimates 2007-2008	
	Plan	Non-Plan	Plan	Non-Plan	Plan	Non-Plan
Estt. charges	0.00	5540.00	0.00	6772.50	0.00	5790.00
OTA	0.00	3.50	0.00	3.50	0.00	3.50
TA	0.82	17.00	0.90	20.00	30.00	16.00
Other charges	1184.41	1125.50	1237.10	1800.00	920.00	1160.50
Works	517.77	380.00	465.00	745.00	564.00	370.00
Other items	0.00	170.00	0.00	170.00	10.00	170.00
Total	**1703.00**	**7236.00**	**1703.00**	**9511.00**	**1524.00**	**7510.00**

13. STAFF POSITION

(As on 31.12.2007)

Category	No. of posts*	
	Sanctioned	Filled
SCIENTIFIC STAFF		
1) Research Management Personnel	7	5
2) Principal Scientist	69	176(38)
3) Senior Scientist/Scientist (S.G.)	184	161 (62)
4) Scientist	355	56 (293)
TECHNICAL STAFF		
1) Category III	27	23
2) Category II	343	310
3) Category I	425	380
4) Auxiliary	2	2
C. ADMINISTRATIVE STAFF		
1) Group A	20	19
2) Group B	271	228
3) Group C	250	33
D. SUPPORTING STAFF		
1) SS Grade IV	193	164
2) SS Grade III	388	379
3) SS Grade II	648	592
4) SS Grade I	358	288

Note : For scientific staff, the figures shown out of parentheses represent the number of scientists working in the particular grade (by assessment/direct recruitment/induction). The figures shown in the parentheses represent the number of scientists initially appointed by direct recruitment/induction in the grade (i.e., excluding assessment)

- Excluding the cadre strengths of the Directorate of Maize Research, and the NRC on Plant Biotechnology

14. MISCELLANY

I. On-going Projects at IARI as on 31.12.2007

a)	School of Crop Improvement	39
b)	School of Resource Management	28
c)	School of Crop Protection	18
d)	School of Basic Sciences	14
e)	School of Social Sciences	13
f)	Mega & X Plan Projects	08
	Total	**121**

II. Scientific Meetings Organized

a)	Workshops	3
b)	Seminars	9
c)	Summer institute	1
d)	Farmers' days	34
e)	Others	41
	Total	**88**

III. Participation of Personnel in Scientific Meetings

India

a)	Seminars	125
b)	Scientific meetings	133
c)	Workshops	87
d)	Symposia	118
e)	Others	60
	Total	**523**

Abroad

a)	Seminar	1
b)	Scientific meetings	19
c)	Workshops	2
e)	Others	7
	Total	**29**

IV. Publications

a)	Research papers published in international journals	183
b)	Research papers published in national journals	342
c)	Symposia/conference papers	444
d)	Books	56
e)	Chapters in books	139
f)	Popular articles	208
	Total	**1372**

V. Honours and Awards

- Dr. S.A. Patil, Director, IARI received the Life Time Achievement Award from the Society for Community Mobilization for Sustainable Development for his contribution to the field of agriculture.
- Dr. P.K. Aggarwal, former Head of the Division of Environmental Sciences was appointed ICAR National Professor. He was a Member of the IPCC team, which was awarded the Nobel Peace Prize 2007.
- Dr. B.S. Parmar, Emeritus Scientist, and former Joint Director (Research), IARI received the 2nd Rao Bahadur Dr. B. Viswanath Award for the biennium 2004-05 consisting of a cash prize of Rs. 1,00,000, a Gold Medal and a Commendation Certificate.
- Dr. D.V.K. Samuel, Head, Division of Post Harvest Technology; Dr. K.D. Srivastava, Professor, Division of Plant Pathology; Dr. Indra Mani, Senior Scientist, Division of Agricultural Engineering; and Dr. (Ms.) K. Annapurna, Senior Scientist, Division of Microbiology were awarded 'Best Teacher Award' for their outstanding contribution to teaching.
- Dr. P.S. Deshmukh, Head, Division of Plant Physiology received the Dr. G.V. Joshi Memorial Lecture Award for his contribution in the field of abiotic stress tolerance.
- Dr. R.K. Jain, Head, Division of Plant Pathology received the Recognition Award (Plant Protection) 2005-2006 from the National Academy of Agricultural Sciences for his significant contributions in the field of plant protection.
- Dr. D.V. Singh, Emeritus Scientist & former Head, Division of Plant Pathology received the Dr. K.C. Mehta Memorial Award for the biennium 2005-2006 from the National Academy of Agricultural Sciences for his outstanding contributions in the field of plant protection.
- Dr. G.C. Srivastava, Professor, Division of Plant Physiology received the Dr. R.D. Asana Memorial Lecture Award for his contribution in the field of post-harvest physiology.
- Dr. R.D. Gautam, Professor, Division of Entomology received the Dr. R.P. Srivastava Memorial National Award 2007 for his outstanding contribution to entomology.
- Dr. B.M. Prasanna, National Fellow, Division of Genetics received the Dr. B.P. Pal Award of IARI for his outstanding contribution to maize genetics and molecular breeding.
- Dr. R.K. Sairam, Principal Scientist, Division of Plant Physiology received the 19th Hooker Award for the biennium 2004-05 consisting a cash prize of Rs. 15000 and a Commendation Certificate.
- Dr. (Ms.) S. Ganguly, Principal Scientist, Division of Nematology received the H.M. Shah Memorial Lecture Award for her contribution to Nematology.
- Dr. Shri Niwas Sharma, Principal Scientist, Division of Agronomy was elected Fellow of the National Academy of Agricultural Sciences from January 1, 2007.
- Dr. T.B.S. Rajput, Principal Scientist, Water Technology Centre received the Rafi Ahmed Kidwai Award of ICAR for the biennium 2005-2006 in the area of natural resource management.
- Dr. (Ms.) V. G. Malathi, Principal Scientist, Plant Virology Unit, Division of Plant Pathology received the 20th Khwarizmi International Award of the Iranian Research Organization for Science and Technology for her contribution to functional genomics and diagnostics of whitefly transmitted geminiviruses infecting crop plants.
- Dr. Charanjeet Kaur, Senior Scientist, Division of Post Harvest Technology received the J.C. Anand Award in the field of Post Harvest Technology.
- Dr. N.P. Singh, Senior Scientist, Division of Agricultural Economics was awarded the Associateship of the National Academy of Agricultural Sciences for the period 2008-2012.
- Dr. R.N. Padaria, Senior Scientist, Division of Agricultural Extension was awarded the Dr. K.N. Singh Memorial Award in recognition of the excellence achieved by him in extension research from the Indian Society of Extension Education.
- Dr. S.K. Singh, Senior Scientist, and Dr. V.B. Patel, Scientist of the Division of Fruits and Horticultural Technology received the Hari Om Ashram Trust Award of ICAR for the biennium 2005-2006.
- Dr. Abhijit Kar, Scientist (Senior Scale), Division of Post Harvest Technology received the NAAS Young Scientist Award for the biennium 2005-2006, and the

Lal Bahadur Shastri Young Scientist Award of ICAR for the biennium 2005-2006 for his contribution to the field of process and food engineering.

