ISSN 0972-6136

वार्षिक रिपोर्ट
Annual Report
2008-09

भाकृ अनुप.
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

भारतीय कृषि अनुसंधान संस्थान
IARI 1905

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Indian Agricultural Research Institute
(मानद विश्वविद्यालय)
(Deemed University)
नई दिल्ली-110 012
New Delhi-110 012

Printed : October, 2009

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Correct citation : IARI. Annual Report 2008-09, Indian Agricultural Research Institute, New Delhi - 110 012, India.

Copies printed: 1500

ISSN 0972-6136

IARI website **:** www.iari.res.in

Published by the Director, Indian Agricultural Research Institute, New Delhi - 110 012, India, and printed at Venus Printers and Publishers, B-62/8, Naraina Industrial Area, Phase II, New Delhi - 110028 (Phone: 25891449, 45576780, 9810089097, 20451501)

PREFACE

The Institute has been making concerted efforts to address the numerous challenges facing Indian agriculture. The goal of ensuring food security to the teeming millions of India has been one of its top priorities. Through the development of new high yielding varieties and novel production practices, the Institute has been making tremendous contributions in improving agricultural production, productivity and quality. It has also given adequate attention to the protection of environment and natural resource base. A multi-disciplinary mode of research has ensured optimization of resources and output. Efforts have also been made to transfer the technologies to the farmers. The Institute has continued to build the desired human resources in agriculture sector through its academic and training programmes. It has been granted accreditation up to August 5, 2013 by the Accreditation Board.

The Institute has released a total of thirteen varieties during the year: four in *Brassica*, three in wheat, two in carrot, and one each in rice, pearl millet, chickpea and pigeonpea. A rice variety Pusa 1121 under cultivation for the last four years in the Indo-Gangetic plains has been reportedly fetching a high premium for the farmers after being categorized as Basmati rice by the Ministry of Agriculture, Commerce and Industry. The Institute has made quantum jumps in seed production of its mandated crops.

The Institute has attracted National Agricultural Innovative Projects worth about 18 crores during the year 2008-09. Several scientists of the Institute received awards and recognitions for their contributions to various fields of specialization. The Institute's Krishi Vigyan Kendra (KVK) received the Best KVK National Award during the year.

This report summarizes the various activities and major accomplishments of the Institute during the year. I appreciate the joint directors, project directors, heads of divisions/establishments and regional stations, project coordinators and other scientists of the Institute for providing the requisite material for this report.

The report was prepared under the technical guidance and supervision of Dr. K.R. Koundal, Joint Director (Research) & Incharge, Publication Unit and edited by Mr. Chacko Thomas, Editor (English). The research material included in this report was vetted by Dr. Anand Swarup, Head, Division of Soil Science and Agricultural Chemistry, Dr. R.K. Sairam, Head, Division of Plant Physiology, Dr. V.V. Ramamurthy, Principal Scientist, Division of Entomology, Dr. B.R. Atteri, Principal Scientist, Division of Agricultural Economics, and Dr. S.S. Singh, Professor, and Dr. D.K. Yadav, Senior Scientist of the Division of Genetics.

I am thankful to all concerned who have helped in bringing out this report.

(H.S. Gupta)
Director

September 23, 2009
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.

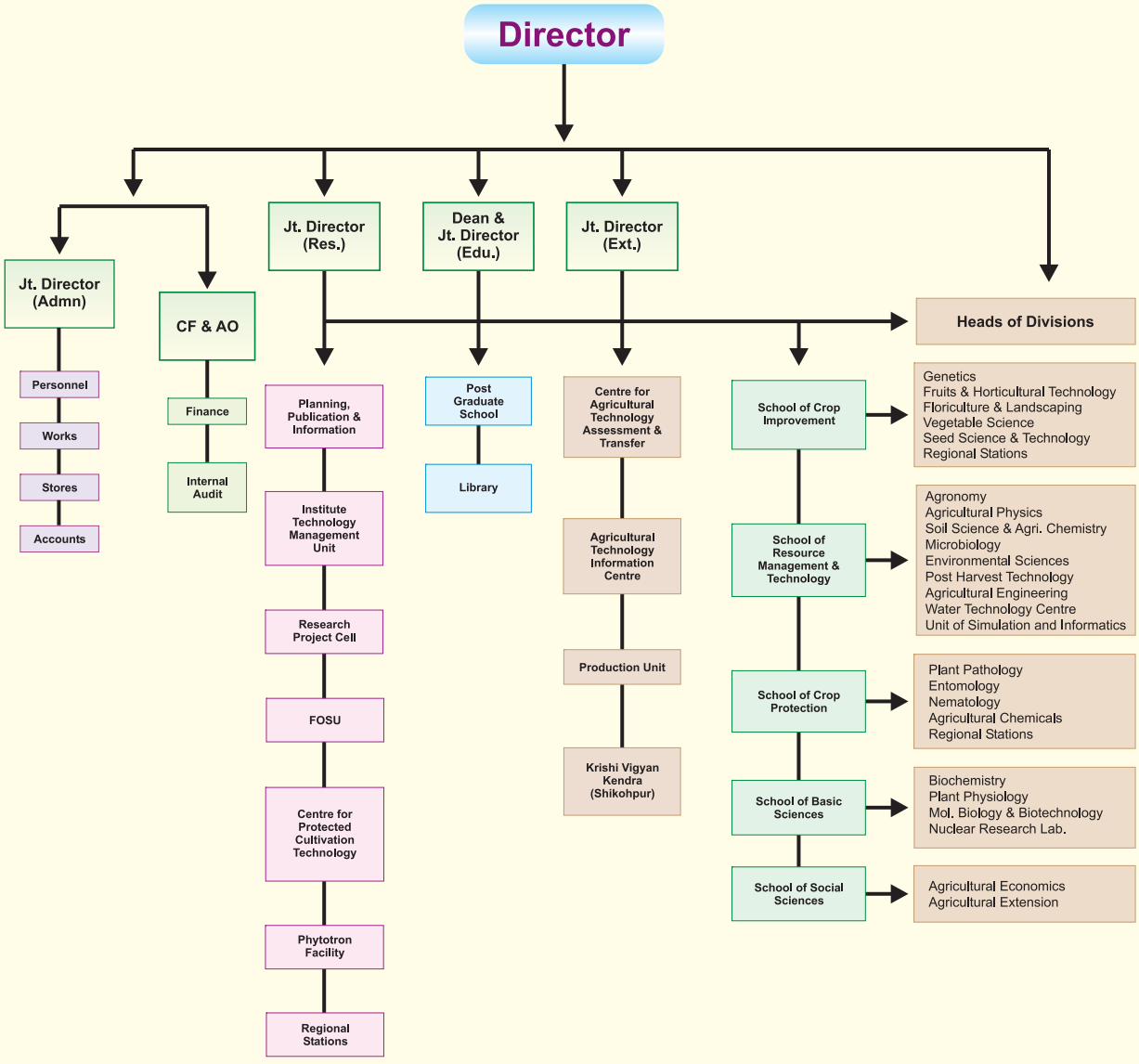
The mandates of the Institute are as follows:

- 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 the 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. It is located about 8 km west of New Delhi Railway Station, about 7 km west of Krishi Bhavan, which houses the Indian Council of Agricultural Research (ICAR), and about 16 km 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 228.61m. 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, one krishi vigyan kendra at Shikohpur, 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 3550 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute amounted to Rs. 10962 lakh for the year 2007-2008.

Indian Agricultural Research Institute



Organizational Structure

विशिष्ट सारांश

भारतीय कृषि अनुसंधान संस्थान वर्ष 2008–2009 के दौरान भी कृषि अनुसंधान, शिक्षा और प्रसार के अपने अधिदेशित क्षेत्रों में निरन्तर नेतृत्व प्रदान करता रहा है।

फसल सुधार के क्षेत्र में फसलों की अनेक किस्में या तो जारी की गईं या जारी किए जाने के लिए पहचानी गईं। अनेक परीक्षण भी सफलतापूर्वक आयोजित किए गए।

गेहूं में, गेहूं की उच्च उपजशील किस्म एच डी–2894 जिसकी औसत बीज उपज 5.2 टन प्रति हैक्टर थी, जारी की गई और उसे राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए अधिसूचित किया गया। इसकी बीज उपज 21 पर्यावरणों में उगाई जाने वाली मौजूदा किस्मों से अधिक थीं और यह 8.6–17.1 प्रतिशत की श्रेणी में थी। यह एक भिन्न ए.पी.आर. *एल.आर. 13* जीन से युक्त है जो पर्ण रतुआ के विरूद्ध बफर के रूप में कार्य करती है। इसमें 12.9 प्रतिशत प्रोटीन होता है और उच्च ग्लूटेन के कारण इसमें *चपाती* बनाने की बेहतर गुणवत्ता होती है। गेहूं की *ड्यूरम* किस्म एच डी–4713 जारी की गई जिसकी औसत उपज 4.71 टन प्रति हैक्टर है और जिसमें कि 5.15 टन प्रति हैक्टर की उपज क्षमता है। इसे राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए अधिसूचित किया गया। यह प्राकृतिक और कृत्रिम दोनों स्थितियों के तहत भूरे रतुए की प्रतिरोधी है और पास्ता उत्पादों के लिए उपयुक्त है क्योंकि इसमें बीज में पीलेपन का औसत केवल 2.8 प्रतिशत होता है। इस किस्म में–गिलयाडिन के लिए बैंड–45 है और यह एक वांछनीय विशेषता है। गेहूं की एक अन्य ड्यूरम किस्म एच डी–8638 जारी की गई और इसे मध्य प्रदेश की बारानी और सीमित सिंचाई परिस्थितियों के लिए जारी किया गया। यह पहली ''लम्बी–बौनी'' (मध्यम लम्बी और न गिरने वाली) किस्म है जिसकी उपज मध्य प्रदेश के किसानों के बीच लोकप्रिय गेहूं की किस्मों, सुजाता और लोक 1 की अपेक्षा 22.3 प्रतिशत से 45.0 प्रतिशत अधिक है। यह उच्च दाना उपज के साथ–साथ अधिक चारा भी प्रदान करती है। इसके उच्च â–केरोटीन (~5.0 पीपीएम), उच्च हैक्टोलीटर भार (83 कि.ग्रा.–84 कि.ग्रा.), उच्च एस डी एस अवसादन मान (30 मि.ली.–32 मि.ली.) और उच्च प्रोटीन अंश (~11.0 प्रतिशत) के कारण यह पौष्टिकता से भरपूर *चपाती* और सूजी बनाने के लिए *ड्यूरम* गेहूं जीन प्रारूप के दोनों उद्देश्यों को पूरा करती है। गेहूं की एक नई किस्म पूसा बेकर (एच एस 490) भा.कृ.अ.सं., क्षेत्रीय केन्द्र, टूटीकंडी, शिमला में विकसित की गई और उसकी उत्तरी पर्वतीय क्षेत्र (एनएचजैड) की पछेती बुवाई व सीमित सिंचाई परिस्थितियों के लिए जारी करने के लिए पहचान की गई। यह देश की ऐसी पहली किस्म है जो कि बिस्कुट बनाने की अन्तरराष्ट्रीय मानकों को पूरा करती है क्योंकि इसका उच्चतम 'स्प्रेड फैक्टर' 10.13 तक है और 'दाने की कठोरता का सूचकांक' 33 है। इसकी औसत बीज उपज 3.1 टन/हैक्टर है और उपज क्षमता 5.0 टन/हैक्टर है। यह पट्टीय (स्ट्राइप) रतुए के सबसे अधिक विषाक्त रोगप्ररूप '46S119' सहित सभी तीनों रतुओं की प्रतिरोधी हैं।