- Dr. (Ms.) Anupma Mann, Scientist, Division of Agricultural Chemicals received the Lal Bahadur Shastri Young Scientist Award of ICAR for her research work.
- Dr. (Ms.) Neelam Patel, Scientist, Water Technology Centre received the WATSAVE Annual Award of the International Commission on Irrigation Drainage, and the Golden Jubilee Award of the Fertilizer Association of India.
- Dr. S.P. Datta, Scientist, Division of Soil Science & Agricultural Chemistry received the B.C. Deb Memorial Award of ISCA 2007-2008 in the field of physical chemistry.
- The Institute's Krishi Vigyan Kendra at Shikohpur was given the ICAR Best KVK Award.

VI. Resource Generation

1)	**Consultancy and Other Services**	
	Consultancy service	Rs. 11,11,993
	Contract research	Rs. 13,38,671
	Contract service	Rs. 5,61,835
	Training	Rs. 48,18,298
	Total (A)	**Rs. 78,30,797**
2)	**Revolving Fund**	
(a)	Seed	Rs. 238,16,493
(b)	Commercialization	Rs. 14,43,633
(c)	Prototype manufacturing	Rs. 32,49,429
	Total (B)	**Rs. 285,09,555**
3)	**Post Graduate School Receipt**	
	Training programme	
(a)	Foreigners & Indians	Rs. 3,25,180
	M.Sc./Ph.D Programme	
(b)	Institutional economic fee from foreign scholars under Work Plan	US$ 54800 + Rs. 16,15,464
(c)	Receipt from Registrar (A) Account No. 5432 (9029/201/4314) : all fees except institutional economic fee, including sale of Information Bulletin through D.D.	Rs. 37,56,056
(d)	Cash transferred from Syndicate Bank to Director's Account No. C-49 (9029/305/17) from sale of information bulletin	Rs. 2,12,250
(e)	Receipt deposited in Director's Account No. C-49 (9029/305/17) for theses evaluation, PDC & Misc. (does not include refund of IARI scholarship by students)	Rs. 1,46,150
Total (C)		**US$ 54800 + Rs. 60,55,100**
Grand Total (A + B + C)		**US$ 54800 + Rs. 423,95,452**

VII. Significant Suggestions Given/Decisions Taken at Senior Management Personnel (SMP) Meetings during the Period January 1,2007 to December 31, 2007

Board of Management

- Create a separate pool of residences for lady officers eligible for allotment of residence accommodation.
- Upgrade the existing Unit of Simulation and Informatics to the status of Division of Agri-Informatics.
- Change the name of the Auditorium of IARI as Dr. B.P. Pal Auditorium.
- Reduce the basic pay required for the allotment of Type III residences.

Academic Council

- Inducted 17 scientists as faculty members and 35 scientists as research guides.
- Approved the guidelines for appointment of a Professor in teaching disciplines.
- Approved the introduction of a new course on 'Plant Bio-Security' in the discipline of plant genetic resources.
- Revised three courses in soil science & agricultural chemistry, and one course each in horticulture and post harvest technology.

Executive Council

- Institution of Best Worker Award.
- Conducting of an economic survey on the contribution of IARI to Indian economy.

- Constitution of a committee to examine and recommend the areas where villages may be adopted by KVK for extension activities.
- Framing guidelines for the officials working in various research projects running in the Institute.

Extension Council

- The IARI website may be linked with TAFE Web-site (website of a private company) on payment basis provided that the latter is technically sound and feasible.
- The quality parameters in participatory seed production programme in farmers' fields must be ensured by all means. A certificate course on Entrepreneurship Development (ED) for rural youths should be organized on PG school certificate course pattern. The ED training modules should have components of technology, processing, marketing, etc.
- The field demonstration programmes should have components of technology, processing, marketing, etc.
- The field demonstration programmes should clearly define the local check, highlight the ranges of yields/ productivity, maintain uniformity in all trials/ demonstrations and include social and economic parameters of technology.
- A model of integrated agriculture should be developed in the context of a backward village in NCR of Delhi. Consequent upon successful accomplishment the model may be replicated in other regions/states.
- The feedback from the farming community received by the ATIC should be constantly processed and followed up.
- The KVK (Shikohpur) should organize farmers and conduct tours to identified locations. The feedback generated through impact analysis of KVK interventions should be followed up.
- A new village based business oriented extension model of national character should be developed under the ongoing new extension/TOT strategy of IARI.
- An annual collaborative plan between IARI and Development Departments should be developed and implemented, wherein the IARI will provide all the needed technical expertise.

Research Advisory Council

- The wheat programme at IARI needs major strengthening with additional funding support. The Institute should strive to regain its position of leadership in wheat research.
- The Institute should develop the technology of life saving irrigation by developing suitable reservoir systems on the farm.
- The Institute should take the leadership in research in the field of protected horticulture.
- The work on fruits and vegetables should aim at nutritional improvement along with high yields. The anti-oxidant properties through selection for pigmentation should receive greater attention.
- IARI should collaborate with NBPGR in DNA bar coding of plant genetic resources by the use of molecular techniques.
- IARI should organize a major study in collaboration with other ICAR research centers on the extent of yield losses due to pests and diseases at the pre- and post-harvest stages.
- IARI should focus on insect pests and diseases of national importance.
- IARI should focus on horticultural crops by using bio-control agents.
- IARI should standardize a general package of practices for organic farming and should prepare a policy paper on the subject. The Division of Soil Science & Agricultural Chemistry should take the leadership in this regard.
- The issue of contract farming is receiving major attention. IARI should organize a major study on contract farming based on the experience so far in states like Punjab. The opportunities and pitfalls should be clearly defined, and recommendation made so that contract farming can be made more rewarding for the small and marginal farmers in particular.
- The Division of Agricultural Extension should come out with new approaches for the transfer of complex technologies like soil and water management to farmers. The present models of extension services have not worked well for India's changing agriculture.
- IARI should develop a Master's degree course in agri-business management.
- The Institute should carry out a major review of the impact of the work of the Division of Microbiology.

The feeling in the farming community is that they have received little support from microbiologists in improving the soil fertility.