चावल में, अगस्त–2008 में जारी की गई पूसा बासमती–6 ने उपज क्षमता, सस्यविज्ञानी गुणों, अर्ध बौनी ऊंचाई, न गिरने की आदत और पकाने की बेहतर गुणवत्ता सभी दृष्टियों से पूसा–1121 की अपेक्षा बेहतर निष्पादन किया। दाना और पकाने की गुणवत्ता की दृष्टि से यह पूसा 1121 से काफी बेहतर है।

बाजरा में, अगेती पकने वाली और तेजी से उगने वाली किस्म पूसा कम्पोज़िट–443, जो कि मृदुरोमिल आसिता (डाउनी मिल्ड्यू) की उच्च प्रतिरोधी है और आर्द्रता प्रतिबल की परिस्थितियों के लिए उपयुक्त है, राजस्थान, हरियाणा, गुजरात और अन्य उन क्षेत्रों में उगाए जाने के लिए जारी की गई, जहां वार्षिक वर्षा 400 मि.मी. से कम है। इसकी औसत उपज 1.8 टन/हैक्टर है।

चने में, बड़े दानों वाली *काबुली* किस्म पूसा–2024 जो कि दोहरे संकर (बी जी 26 x आई सी सी 88503) x (जी एल 920 x बी जी 1003) के माध्यम से विकसित की गई थी, को राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए जारी और अधिसूचित किया गया। यह सामान्य और पछेती बुवाई, दोनों के लिए, उपयुक्त है और इसकी औसत उपज 2.4 टन/हैक्टर है। यह मिट्टी से होने वाले रोगों की मध्यम रूप से प्रतिरोधी हैं और आर्द्रता प्रतिबल व उच्च तापमान के प्रति सहिष्णु है। यह किस्म जिसकी पकाने की गुणवत्ता उत्कृष्ट है, खाने के उद्देश्य से भी उत्तम है। भा.कृ.अ.सं. किस्म पहचान समिति ने चने की दो किस्मों बी जी 5028 (*देसी* अतिरिक्त लम्बे बीजों वाली) और बी जी 5023 (*काबुली* अतिरिक्त लम्बे बीजों वाली) की पहचान की और ये दिल्ली राज्य बीज उप–समिति द्वारा राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए जारी किए जाने की प्रक्रिया में है।

अरहर की एक मध्यम लम्बी किस्म पूसा 2002 राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए जारी और अधिसूचित की गई। इस

किस्म की औसत बीज उपज 1.77 टन/हैक्टर है और इसके पकने की अवधि 143 दिन है। यह मध्यम मोटे बीज वाली किस्म है जिसके 100 बीजों का भार 8.7 ग्रा. है। यह उच्च प्रोटीन मान (20.2 प्रतिशत), पकाने के कम समय (20 मिनट) और दाल वसूली (85 प्रतिशत) जैसे उत्तम गुणों से युक्त है।

ब्रैसिका में चार किस्में नामतः एल ई टी 18 (पूसा मस्टर्ड 24), एल ई टी 17 (पूसा मस्टर्ड 22), एन पी जे 93 (पूसा विजय) तथा ई जे 13 (पूसा तड़क) जारी की गईं। पूसा मस्टर्ड 24 भारतीय सरसों की निम्न इरूसिक अम्ल वाली (<2.0 प्रतिशत) किस्म है जिसे ज़ोन–II (राजस्थान, पंजाब, हरियाणा, दिल्ली, जम्मू और कश्मीर के मैदानी क्षेत्रों तथा उत्तर प्रदेश के पश्चिमी भाग) के लिए जारी किया गया। इस किस्म की औसत बीज उपज 2.11 टन/हैक्टर है और उपज क्षमता 2.9 टन/हैक्टर है। इस किस्म की फसल सरसों की पारम्परिक किस्मों के समान 140 दिनों में पक जाती है। यह छोटे बीजों वाली किस्म है (4 ग्रा./1000 बीज)। बीजों में तेल की मात्रा 36.55 प्रतिशत होती है। पूसा मस्टर्ड 22 भारतीय सरसों की एकल शून्य इरूसिक अम्ल (<2 प्रतिशत) वाली किस्म है जिसे राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए जारी किया गया। इस किस्म की औसत बीज उपज 2.07 टन/हैक्टर है, जबकि इसकी उपज क्षमता 2.75 टन/हैक्टर तक है। इसकी फसल सरसों की पारम्परिक किस्मों के समान 142 दिनों में पक जाती है। इस किस्म का माध्य 1000 बीज भार 3.6 ग्राम है तथा तेल की मात्रा 36.0 प्रतिशत है। पूसा विजय को राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए 2008 के दौरान जारी और अधिसूचित किया गया। इस किस्म की औसत बीज उपज 2.5 टन/हैक्टर है। कुल 38.51 प्रतिशत की तेल अंश से युक्त यह किस्म बड़े बीजों वाली (6 ग्राम/1000 बीज) है। यह मध्यम पकने वाली (145 दिन) किस्म है और अजैविक प्रतिबलों अर्थात् पौद की स्थिति पर उच्च तापमान, 12 डी एस/एम तक की लवणता और गिरने व बिखरने आदि के प्रति सहिष्णु भी है। पूसा तड़क, भारतीय सरसों की अगेती पकने वाली (100–120 दिन का परिपक्वता) व बड़े बीजों वाली (6 ग्राम/1000 बीज) किस्म है जिसे राष्ट्रीय राजधानी क्षेत्र, दिल्ली में सितम्बर में बुवाई के लिए जारी किया गया। इसकी औसत बीज उपज 1.924 टन/हैक्टर है और उपज की क्षमता 2.90 टन/हैक्टर है। इस किस्म के बीजों में तेल की औसत मात्रा 40 प्रतिशत है जो कि मौजूदा किस्मों से बेहतर है। यह किस्म बहु–सस्यन प्रणाली, विशेष रूप से सितम्बर से दिसम्बर की अवधि के दौरान, उपयोगी है। समन्वित परीक्षणों में निरन्तर तीन वर्षों की प्रचलित किस्मों से बेहतर निष्पादन देने वाले सोयाबीन के जीन प्रारूप राष्ट्रीय राजधानी क्षेत्र, दिल्ली में जारी किए जाने के लिए पहचाने जाने हेतु प्रस्तावित किया गया।

सब्जी फसलों में, गोभी की एक मध्यम पकने वाले समूह की किस्म डी सी 5 (पूसा शक्ति) की भा.कृ.अ.सं. किस्म पहचान समिति द्वारा पहचान की गई। किस्म पहचान समिति ने एक कोल किस्म, पूसा विराट (के के एस–1) को हिमाचल प्रदेश में जारी करने के लिए पहचाना। अखिल भारतीय समन्वित अनुसंधान परियोजना (शाकीय फसलें) परीक्षणों में प्रविष्टि के एस–1 ने कटराईं में ए वी टी–1 में 66.0 टन/हैक्टर की उच्चतम उपज दी। भा.कृ.अ.सं. किस्म पहचान समिति ने राष्ट्रीय राजधानी क्षेत्र दिल्ली के लिए तोरई की किस्म डी आर जी 2 (पूसा नूतन) की पहचान की। इससे वसंत–ग्रीष्म और *खरीफ* मौसमों के दौरान प्रचलित किस्म पूसा नासदार की अपेक्षा क्रमशः 59.3 प्रतिशत और 49.0 प्रतिशत अधिक उपज प्राप्त हुई जो 18.5 टन/हैक्टर और 17.5 टन/हैक्टर थी। दिल्ली राज्य बीज उप–समिति द्वारा राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए गाजर की दो किस्में नामतः पूसा रुधिरा (लाल) और पूसा आसिता (काली) जारी की गईं। भा.कृ.अ.सं. किस्म पहचान समिति ने बहु–स्थानिक परीक्षणों में इसके उत्कृष्ट निष्पादन के आधार पर एक आशाजनक शीतोष्ण गाजर संकर के टी सी टी एच 7 (पूसा नयनज्योति) की पहचान की। उच्चतर उपज और वांछनीय औद्यानिक जड़ विशेषताओं के अलावा इस संकर में â–केरोटीन (7.552 मि.ग्रा/100 ग्राम ताजा भार) की उल्लेखनीय मात्रा थी। आम के चार संकर नामतः एच 1–1, एच 1–6, एच 2–6 तथा एच 4–12 पिछले काफी समय से बेहतर निष्पादन दे रहे थे। इन्हें जारी किये जाने के लिए पहचाना गया।

अलंकारिक फसलों में, गुलाब की 20 आशाजनक किस्मों का कम लागत के पॉलीहाउस में मूल्यांकन किया गया जिनमें से दो किस्में, नामतः पूसा प्रिया और पूसा बहादुर ने फूलों की गुणवत्ता के संबंध में बेहतर निष्पादन किया। भारतीय बागवानी अनुसंधान संस्थान, बैंगलूरू में विकसित की गई ग्लेडियोलस की 12 किस्मों का दिल्ली की स्थितियों में मूल्यांकन किया गया जिनमें से मीरा, सागर, पूनम, सपना, शक्ति और अर्का केसर दिल्ली की स्थितियों में उगाए जाने के लिए उपयुक्त पाई गईं। ग्लेडियोलस के संकर सेलमॉन क्वीन ओपन (वीरांगना), लिटल फॉन ओपन (कटाक्ष) और एव ओपन (किरण) निरन्तर मूल्यांकन के तहत आशाजनक पाए गए।

संस्थान ने संकर बीज उत्पादन प्रौद्योगिकी में महत्वपूर्ण प्रगति की है। पिछले तीन वर्षों के दौरान स्त्री पूर्वता की किस्म, वर्तिकाग्र ग्रहणशीलता, परागण जीवन क्षमता और इसके स्वतः गुणन आदि की जांच करने के उद्देश्य से भारतीय सरसों (*ब्रैसिका जुन्सिया* (एल.) जर्न एंड कॉस) में स्त्री पूर्वता धारण करने वाले पौधों का मूल्यांकन किया गया। इसके परिणामों से यह स्थापित हो गया कि संकर विकास के लिए स्त्री पूर्वी स्वतः असंगत वंशक्रम को आधार सामग्री के रूप में इस्तेमाल किया जा सकता है। गोभी के संकर पूसा कार्तिक शंकर के पैतृक वंशक्रमों के पुष्पन में तुल्यकालन पर किए जा रहे पूर्ववर्ती अध्ययनों से यह पुष्टि हो गई कि गोभी परिपक्वता (सी एम), बोल्टिंग (बीओएल) और कलिका मुकुलन (बी आई) स्थितियों पर 50 पीपीएम

की दर से आई ए ए के छिड़काव से पछेती पैतृक (मादा) के पुष्पन को 13 दिन अगेती प्राप्त किया जा सकता है जिससे पैतृक वंशक्रमों के बीच पुष्पन के अन्तराल को समाप्त किया जा सकता है। तथापि, बीज पैतृकों के पुष्पन की अवधि में थोड़ी सी कमी (2 दिन) हुई। निष्कर्षतः अगेती वर्ग के गोभी संकर पूसा कार्तिक शंकर के संकर बीज उत्पादन के लिए अगस्त के पहले सप्ताह में पैतृक वंशक्रमों के प्रतिरोपण और बीज पैतृकों में गोभी परिपक्वता, बोल्टिंग और कलिका मुकुलन की स्थितियों पर 50 पीपीएम की दर से आई ए ए के छिड़काव की सिफारिश की जाती है। यह अनुमान लगाया गया कि सीआई + सीएम + बीओएल + बीएल स्थितियों पर 250 पीपीएम की दर से GA_3 या सीएम + बीओएल + बीआई पर 50 पीपीएम की दर से आईएए का छिड़काव करके 500 वर्ग मीटर क्षेत्र से संकर गोभी की औसतन 15 किलोग्राम बीज उपज प्राप्त हो सकती है। इन रसायनों का कम से कम एक मौसम तक बीज की जीवन क्षमता पर कोई विपरीत प्रभाव देखा गया।