- The Division of Biochemistry should redefine its mission and mandate. Working in collaboration with other divisions, the Division of Biochemistry should aim at making an impact in terms of quality and quantity of agriculture produce.
- The Division of Agronomy should be reorganized as the Division of New Agronomy and Precision Farming. The major objective should be more efficient management of natural resources as well as modern farm inputs.
- The WTC should review its past work to determine how far it has contributed to irrigation water use efficiency in the country and how far its developed technology can be adopted under rainfed conditions.
- The Division of Soil Science and Agricultural Chemistry, based on soil fertility maps it had prepared, should review India's present cropping systems and suggest changes for optimum utilization of natural resources. This should be done in collaboration with the National Bureau of Soil Survey and Land Use Planning. Above all, the Division should come out with a strategy for improving India's degraded and low soil fertility lands.
- The Regional Station, Amartara should create a national nursery of temperate fruit crops, specially apple. It should become a national centre of germplasm resources of diverse temperate fruits.
- Improvement in fruit size in kiwi is important and the role of plant nutrition and growth regulators should be studied in this regard.
- The varieties of apple, which are being developed, should be selected for attractive colour and other traits so as to become competitive in the market.
- The Regional Station, Amartara should focus on integrated nutrient management, micro-irrigation, and fertigation in temperate fruit crops.
- The diseases of strawberry should be studied in order to increase the yield of this fruit.
- The Tutikandi Station should be developed as a Centre of Excellence for wheat research in the hills.
- The Institute should distribute much larger quantity of seeds of its improved varieties to the attending farmers in *Kisan Melas*. A separate programme of seed multiplication should be organised for this purpose.

Staff Research Council

School of Crop Improvement

- Attempt should be made to popularize/spread IARI varieties with sufficient quantity of nuclear/breeder/ foundation seed. The input output ratio should be analyzed for IARI varieties. Varieties released for Delhi should be extended to/promoted in other states. The variety release and recommendations should be linked with nutrition status quality parameters.
- A theoretical design for ideal plant type in different environmental conditions should be defined
- Maintenance breeding should be done faithfully. National/ international certifying agency should certify organic seed production.
- While releasing a variety, its nutrient requirement should be recommended.
- The pre-breeding activity to develop suitable parental line should be focused.
- Agronomy of vegetable needs to be emphasized.
- The onion variety should be tried for mechanical grading. In yellow onion and peel free cucumber, specific size to meet the export market should be developed.
- The Division of Vegetable Science should have sufficient land for developing parental lines and seed production.
- Utilization of byproduct like leaf of cauliflower and garden pea should be looked into.
- Close collaboration be made with hospitals for recommendation of nutritive vegetables.
- There has to be a conscious effort to include the nutritional and post-harvest processing quality parameters in the breeding programme. The breeders may take the PHT scientists along with them for better results.
- The packages of production practices including good agricultural practices (GAP) need to be developed involving Agronomists.

- Root stock research for perennial crop should be carried out.
- Utilize available resistant varieties from Lucknow against mango malformation.
- Confirm Tea Wed on controlling of mango malformation.
- Work on tissue culture/micro-propagation for faster multiplication of fruit crop should be continued.
- Breed mango for industry/colour preference for consumer for export purpose.
- Reconsider the research on papaya cultivation in north Indian conditions since changes have taken place in the climate.
- Nutritional characterization of fruits along with the GAP, and post harvest processing quality issues need to be given greater emphasis.
- While attempting to use municipal solid waste based organic matter for soil fertility improvement, data on heavy metal toxicity and other quality issues also need attention.
- Attempt should be made to develop hybrid of marigold.
- Attention should be given to germplasm collection and utilization for crop improvement with regard to any crop.
- Seed production programme at the Institute should be strengthened.
- Agrotechnology for protected and open cultivation should be streamlined.
- Post harvest technology for flowers, specially cut flowers and dry flowers is to be strengthened.
- Cost-benefit ratio of tissue culture plant, and issues on natural colours from flowers for textile industry must be workout.
- The Division of Post Harvest Technology should give more emphasis on post harvest engineering aspects of horticultural crops. This will result in development of equipment/tools for post harvest operation of fruits and vegetables.
- Programme must be developed to monitor and ensure quality and safety aspects along the post harvest processing chain.
- The post harvest management and processing activities should culminate in the development of pilot plants and commercialization of the technology.
- Mandate of the Division of Seed Science & Technology should be modified with regard to seed testing in view of the changing need.
- Develop a technology for seed testing in transgenic crop, especially in Bt cotton.
- Economy of seed production in tomato should be worked out.
- Maintenance breeding by the Division of Seed Science & Technology should be encouraged specially for the varieties developed by the Institute.
- The seed developed by private companies should be evaluated for their potentiality.

School of Crop Protection

- Disease modeling should have focused approach.
- HCIO and ITCC need institutional support to sustain these collections. Database of HCIO and ITCC should be well documented.
- The research on mushrooms at the Division of Plant Pathology needs to be collaborated with the national programme at Solan for more productive research output.
- The application strategy in biocontrol and biopesticide research can be collaborated with NCIPM for a wider reach.
- The research on development of resistant transgenic stocks by plant pathologists should be restricted to the crops wherever regeneration protocols are available or it should be carried out in collaboration with physiology/biochemistry or biotechnology divisions for accelerated output.
- Collaboration across disciplines within IARI and institutes across the country is needed.
- Application of genomic technologies should be restricted to the areas wherever there is scope for development of applicable markers.
- Development of new compounds should be restricted to agrochemicals only.
- Multi-residue methods for analysis of pesticides in different commodities should be standardized.

- Various research projects of NCIPM differed with respect to the base data considered while IPM protocols were implemented and evaluated. For a scientific appraisal of the technology, a standardized format for the various base data should have been developed including soil type, composition, quality of irrigation water and cropping system, etc. Similarly, while evaluating the efficacy, a set of parameters consistent over locations and crops should be developed for system analysis.
- Experiments for IPM strategies for protected cultivation and precision agriculture should be planned more critically, and treatments should be randomized as micro plots and not rows.
- The development of database on pests and management practices can be done in collaboration with the regional ICAR institutes or SAU's wherever available, as it will help in quicker and the authentic compilation.
- It gives an impression that the IPM research is being done in a compartmentalized way with reference to the development of strain and protocols by NCIPM and the School of Plant Protection. A coordinated approach may help in accelerating the efforts in this important field of agriculture.
- Software developed by the NCIPM should be developed in farmer's language too.
- Ecological aspect should be given area wide consideration emphasis in IPM programme.
- In biocontrol programme, make attempts in mandated crops including commercial aspect.

School of Basic Sciences

- The focus should be on understanding the biochemical basis of heat tolerance in wheat. For this, studies relating to starch synthetase enzyme in developing grains of heat tolerant and susceptible genotypes of wheat are very necessary.
- Synergistic integration of different energies for investigations on agri-products is a very interesting approach. *Gama* radiation investigations on agri-products should lay stress on energy/dose levels and its effect at molecular level.
- The work on the effect on magnetic field on seed is appreciable. Such investigations should also generate valuable information through instruments like Electro Paramagnetic Resonance (EPR), Differential Scanning Calorimeter (DSC), etc.
- The cotton fibre quality studies should be extended to include studies on physical and structural analysis of materials in a well-defined manner using various instrumentation techniques.
- The report on water quality parameters, certified reference material/reference water standard should be used as check. NRL should also try to develop its own reference standards/materials.
- Share and disseminate information with the stakeholders through technical and popular articles. Instead of number of publications, a complete reference should be provided.