बुआई पूर्व स्थिर चुंबकीय क्षेत्र के प्रभाव संबंधी अध्ययन से यह स्पष्ट हुआ कि सम्पर्कहीन नियंत्रित पौधों की तुलना में चुम्बकीय क्षेत्र के सम्पर्क में आने वाले पौधों के प्ररोहों और जड़ों के शुष्क भार में उल्लेखनीय वृद्धि हुई। पौधों की जड़ों के गुणों के संदर्भ में एक मास पुराने पौधों की जड़ों की लंबाई व जड़ों की सतह क्षेत्र में आश्चर्यजनक रूप से दोगुनी वृद्धि देखी गई। सुधरे हुए जड़ संबंधी प्राचलों से यह संकेत मिलता है कि यह तकनीक चने की उस फसल के लिए लाभदायक रूप से उपयोग में लाई जा सकती है जो सामान्यतः बिना सिंचाई के उगाई जाती है। इसके अतिरिक्त अधिक लंबी जड़ों के कारण पौधे जमीन की गहरी सतहों से नमी खींच कर उसका उपयोग करने में भी समर्थ हो सकते हैं। मक्का में अंकुरण के दौरान बीज–जल वितरण तथा अंकुरण से संबंधित एंज़ाइमों पर स्थिर चुंबकीय क्षेत्र में बीजों के बुआई के पूर्व सम्पर्क संबंधी एक अध्ययन से यह स्पष्ट हुआ कि नियंत्रित की तुलना में स्थिर चुंबकीय क्षेत्र में रखे गए मक्का के बीजों में डिहाइड्रोजनेज सक्रियता 86 प्रतिशत अधिक थी और उपचारित बीजों में एल्फा–एमाइलेज़ सक्रियता 17–22 प्रतिशत उच्च थी। एंज़ाइमों की यह उच्च सक्रियता साइटोप्लाज़्मी जल अंश के उच्च निर्मोचन समय से मेल खाती थी जिसे T_2 निर्मोचन समय को नापने के बाद घटक विश्लेषण के माध्यम से पर्यवेक्षित किया गया। गौण अणुओं तथा झिल्लियों का अगेती जलीकरण और एंज़ाइम से संबंधित अंकुरण की अधिक सक्रियता के परिणामस्वरूप बीजों का अंकुरण शीघ्र हुआ और मक्का के चुंबकीय रूप से उपचारित बीजों से निकली अगेती पौदों की पुष्टता भी श्रेष्ठ पाई गई।

फसल आनुवंशिक संसाधनों पर हुए अनुसंधानों के अंतर्गत विभिन्न फसलों के अनेक जीनप्ररूप रोग–प्रतिरोधिता, गुणवत्ता तथा अन्य आर्थिक गुणों की दृष्टि से उपयुक्त पाए गए।

गेहूं के एक आनुवंशिक स्टॉक डब्ल्यूआर 95 (आईएनजीआर 08070) जिसमें एपिकल लेथेलिटी apd_1 के लिए नए पहचाने गए जीन उपस्थित थे, को जीन apd_1 के लिए राष्ट्रीय पादप आनुवंशिक संसाधन ब्यूरो में परीक्षक स्टॉक के रूप में पंजीकृत कराया गया। भा.कृ.अ.सं. क्षेत्रीय केन्द्र, टुटीकंडी, शिमला द्वारा विकसित गेहूं के दो जीनप्ररूप नामतः एचएस 424 (आईएनजीआर सं.08006) तथा एचएस 431 (आईएनजीआर सं. 08007) को पत्ती और तना रतुओं के विरुद्ध प्रतिरोधी स्रोतों के रूप में राष्ट्रीय पादप आनुवंशिक संसाधन ब्यूरो में रजिस्टर्ड कराया गया। गेहूं के दो अन्य जीन प्ररूपों नामतः एचएस 491 और एचएस 492 को बिस्कुट बनाने की उपयुक्तता के गुण से सम्पन्न पाया गया और इनके पंजीकरण के लिए आवेदन किया जा चुका है। इनकी राष्ट्रीय पंजीकरण संख्याएं क्रमशः 08116 (आईसी 566222) तथा 08117 (आईसी 566223) हैं। ड्यूरम गेहूं का जीनप्ररूप एचआई 8591 सभी तीनों रतुओं के प्रतिरोधी तथा उच्च उपज देने वाले जीनप्ररूप के रूप में आनुवंशिक स्टॉक के तौर पर राष्ट्रीय पादप आनुवंशिक संसाधन ब्यूरो, नई दिल्ली में पंजीकृत कराया गया। *मेइडिस* पत्ती झुलसा प्रतिरोध के लिए मक्का के आनुवंशिक स्टॉक एससी–24–92–3–2–1–1 को राष्ट्रीय पादप आनुवंशिक संसाधन ब्यूरो में पंजीकृत कराया गया (आईएनजीआर 08117)।

सूक्ष्मजैविक आनुवंशिक संसाधनों पर अनुसंधान के अंतर्गत नील हरित शैवल जननद्रव्य को सबल बनाया गया और वर्तमान में इस भंडागार में कुल 550 साइनोबैक्टीरियाई आइसोलेट हैं जिन्हें यूनीएल्गल अवस्था में रखा गया है।

पचास किस्म नमूनों सहित विभिन्न समूहों के सात सौ बहत्तर रोगग्रस्त कवकीय नमूनों को एचसीआईओ में प्रविष्टि दी गई है और इस प्रकार यहां उपस्थित नमूनों की कुल संख्या 48,222 हो गई है।

कवकीय जैवविविधता में अनेक नई प्रजातियां जोड़ी गई हैं, जिनमें सम्मिलित हैं : *आल्टर्नेरिया पाल्मीवोरा, एस्टेरीना आर्डिसीकोला, ए. कैसीई, ए. एम्सीसियाना, एस्टेरिडिएला इम्सीसियाना, सर्कोस्पोरा एटाइलोसीई, सी. माइक्नीजेना, सी.निम्फीजेना, मेलिओलेस्टर एपोरूसी, मेलियोला वाटसवायाई, एम. लोफोपेटालिलोटा, एम. केईरेटीई, पैसालोरा सीसेलपिनीकोला, स्यूडोसर्कोस्पोरा, एम्पाइलोसिसिकोला, पी. बाइस्कोफिगेना, पी. सीसेलपिन्यिाना, पी.कोकुलिगेना, पी. थनबर्जियाना, सिफेनेरूला वैडेलीई, सार्सीनेला लिमोनीई, स्टेनेला पेंटारोपिडिकोला* तथा *स्लेईकैरियोलिओसा* ।

मैस्टीगोमाइकोटीना, ज़ाइगोमाइकोटीना, एस्कोमोइकोटीना तथा ड्यूटेरोमाइकोटीना के अंतर्गत आने वाले लगभग 3663 कवकीय संवर्धनों को इंडियन टाइप कल्चर कलेक्शन (आईटीसीसी) में रखा गया है तथा आईटीसीसी को विभिन्न प्रकार के 143 कवकीय संवर्धनों से समृद्ध किया गया है। कुछ उल्लेखनीय पादप रोगजनक प्रविष्टियों

में सम्मिलित हैं: *एक्रेमोनियम जोजियोग्रीसेयम, कर्वुलेरिया फैलेक्स, सी. एराग्रोस्टाइडिस, सी. क्लावाटा, फ्यूज़ेरियम फ्यूज़ारॉइडिस, टेलारोमाइसिस फ्लेवस, स्टेम्फाइलियम वर्सीकेरियम* तथा *स्क्लेरोटियम डेल्फिनी*।

कीट पहचान सेवा के अंतर्गत 529 कीट नमूनों की पहचान की गई। *स्क्यूटेलेरा परप्लेक्सा* तथा *क्राइसोकोरिस* प्रजाति (हेमिप्टेरा : पेंटाटोमॉइडी : स्क्यूटेलेरिडी) को दिल्ली तथा इसके आसपास उगाई जाने वाली जैट्रोफा प्रजाति के लिए एक गंभीर और नियमित नाशकजीव के रूप में रिकॉर्ड किया गया। एक नई प्रजाति नामतः *प्रिएसस पंक्टाटा* का वर्णन विभिन्न प्रजातियों की पहचान के लिए किया गया। चार पेंटामॉइड प्रजातियों नामतः *कोरिडियस आब्सक्यूरस, युरीडेमा पल्क्रम, प्रिएसस एक्समटस* तथा *प्रिएसस पंक्टाटा* (नई प्रजातियों) को हिमाचल प्रदेश से पहली बार रिकार्ड किया गया। सूत्रकृमि जैव–वर्गीकरणविज्ञान तथा पहचान सेवा के अंतर्गत संस्थान ने राइबोसोमल डीएनए के आईटीएस क्षेत्र के 7 नए जीन क्रम प्रस्तुत किए – *स्टेईनर्नेमा* के चार, *हेटरोरेब्डिटिस* के दो तथा गैर–सहजीवी जीवाणु *ल्यूकोबैक्टर इएरियस* प्रजाति का एक, जो *एस.थर्मोफिलस* से प्राप्त किए गए थे और जिन्हें जीन बैंक में क्रमशः प्रविष्टि सं. एफजे418046; एफजे715947; एफजे715946; एफजे418045; एफजे744544; एफजे751864; तथा एएम 040493 के अंतर्गत दर्ज किया गया। राष्ट्रीय सूत्रकृमि संकलन को नई प्रजातियों का प्रतिनिधित्व करने वाली 21 टाइप स्लाइडों पर 35 टाइप नमूनों को शामिल करके समृद्ध किया गया। इस प्रकार इनकी कुल संख्या 2232 नमूना प्रविष्टियां हो गई हैं। नम संकलनों का डेटाबेस 625 से बढ़ाकर 1830 रिकार्ड किया गया है।