School of Resource Management

- A comprehensive review on clay-humus interaction between the soil of organic growing field and soil of vegetable growing field, cropping system, micronutrient status, FLD and aerobic rice should be made.
- Effort to reduce losses through conveyance, and seepage through proper management technology should be made.
- Aqua-ferti-seed drill should be popularized among the Delhi farmers.
- DSS developed by the Division at Agricultural Physics should be evaluated in the farmers' fields.
- The implication of climate change in nutrient uptake/utilization by the plant needs to be understood.
- There is a need to devise soil health index by integrating physical, chemical and biological properties of soil.
- The project on "Spatial Modeling of Net Primary Productivity of Indian Agro-system" by using production efficiency modelling approach to be continued.
- There is a need to relook the fertilizer recommendation for various crops and refine compost enrichment.
- Package and practices for cultivation of *Jatropha* in wasteland/marginal land to be worked out.
- Emission results should not be published hurriedly. It may jeopardize the environmental policy.

- Cost of cultivation of growing ginger in *Jatropha* intercropping needs to be looked into carefully.
- Pilot plant for extraction of *Jatropha* oil should be made after its chemistry is established.
- Efforts should be made to develop linkages with ICAR institutes and other non-ICAR organizations for the work on ergonomics where such type of research work is undertaken.
- Efforts should be made to develop a continuous type plant instead of batch type pilot plant for bio-fuel (*Jatropha* oil).
- Develop a machine bank emerging out of the survey undertaken by the Division of Agricultural Engineering in U.P.
- Work should also be initiated for making briquettes for fuel from agricultural waste.

School of Social Sciences

- There is a need to study the 'contract farming' as a system under Farming System Research Project.
- The extension problems of small and marginal farmers have to be investigated.
- The Division of Agricultural Extension should continue to focus on 'action research' which will provide practical solutions to extension problems.
- Impact analysis of extension programme and policies should include multi-dimensions such as economical, social and environmental components.
- Implication of changes in provisions especially those relating to trade in agricultural commodities on consumer, producers and traders needs to be evaluated.
- Application of advanced econometric analysis and modeling in the research work needs to be emphasized.
- Under the activities of Marketing Intelligence Cell, implications of changed scenario of market and trade in agriculture on research and development agenda need to be examined.
- In a study on management of peri-urban agriculture, there is a need to focus on management aspects and expand the study area as well as activities (such as livestock, dairying, poultry, high value commodities, etc.) to provide more holistic findings for policy implications of peri-urban agriculture.
- Each and every scientist of the Division of Agricultural extension should strive to publish their work in high standard journals with high impact factor.
- TOT programme should be focused as per the need of small and marginal farmers.
- Training manuals/capsules should form an integral part of the farmer's training under Action Research Programme and a few long-term training programme should also be organized.
- Impact analysis of action research programme/TOT programme in terms of economic parameters will be helpful.

VIII. Infrastructural Development

Unit of Simulation and Informatics

- A video conference facility for the Institute

Regional Station, Katrain

- Establishment of a tissue culture laboratory

IX. All India Coordinated Research Projects in Operation during the year 2007

Project headquarters

1. All India Coordinated Research Project on Nematodes
2. All India Coordinated Research Project on Pesticide Residues
3. All India Coordinated Research Project on Floriculture Improvement

National centres functioning under All India Coordinated Research Projects

1. All India Network Project on Biofertilizers (Erstwhile All India Coordinated Research Project on Biological Nitrogen Fixation)
2. All India Coordinated Project on Long Term Fertilizer Experiments
3. All India Coordinated Research Project on Soil Test Crop Response
4. All India Coordinated Research Project on Tillage Requirements of Major Indian Soils for Different Cropping Systems
5. All India Coordinated Research Project on Floriculture Improvement

6. All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries

7. All India Coordinated Research Project on Honey Bees

8. All India Coordinated Research Project on Biological Control of Crop Pests

9. All India Coordinated Research Project on Soybean

10. All India Coordinated Research Project on Sub-tropical Fruits

IX. Foreign Visitors during 2007

Sl. No.	Visitor (s)	Month
1.	Mr Nagash Gemtessc, General Manager, and Mr. Tesfaye Kidane, Deputy General Manager, Water Works Design, Ministry of Water Resource, Ethiopia	January
2.	Mr. Quigyao Shu, NAFA, Plant Breeding and Genetics Section, International Atomic Energy, Austria	January
3.	A 3-member delegation from the United States of America (USA)	February
4.	A 6-member delegation from France	February
5.	H.E. Rosann Wqwchuk, Deputy Premier and Agriculture Minister of Mantoba, Canada	February
6.	A high level delegation from East African Community (EAC)	February
7.	A delegation from ICARDA, Syria	March
8.	H.E. Francisco Lainez, Minister of External Relations of El-Salvador	March
9.	A team of Scientists from USA	March
10.	Dr. Jerry Hatfield, Director, National Soil Tilth Laboratory, United States Department of Agriculture, and President, American Society of Agronomy	March
11.	Mr. Cao Jianru, First-Secretary, Science & Technology, Embassy of the People's Republic of China, New Delhi	March
12.	A high level delegation from Eritrea	April
13.	Dr. Mark E. Keenum, Under Secretary for Farm and Foreign Agricultural Services, United States Department of Agriculture, USA	April
14.	Ms. Jingshun Yin, Senior Market Analyst and Mr. Bruce Burnet, Director of Weather & Crop Surveillance, Canadian Wheat Board, Winnipeg, Canada	April
15.	A high level delegation from Korea	April
16.	Dr. Clarice Coyne, Professor, Washington State University, Pullman, Washington, USA	May
17.	A high level delegation from the People's Republic of China	May
18.	Dr. Jose Maria Sumpsi Vinas, Assistant Director-General, Agriculture and Consumer Protection Department, FAO, Rome, Italy	July
19.	Mr. M. Mbongwa, Director-General, Department of Agriculture, South Africa	July
20.	A 3-member delegation from Bhutan	July
21.	A 3-member delegation from Madagascar	July
22.	A high level delegation from Swaziland	August
23.	A 7-member delegation from Nepal	August
24.	A group of eight senior Scientists from Uzbekistan	August
25.	H.E. F.B. Marshoff, Premier, Free State Provice of South Africa	September
26.	Dr. Bob Stewart, Director of Dryland Agriculture, West Texas University, USA	September
27.	H.E. Kayumbo Nyamwasa, Ambassador, and Mr. Eric Rubayita, First Secretary of Republic of Rwanda, New Delhi	September
28.	A 9-member delegation from Ethiopia	September
29.	Dr. Abdul Rashid, Director-General, National Agricultural Research Centre, Faislabad, Pakistan	October
30.	Dr. Indrajeet Chaubey, Associate Professor, Purdue University,USA	October
31.	H.E. Barry Todd, Hon'ble Deputy Minister of Agriculture, Food and Rural Initiatives, Manitoba, Canada	November
32.	An Israeli delegation	November
33.	Mr. Ivanov Audrey, Vice President, Russian Academy of Agricultural Sciences	November
34.	Dr. Stephen W. Muliokela, Director, Golden Valley Agricultural Research Trust, Lusaka, Zambia	November
35.	Dr. Ramano M. Kiome, Permanent Secretary, Ministry of Agriculture, Zamia, Zambia	November
36.	Dr. Keith Davies, Senior Nematologist, IACR Rothamsted Research, Harpenden, UK	December
37.	H.E. Montse Huget-Guell, President-Prodeca, Spain	December
38.	A 10-member delegation from Manitoba, Canada	December
39.	A team of scientists from USA	December
40.	A 3-member delegation from Iran	December

Dr. S.A. Patil, Director, IARI presenting a set of the Institute's publications and a CD containing information on the growth and development of the Institute to Her Excellency Rosann Wqwchuk, Deputy Premier and Agriculture Minister of Mantoba, Canada during her visit to IARI

Dr. K.R. Koundal, Joint Director (Research), IARI welcoming Dr. Abdul Rashid, Director-General, National Agricultural Research Centre, Faislabad, Pakistan, at IARI

Appendix 1
Members of Board of Management of IARI
(As on 31.12.2007)

Chairman

1. Dr. S.A.Patil
   Director, IARI

Members

2. Dr. H.S. Gaur
   Dean & Joint Director (Education), IARI
3. Shri P.K. Mishra
   Secretary (Agril. & Coop.), Govt. of India
   Ministry of Agriculture
   Department of Agriculture & Cooperation
   Krishi Bhawan
   New Delhi-110 001
4. Dr. R.B. Deshmukh
   Vice Chancellor,
   Mahatma Phule Krishi Vidyapeeth
   Distt. Ahmednagar, Rahuri-413722
5. Dr. K.R. Koundal
   Joint Director (Research), IARI
6. Dr. Baldeo Singh
   Joint Director (Extention), IARI
7. Dr. (Mrs.) M. Dadlani
   Head, Division of Seed Science & Technology, IARI
8. Dr. A.S. Sidhu
   Head, Division of Vegetable Sciences,
   IARI
9. Dr. G.T. Gujar
   Head, Division of Entomology,
   IARI
10. Project Director,
    WTC, IARI
11. Dr. K.V. Prabhu
    Head, Division of Genetics,
    IARI
12. Dr. S.N. Sinha
    Head,
    IARI Regional Station, Karnal
13. Dr. S.L. Mehta
    Vice Chancellor
    Maharana Pratap University of Agriculture &
    Technology, Udaipur
14. DDG (CS), ICAR, Krishi Bhavan
    New Delhi- 110 001
15. Director, IVRI
    Izatnagar, Bareilly, U.P.
16. Agricultural Commissioner, Deptt. of Agril.
    and Cooperation, Min. of Agril., Krishi Bhawan
    New Delhi-110001
17. Dr. S.K. Vasal
    Ex. Director, CIMMYT
    C-2/2394, Vasant Kunj
    New Delhi
18. Dr. A.N. Mukhopadhyay
    Ex. Vice Chancellor,
    151, Akansha Uday
    Raibarielly Road
    Lucknow-226025, U.P.
19. Dr. A.G. Sawant
    Former Chairman
    Agricultural Scientists Recruitment Board
    Plot No 13, Gagan Giri, Sehwas Cooperative
    Housing Society, Karve Nagar, Pune
20. Dr. Jagdish Chander Bakshi
    Former Vice Chancellor, RAU, Pusa Bihar
    132D, Kitchlu Nagar, Ludhiana-1410001
21. Director (F), ICAR
    Krishi Bhawan, New Delhi-110001
22. Development Commissioner
    Govt. of NCT of Delhi, 5/9 Under Hill Road
    Delhi-110054
23. **Member-Secretary**
    Shri P.C. Jacob
    Joint Director (Administration), IARI

Appendix 2
Members of Research Advisory Council of IARI
(As on 06.12.2007)

Chairman

1. Dr.H.K.Jain
   Ex-Director, IARI,
   40, Surya Niketan,
   Vikas Marg Extension,
   Delhi-110092

Members

2. Dr.G.L.Kaul
   Ex-Vice Chancellor,
   Assam Agriculture University,
   K.A -59 (F.F.), Kaushambi,
   Ghaziabad-201012 U.P.

3. Dr.V.P.Gupta
   Ex-Vice Chancellor,
   GH-10 / 69A, Sunder Apartments,
   Paschim Vihar,
   New Delhi-110 087

4. Dr. Asis Datta
   Director,
   National Centre for Plant Genome Research,
   JNU Campus, New Delhi

5. Dr. S.S. Magar
   Ex-Vice Chancellor,
   B.S.Konkan Krishi Vidyapeeth,
   Dopoli, Distt. Ratnagiri,
   Maharashtra

6. Prof. S. Kannaiyan
   Ex-Vice Chancellor,
   Tamil Nadu Agricultural University,
   Chairman, National Biodiversity Authority 475,
   9th South Cross Street,
   Kapaleeswarar Nagar, Neelankarai,
   Chennai- 600041 (T.N.)

7. Dr. S.N. Shukla
   Assistant Director-General (F &FC),
   ICAR, New Delhi-110001

8. Dr. S.A. Patil
   Director, IARI

Member-Secretary

9. Dr. K.R. Koundal
   Joint Director (Research),
   IARI, New Delhi

Appendix 3
Members of Academic Council of IARI
(As on 31.12.2007)

Chairman

1. Dr. S. A. Patil
   Director, IARI

Vice-Chairman

2. H.S. Guar
   Dean & Joint Director (Education), IARI

Members

3. Dr. S.P.Tiwari
   Dy. Director-General (Education), ICAR
4. Dr. S. Edison
   Director, CTCRI
5. Dr. Baldeo Singh
   Joint Director (Extension), IARI
6. Dr. S.K. Sharma
   Director, NBPGR
7. Dr. J.P. Tiwari
   Dean, GBPUA & T
8. Dr. S.D. Sharma
   Director, IASRI
9. Dr. K. R. Koundal
   Joint Director (Research), IARI
10. Dr. J.S. Panwar
    Professor of Agril. Engineering
11. Dr. P.S. Datta
    Project Director, NRL
12. Dr. P.A. Kumar
    Director, NRCPB
13. Dr. D.B. Saxena
    Professor of Agril. Chemicals
14. Dr. Puran Chand
    Professor of Agril. Economics
15. Dr. S.N. Puri
    Vice Chancellor of CAU, Imphal
16. Dr. K. Vijayaraghavan
    Professor of Agril. Extension
17. Dr. (Ms.) U.K. Chopra
    Professor of Agril. Physics
18. Dr. V.K. Sharma
    Professor of Agril Statistics
19. Dr. R.K. Rai
    Professor of Agronomy
20. Dr. (Ms.) Archna Sachdev
    Professor, Division of Biochemistry
21. Dr. P.K. Malhotra
    Professor of Computer Application
22. Dr. R.D. Gautam
    Professor of Entomology
23. Dr. H. C. Joshi
    Professor of Environmental Sciences
24. Dr. R.D. Singh
    Professor of Genetics
25. Dr. R.R. Sharma
    Professor of Horticulture
26. Dr. M.T. Patil
    Head, Division of Floriculture & Landscaping
27. Dr. D.V.K. Samual
    Head & Professor, Post Harvest Technology
28. Dr. A.N. Srivastava
    Professor of Nematology
29. Dr. D.K. Agrawal
    Professor of Plant Pathology
30. Dr. G.C. Srivastava
    Professor of Plant Physiology
31. Dr. B.B. Mondal
    Professor of Plant Genetic Resources