फसल एवं संसाधन प्रबंध तथा पर्यावरण के अंतर्गत संस्थान द्वारा अनेक महत्वपूर्ण अध्ययन किए गए। इनमें शामिल हैं : ग्रीष्म ऋतु में हरी खाद देने का प्रभाव; सुगंधित चावल की उत्पादकता पर फसल अपशिष्ट तथा जस्ता उर्वरक का प्रभाव; कपास में मूंग की अंतरफसल उगाना; वसंत ऋतु की सूरजमुखी (*हेलियंथस एनस*) की फसल में पोषक स्रोत के रूप में जैट्रोफा (*जेट्रोफा काक्रस*) तथा अरण्ड (*रिसिनस कोम्युनिस*) की तेलविहीन खलियों के उपयोग संबंधी अध्ययन तथा मक्का (*जी.मेज*) की परवर्ती फसल पर उसका अपशिष्ट प्रभाव; सोयाबीन की गंधक तथा बोरॉन पोषण के प्रति प्रतिक्रिया; पोषकता प्रबंध के संबंध में चावल आधारित फसल प्रणाली की जैविक खेती; बारानी परिस्थितियों में अरहर तथा मूंग अंतर–फसल प्रणाली पर पौध प्रणाली तथा उर्वरता स्तर का प्रभाव; संरक्षित जुताई हेतु उपयुक्त फसल प्रणाली; बारानी परिस्थितियों में नाइट्रोजन के विभिन्न स्तरों पर गेहूं जीनप्ररूपों का निष्पादन; उत्तर–पूर्वी मैदानी क्षेत्रों में गेहूं उत्पादकता पर बोरॉन अनुप्रयोग का प्रभाव; पारम्परिक जुताई एवं शून्य जुताई परिस्थितियों के अंतर्गत गेहूं किस्मों का मूल्यांकन; गेहूं की फसल पर पीएसबी संवर्धन तथा एज़ोटोबैक्टर के साथ बीज उपचार का प्रभाव; उन्नत पूसा बासमती 1 (पूसा 1460) का सस्यविज्ञान; पीआरएच10 के पैतृक वंशक्रम की समकालिकता और बीज पैदावार पर सस्यविज्ञानी क्रियाओं का प्रभाव; तथा खरपतवार मुक्त एवं स्वस्थ चावल नर्सरी उगाने की नई तकनीकें। मृदा प्रबंधन में, विभिन्न जैविक सामग्री तथा यूरिया के साथ संशोधित मृदा में कार्बन खनिजीकरण पर तापमान तथा नमी के प्रभाव पर अध्ययन किए गए। इस विषय के अंतर्गत किए गए अध्ययन में शामिल हैं : मंद गति से सक्रिय होने वाले उर्वरक के रूप में नैनो क्ले–पॉलीमर कम्पोजिट; चावल–गेहूं तथा मक्का–गेहूं फसल चक्र की लंबे समय तक की गयी खेती के अंतर्गत मृत्तिका ढेले युक्त मिट्टी का परिवेश में खाद मिट्टी तथा डीटीपीए से निकले सूक्ष्म पोषक अवयवों का प्रचुर वितरण; वायुजीवी रूप से बोई गई चावल फसल में आयरन कमी सुधारने के लिए मिट्टी की पारस्परिक प्रभावशीलता तथा आयरन का पर्णीय अनुप्रयोग; विभिन्न जुताई प्रणालियों तथा फसल अवशिष्ट प्रबंध की विभिन्न क्रियाओं के साथ गेहूं आधारित फसल प्रणाली में फास्फोरस गतिकी; गेहूं पैदावार में सीवर गाद तथा चावल पुआल समामेलन का प्रभाव तथा पोषक तत्वों का खनिजीकरण; गेहूं तथा लोबिया की पोषकता एवं मृदा स्वास्थ्य पर चावल पुआल से समृद्ध कम्पोस्ट का प्रभाव; तथा मृदा संरचना पर भारी धातु संदूषण का प्रभाव और उसका निदान। जल प्रबंधन के क्षेत्र में, प्रमुख अध्ययन क्षेत्र थे : भा.कृ.अ.सं. फार्म में दीर्घावधि वर्षा के संबंध में डाटा सीरीज में किसी भी प्रवृत्ति की उपस्थिति की पहचान के लिए मौसमविज्ञान अध्ययन; भा.कृ.अ.सं. परिसर में सतही अप्रवाह आंकलन तथा भू–जल मानीटरिंग; गुड़गांव (हरियाणा) में मानेसर नाला जलसंभर से एससीएस कर्व नम्बर (सीएन) उपाय, सुदूर संवेदन तथा जीआईएस के उपयोग द्वारा सतही अप्रवाह का आंकलन; मक्का आधारित फसल चक्र के तहत मक्का तथा मूंगफली की पैदावार पर पौध रोपण तरीकों एवं अंतर फसल चक्र का प्रभाव; ड्रिपर क्लोगिंग का निकृष्ट जल गुणवत्ता पर प्रभाव; ग्रीष्म टमाटर फसल के लिए उप–सतही ड्रिप प्रणाली; भिण्डी उत्पादन पर सूक्ष्म सिंचाई प्रणाली का प्रभाव; ड्रिप सिंचाई तथा बारानी परिस्थितियों के अंतर्गत मूंगफली (*अरेकिस हाइपोजिया* एल.) की फसल का निष्पादन; सुदूर संवेदी तथा जीआईएस तकनीक के माध्यम से भारत के गंगा पार मैदानों (टीजीपी) में फसल प्रणाली विश्लेषण के लिए मॉडलिंग वाष्पन उत्स्वेदन तथा जड़ क्षेत्र मृदा जल संतुलन; भूजल अध्ययन; जल गुणवत्ता अध्ययन तथा सिंचाई जल प्रबंधन में संस्थागत भूमिका तथा संगठनात्मक सेट–अप का मूल्यांकन।

समेकित पोषक तत्व प्रबंध के अंतर्गत अनेक महत्वपूर्ण अध्ययन किए गए। इनमें शामिल थे : मक्का–गेहूं फसल क्रम के तहत फसल उत्पादकता तथा मृदा उर्वरता पर उर्वरक एवं खाद का दीर्घावधि प्रभाव; अरहर–गेहूं फसल प्रणाली में समेकित पोषक तत्व आपूर्ति तथा प्रबंध; बाजरा–सरसों फसल प्रणाली में समेकित पोषक तत्व आपूर्ति तथा प्रबंध; चावल–गेहूं फसल प्रणाली में समेकित पोषक

तत्व प्रबंध के संदर्भ में जैव–उर्वरक; गेहूं–मक्का फसल प्रणाली के अंतर्गत टिकाऊ फसल उत्पादन पर मूल्य संवर्धित कम्पोस्ट के प्रभाव का मूल्यांकन एवं मृदा गुणवत्ता पर उनका प्रभाव; तथा अरहर एवं गेहूं के लिए सुझाए गए मृदा परीक्षण आधारित उर्वरकों से संबंधित मूल डाटा का विकास। पोषक तत्व प्रबंध के अंतर्गत किए गए अन्य अध्ययन में मृदा में विभिन्न पोषक तत्वों की कमी का आकलन तथा स्थान विशिष्ट पोषक तत्व प्रबंध एवं मृदा जैविक कार्बन के माध्यम से उनमें सुधार करना और संरक्षित जुताई के अंतर्गत चावल–गेहूं फसल चक्र में उपलब्ध पोषक तत्व मात्रा संबंधी अध्ययन शाामिल थे।