32. Dr. (Ms.) M. Dadlani
Head, Division of Seed Science & Technology

33. Dr. L.M. Shukla
Professor of Soil Science & Agril. Chemistry

34. Dr. B.R. Yadav
Professor of Water Science & Technology

35. Dr. R.K. Rai
Master of Halls of Residences

36. Shri N.S. Pakhale
Head, IARI Library

37. Dr. Subedar Singh
Academic Council Representative

38. Dr. S.K. Mishra
Faculty Representative to the Academic Council

39. Shri R. Dhandapani
President, PGSSU

40. Shri Tarak Nath Saha
Students' Representative

41. Dr. K.C. Bansal
Professor of Molecular Biology and Biotechnology

42. Dr. (Ms.) D.W. Dhar
Professor of Microbiology

43. Dr. A.S. Sidhu
Head, Division of Vegetable Science

44. Dr. A.K. Singh
Head, Division of Fruits and Horticultural Technology

45. Dr. S.L. Mehta
Vice Chancellor, MPUA&T,
Udaipur

Member-Secretary

46. Shri P.C. Jacob
Registrar (Academic)

Appendix 4
Members of Extension Council of IARI
(As on 31.12.2007)

Chairman

1. Dr. S.A. Patil
   Director, IARI

Members

2. Dr. I.P.S. Ahlawat
   Head,
   Division of Agronomy,
   IARI
3. Dr. K.V. Prabhu
   Head,
   Division of Genetics, IARI
4. Dr. Anand Swarup,
   Head,
   Division of Soil Science & Agricultural Chemistry, IARI
5. Dr. A.N. Srivastava
   Head,
   Division of Nematology, IARI
6. Dr. (Ms.) Malvika Dadlani
   Head,
   Division of Seed Science & Technology, IARI
7. Dr. K. Vijayaraghavan
   Professor, Division of Agricultural Extension, IARI
8. Dr. A.P. Srivastava
   Principal Scientist,
   Division of Agricultural Engineering, IARI
9. Dr. (Ms.) Pratibha Sharma
   Principal Scientist,
   Division of Plant Pathology, IARI
10. Dr. Anjani Kumar
    Incharge,
    KVK, Shikohpur, Gurgaon, Haryana
11. Dr. R.K. Chowdhary
    Principal Scientist,
    Division of Seed Science & Technology, IARI
12. Dr. H.N. Pandey
    Head,
    IARI Regional Station, Indore, M.P.
13. Dr. Joginder Singh
    Additional Commissioner (Crops),
    Department of Agriculture, Ministry of Agriculture,
    Krishi Bhawan, New Delhi
14. Dr. K.L. Khurana
    Director (A.H.),
    Govt. of NCT of Delhi
    MSO Building, 11th floor, IP Estate, New Delhi
15. Dr. D.K. Thakur
    Joint Director (Agri.),
    Govt. of NCT of Delhi
    MSO Building, 11th floor, IP Estate, New Delhi
16. Dr. Ram Kumar
    Principal Scientist (Dairy Extension),
    NDRI, Karnal
17. Dr. V.S. Pangtey
    Director,
    Extension Management, Directorate of Extension,
    Ministry of Agriculture, IASRI Campus,
    Pusa, New Delhi.
18. Dr. P. Das
    DDG (Extension), ICAR,
    KAB, Pusa, New Delhi
19. Shri P.C. Jacob
    Joint Director (Administration), IARI
20. Dr. Baldeo Singh
    Joint Director (Extension),
    IARI
21. Dr. K.R. Koundal
    Jt. Director (Research),
    IARI

Member-Secretary

22. Dr. (Ms.) Rekha Bhagat
    Head,
    Division of Agricultural Extension, IARI

Appendix 5
Members of Staff Research Council of IARI
(As on 31.12.2007)

Chairman

1. Director, IARI

Members

2. Joint Director (Research), IARI
3. All Project Directors/Project Coordinators of IARI
4. All Heads of Divisions/Regional Stations of IARI
5. All Principal Investigators of IARI
6. Deputy Director-General (Crop Sciences), ICAR

Member-Secretary

7. Principal Scientist (PPI), IARI

Appendix 6
Members of Executive Council of IARI
(As on 31.12.2007)

Chairman

1. Dr. S.A. Patil
   Director, IARI

Members

2. Deputy Director-General (CS), ICAR
3. Dr. K.R. Koundal
   Joint Director (Research),
   IARI
4. Project Director
   Water Technology Centre,
   IARI
5. Dr. Baldeo Singh
   Joint Director (Extension),
   IARI
6. Dr. H.S. Gaur
   Dean & Joint Director (Education),
   IARI
7. Dr. (Ms.) Rekha Bhagat
   Head,
   Division of Agricultural Extension
   IARI
8. Dr. N.V.K. Chakravarti
   Head,
   Division of Agricultural Physics
   IARI
9. Dr. P.S. Deshmukh
   Head,
   Division of Plant Physiology, IARI
10. Dr.(Ms.) Prem Dureja
    Head,
    Division of Agricultural Chemicals, IARI
11. Dr. R.K. Jain
    Project Coordinator,
    Division of Nematology, IARI
12. Dr. A.S. Sidhu
    Head,
    Division of Vegetable Science
    IARI
13. Dr. K.V. Prabhu
    Head ,
    Division of Genetics
    IARI
14. DR. D.V.K. Samuel
    Head,
    Division of Post Harvest Technology, IARI
15. Dr. H.N. Pandey
    Head,
    IARI Regional Station, Indore

Member-Secretary

16. Shri P.C. Jacob
    Joint Director (Administration), IARI

Appendix 7
Members of Institute Joint Staff Council (IJSC)
(As on 31.12.2007)

Chairman

1. Dr. S. A. Patil
   Director

Members (Official Side)

2. Dr. K.R. Koundal
   Joint Director (Research)
3. Dr. H.S. Gaur,
   Dean & Joint Director (Education)
4. Dr. (Ms.) Malvika Dadlani
   Head,
   Division of Seed Science & Technology
5. Dr. S.N. Sinha
   Head,
   IARI Regional Station, Karnal
6. Shri Devendra Kumar
   Chief Finance and Account Officer

Secretary (Official Side)

7. Shri. P.C. Jacob
   Joint Director (Administration)

Elected Members (Staff Side)

1. Shri Ganesh Rai
2. Shri Ishwar Chand
3. Shri Bhagat Singh
4. Shri Subed Chandra Dikshit
5. Shri R.K. Duggal
6. Shri S. K. Jain
7. Shri Yogesh Kumar
8. Shri Umesh Thakur
9. Shri Shashi Kant Kamath
10. Shri Ram Gopal
11. Shri Bijender Singh

Secretary (Staff Side)

12. Shri Vijay Kumar Sharma

Appendix 8
Members of Grievance Committee of IARI
(As on 31/12/2007)

Members (Official Side)

1. Dr. A.K. Singh
   Project Director,
   Water Technology Centre
2. Dr. I.P.S. Ahlawat
   Head,
   Division of Agronomy
3. Shri Ravi Kumar
   Senior Administrative Officer
4. Shri B.K. Bansal
   Finance & Accounts Officer

Members (Staff Side)

1. Dr. G.P. Singh
2. Shri Ishwari Singh
3. Shri Davinder Rai

Member-Secretary

4. Shri Umesh Chandra Sharma

Appendix 9
Personnel
(As on 31.12.2007)

Directorate

Director
Dr. Patil, S.A.

Joint Director (Research)
Dr. Koundal, K.R.

Dean & Joint Director (Education)
Dr. Gaur, H.S.

Joint Director (Extension)
Dr. Singh, Baldeo

Joint Director (Administration)
Mr. P.C. Jacob

Incharge (Publication Unit)
Dr. Koundal, K.R.

Principal Scientist (PPI Unit)
Dr. Ganguly, A.K.

Principal Scientist (ITMU)
Mr. Saxena, J.P.

Chief Administrative Officers
Mr. Deshbandhu, G.R.
Mr. Randhava, N.S.

Chief Finance and Accounts Officer
Mr. Devendra Kumar

Editor (Hindi)/T-9
Mr. Dubey, A.K.

Editor (English)/T-9
Mr. Thomas, Chacko

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Mr. Gajmoti, S.K.
Mr. Jain, M.K.
Mr. Pachauri, M.K.
Mr. Raja, N.
Mr. Ravi Kumar

Registrar (Academic)
Mr. P.C. Jacob

Agricultural Chemicals

Head
Dr. (Ms.) Dureja, Prem

Professor
Dr. Saxena, D.B.

National Fellow
Dr. Gopal, Madhuban

Principal Scientists
Dr. Devakumar, C.
Dr. Dikshit, A.K.
Dr. Gajbhiye, V.T.
Dr. Gupta, R.L.
Dr. (Ms.) Mukherjee, Irani
Dr. Rangaswamy, S.
Dr. Sharma, K.K.
Dr. (Ms.) Singh, Shashi Bala
Dr. Tomar, S.S.
Dr. Walia, Suresh

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Dr. Jitender Kumar
Dr. Shakil, N.A.
Dr. (Ms.) Singh, Neera

Scientists
Dr. (Ms.) Mann, Anupama
Dr. Rajesh Kumar

Agricultural Economics

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Dr. Mathur, V.C.

Professor
Dr. Mathur, V.C.

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Dr. Kar, Amit
Dr. Puran Chand
Dr. (Ms.) Singh, Alka
Dr. Tyagi, V.P.

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Dr. Jha, G.K.

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Dr. Parmod Kumar
Mr. Sekar, I.
Dr. Shiv Kumar
Dr. Singh, N.P.

Agricultural Engineering

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Professor
Dr. Panwar, J.S.

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Mr. Saxena, J.P.
Dr. Shrivastava, Ranjan
Mr. Singh, Amar
Dr. Singh, J.K.
Dr. Tomar, S.S.

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Mr. Adarsh Kumar
Dr. Indra Mani
Dr. Sharma, P.K.

Scientists
Mr. Arvind Kumar
Dr. (Ms.) Gupta, M.J.

Agricultural Extension

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Dr. (Ms.) Bhagat, Rekha

Professor
Dr. Vijayaraghavan, K.

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Dr. Bahal, Ram
Dr. (Ms.) Singh, Prem Lata
Dr. Vashishtha, S.B.

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Dr. Dommeti, U.M.R.
Dr. Padaria, R.N.
Ms. Singh, Rashami
Dr. (Ms.) Wasan, Monika

Scientist
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Mr. Saxena, C.M.
Dr. Sehgal, V.K.

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Dr. Sahoo, R.N.
Ms.Vashisth, Ananta

Agronomy

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Dr. Rana, K.S.
Dr. Sharma, A.R.
Dr. Sharma, S.N.
Dr. Singh, Ranbir

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Dr. Behra, U. K.
Dr. Das, T.K.
Dr. Dhar, Shiva
Dr. Dinesh Kumar
Dr. Gangaiah, B.
Dr. Rana, D.S.
Dr. Sharma, Rajvir
Dr. Shivay, Y.S.
Mr. Shivakumar, B.G.S.

Scientist
Mr. Dass, Anchal

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Dr. (Ms.) Santha, I.M.

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Dr. Paul, B.
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Dr. Jain, Niveta
Dr. (Ms.) Mina, Usha
Mr. Sanjeev Kumar
Dr. Shakeel A. Khan
Dr. Sharma, Dinesh Kumar
Mr. Shiv Prasad
Dr. Singh, Omveer
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Dr. Sindhu, S.S.
Mr. Singh, Kanwar Pal
Dr. Singh, K.P.

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Dr. Raju, D.V.S.

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Mr. Singh, Kashmir
Dr. Singh, Sanjay Kumar
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Dr. Singh, R.D.
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Dr. Satyavathi, Tara
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Dr. Sharma, J.B.
Dr. Sharma, Ram Kumar
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Dr. Singh, Rishi Pal
Dr. Singh, R.V.P.
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Dr. Yadav, Rajbir

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Dr. Dubey, S.C.

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Dr. Maheshwari, C. Uma
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Dr. Sharma, R.K.
Dr. (Ms.) Shelly, Praveen
Dr. Singh, Dinesh
Mr. Sinha, Parimal

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Dr. Promod Kumar
Dr. (Ms.) Santosh Kumari
Dr. Vijay Paul

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Dr. Pandey, Renu

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Dr. Sagar, Vidya Ram

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Dr. Ram Ashrey
Dr. Sharma, R.R.

Scientists
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Dr. Kar, Abhijit
Dr. (Ms.) Sethi, Shruti

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Professor
Dr. Singh, J.N.

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Dr. Parihar, S.S.
Dr. Singh, Jai
Dr. (Ms.) Vari, A.K.

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Dr. Yadav, S.K.

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Dr. (Ms.) Basu, Sudipta
Dr. Lal, S.K.
Dr. Pandey, Sunil
Mr. Singh, K.K.

Soil Science and Agricultural Chemistry
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Swaroop, Anand

Professor
Dr. Shukla, L.M.

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Dr. Deopal
Dr. Dwivedi, B.S.
Dr. Patra, A.K.
Dr. Rattan, R.K.
Dr. Sharma, B.M.
Dr. Singh, Dhyan
Dr. Singh, R.D.
Dr. Singh, Sarjeet

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Dr. Biswas, D.R.
Dr. Datta, S.P.
Dr. Nayan Ahmed
Dr. Pandey, R.N.
Mr. Purakayastha, T.J.
Dr. Sharma, J.P.
Dr. Singhal, S.K.

Scientist
Dr. Meena, M.C.

Vegetable Science
Head
Dr. Sidhu, A.S.

Professor
Dr. Sharma, R.R.

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Dr. Joshi, Subodh
Dr. Kalia, Pritam
Dr. Mishra, J.P.
Dr. Raj Kumar

Sr. Scientist
Dr. Ravinder Kumar

Scientist
Dr. Behera, T.K

Nuclear Research Laboratory
Project Director
Dr. Datta, P.S.

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Dr. Kaim, M.R.S.
Dr. (Mrs.) Nagarajan, Shanta
Dr. Sachdeva, M.S.
Dr. (Ms.) Sachdeva, P.
Dr. Sud, Y.K.

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Dr. (Ms.) Anand, Anjali
Dr. Manjaiah, K.M.
Dr. Mookerjee, P.
Dr. Singh, Bhupinder

Water Technology Centre
Project Director
Dr. Koundal, K.R.

Professor
Dr. Yadav, B.R.

National Fellow.
Dr. (Ms.) Chopra, Renu Khanna

Principal Scientists
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Dr. Parihar, S.S.
Dr. Rajput, T.B.S.
Dr. Sharma, R.K.
Dr. Singh, Subedar

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Dr. Khanna, Manoj
Dr. Misra, A.K.
Dr. Sarangi, A.
Dr. Singh, D.K.
Dr. Singh, Man
Dr. (Ms.) Sudhishri, Susama
Dr. Vishwanathan, C.

Scientist
Dr. (Ms.) Patel, Neelam

Unit of Simulation and Informatics (USI)
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Dr. Chandrasekharan, H.

Principal Scientist
Dr. Bandhopadhyay, S.K

Sr. Scientist
Dr. Pathak, H.

Scientists
Dr. Kumar, S. Sujith
Mr. Mishra, A.K.

Centre for Agricultural Technology Assessment and Transfer (CATAT)
In-charge
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Sr. Scientists
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Dr. Sharma, J.P.
Dr. Singh, B.K.

Centre for Conservation and Utilization of Blue-Green Algae
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Dr. Pabbi, Sunil

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Ms. Arora, Anju
Dr. (Ms.) Prasanna, Radha
Dr. Singh, Yudhvir

Centre for Protected Cultivation Technology

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Sr.Scientist
Dr. Munshi, A.D.

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Mr. Hasan, Murtaza
Mr. Singh, M.C.

Farm Operation Service Unit

Incharge
Dr. Kamble, H.G.

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Dr. Sanjay Kumar
Dr. Sharma, S.K.

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Dr. Verma, P.K.

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Dr. Samdar, M.Y.

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Dr. Singh, A.K.

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Scientist-in-charge
Dr. Pun, K.B.

IARI Regional Station, Karnal

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Dr. Pandit, V.K.

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Dr. Atwal, S.S.
Mr. Chopra, N.K.
Dr. (Ms.) Chopra, N.K.
Dr. Gupta, Anuja
Dr. Rakesh Seth
Dr. Singh, P.B.
Mr. Sinha, J.P.
Dr. Yadav, R.N.

Scientists
Dr. Raj Kumar
Dr.Rana, S.C.

IARI Regional Station, Katrain

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Dr. Kapoor, K.S.

Sr. Scientist
Dr. Chander Parkash

Scientists
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Dr. Ranjan Kumar, P.
Dr. Suman, R.S.

IARI Regional Station, Pune

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Dr. Sharma, S.K.

Sr. Scientist
Dr. (Ms.) Verma, Raj

IARI Regional Station, Pusa

Head
Dr. Anil Kumar

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Dr. Dilip Kumar

Dr. Singh, Kannaiya

IARI Regional Station, Wellington (The Nilgiris)

Head

Dr. R.N. Brahma

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Dr. Sivasamy, M.

IARI Rice Breeding & Genetics Research Centre, Aduthurai

Scientist-in-charge

Dr. Nagarajan, M.

IARI Centre for Improvement of Pulses in South, Dharwad

Scientist-in-charge

Dr. Hegde, V.

IARI Krishi Vigyan Kendra, Shikohpur, Gurgaon

Scientist-in-charge

Dr. Anjani Kumar

National Professor

Dr. Agrawal, P.K. (Division of Environmental Sciences) (22/08/2007 to 26/08/2012)

Emeritus Scientists

Dr. Ahlawat, Y.S.(Division of Plant Pathology) (17/08/2006 to 16/08/2008)

Dr. Bhattacharya, A.K. (WTC) (22/05/2006 to 21/05/2008)

Dr. Chhonkar, P.K. (Division of SS&AC) (17/05/2006 to 16/05/2008)

Dr. Gupta, G.P. (Division of Entomology) (01/08/2006 to 31/07/2008)

Dr. (Ms.) Kulshrestha, Gita (Division of Agricultural Chemicals) (16/07/2007 to 15/072009)

Dr. Lodha, M.L. (Division of Genetics) (01/05/2007 to 30/06/2009)

Dr. Mishra, S.M. (Division of Nematology) (01/07/2006 to 30/06/2008)

Dr. Parmar, B.S. (Division of Agricultural Chemicals) (30/08/2006 to 29/08/2008)

Dr. Sharma, S.P. (Division of Seed Science & Technology) (01/10/2007 to 30/09/2009)

Dr. Sharma, P. Usha (Division of Plant Pathology (12/08/2004 to 11/08/2006

Dr. Singh, Dalmir (Division of Genetics) (06/04/2004 to 31/08/2008)

Dr. Singh, D.V. (Division of Plant Pathology) (01/12/2006 to 30/11/2008)

Dr. Sirohi, P.S. (Division of Vegetable Science) (01/05/06 to 30/04/08)

Dr. Uprety, D.C. (Division of Plant Physiology) (01/10/2007 to 30/09/2009)

INSA Senior Scientists

Dr. Rajendra Prasad (Division of Agronomy) (01/01/2004 to 31/12/2007)

Dr. Sharma, R.P. (NRCPB) (01/03/2005 to 29/02/2008)

Dr. Varma, Anupam (Division of Plant Pathology) (05/07/2005 to 04/07/2008)