बागवानी प्रबंधन के अंतर्गत अध्ययन किए गए क्षेत्र इस प्रकार हैं : आम अपरूपण का महामारीविज्ञान; किन्नो पर एएमएफ की प्रतिक्रिया; किन्नो में सूक्ष्म पोषक तत्व प्रबंध, आम में सोडियम क्लोराइड की कमी स्ट्रेस पर पेक्लोबुट्राजॉल का प्रभाव; लवण प्रतिबल स्थितियों के अन्तर्गत नींबूवर्गीय फलों के मूलवृंत पेक्लोबुट्राज़ॉल तथा प्यूटेसाइन का प्रभाव; तथा पपीते की बढ़वार, पैदावार एवं गुणवत्ता पर जैव–उर्वरकों एवं सूक्ष्म पोषक तत्वों का प्रभाव। संरक्षित खेती प्रौद्योगिकी के अंतर्गत हुए अध्ययन इस प्रकार थे : उच्चतम ग्रीष्म ऋतु के दौरान पार्थेनोकार्पिक खीरा की खेती के लिए अर्ध–जलवायु नियंत्रित ग्रीन हाउस का मूल्यांकन; सब्जियों में विषाणु मुक्त तथा गैर–मौसमी नर्सरी उगाने के लिए कम लागत वाले कीट प्रतिरोधी नेटहाउस की तकनीकी – आर्थिक उपयुक्तता; विभिन्न संरक्षित परिस्थितियों में बीज मसालों (जीरा तथा धनिया) का मूल्यांकन; ड्रिप जलीय उर्वरीकरण प्रौद्योगिकी के अंतर्गत उगाए गए नींबू का तकनीकी–आर्थिक मूल्यांकन; प्राकृतिक रूप से हवादार ग्रीन हाउस में उगाए गए खीरे की जलीय उर्वरीकरण समय–सारणी तथा फसल जल उत्पादकता का मानकीकरण तथा ड्रिप जलीय उर्वरीकरण के साथ बोए गए क्राइसेन्थेमम फूलों की प्रकाश अवधि का नियंत्रण।

संस्थान द्वारा अधिकतम फसल उत्पादन के लिए खेत से जुड़े अनेक उपकरण तैयार किये गए एवं प्रौद्योगिकियां विकसित की गयीं। वर्ष के दौरान, 45 अश्व शक्ति (एचपी) के ट्रैक्टर द्वारा चालित प्याज खुदाई यंत्र का डिजाइन तैयार कर उसका विकास किया गया। पहले से विकसित ओनियन डिटोपर की डिज़ाइन में सरलता लाने के लिए उसमें सुधार किया गया। दो अश्वशक्ति वाले मोटर से चालित सब्जी बीज निकाई यंत्र की डिज़ाइन तैयार कर उसका निर्माण किया गया। पहले से विकसित ग्रेन पोलिशर में दाना सतह से चिपकी धूल को हटाकर दानों की पॉलिश करने के लिए उसमें और सुधार किया गया।

फार्म संचालन सेवा इकाई (फोसू) द्वारा संस्थान के विभिन्न संभागों, परियोजना निदेशालयों अथवा स्थापना को जरुरत के अनुसार सहायता उपलब्ध कराई गई।

कटाई उपरांत प्रौद्योगिकी एवं प्रबंधन के तहत बिना शक्कर वाले जामुन पेय का नया फार्म्यूलेशन विकसित किया गया। इसके तहत अन्य अध्ययन में शामिल था : कटाई परियोजना तथा पैकेजिंग के मानकीकरण द्वारा चीकू के फलों की गुणवत्ता बनाए रखना; परिवेशी तथा निम्न तापमान भण्डारण के दौरान आंवला फलों का किस्मगत मूल्यांकन; पराजीनी टमाटर के कटाई उपरांत गुणवत्ता संबंधी गुणों के संबंध में पीए जैव–संश्लेषण जीन लक्षण; ब्रोकोली पुष्पकों की संशोधित वातावरण पैकेजिंग; सेब के लिए संकुचन रैपिंग तकनीक का मानकीकरण; सेब में कटाई उपरांत बीमारियों के नियंत्रण हेतु सूक्ष्म जैवीय प्रतिरोधिता; संवर्धित हाइड्रोकॉलाइडस के साथ नींबू के जूस का गुणवत्ता मूल्यांकन; अरहर की दाल के फूले बनाने की विधि का मानकीकरण; मक्का की विभिन्न किस्मों के पौष्टिक गुणों का मूल्यांकन तथा आल्स्ट्रोमेरिया में पुष्प जीर्णनकाल में विलम्ब हेतु वृद्धि नियंत्रक उपचारों का मानकीकरण।

सूक्ष्मजीवविज्ञान में मुख्य अध्ययन इन क्षेत्रों में किया गया : कृषि अवशिष्टों के पुनश्चक्रण तथा टिकाऊ एवं जैविक खेती के लिए इनकी उपयोगिता; फसल उत्पादन के लिए सूक्ष्म जीवों का दोहन; जैव नियंत्रण एजेंटों के रूप में सूक्ष्मजीवों तथा कृषि एवं उद्योग के लिए सायनोबैक्टीरियाई आनुवंशिक संसाधनों की खोज एवं उनका दोहन।

पर्यावरणीय सुरक्षा संस्थान के प्रमुख अनुसंधान उद्देश्यों में से एक है। पर्यावरण विज्ञान से जुड़े विषयों पर महत्वपूर्ण अध्ययन किए गए; जैसे कि चना की पैदावार में बढ़ते तापमान एवं कार्बन डाइऑक्साइड का प्रभाव; फसल की गुणवत्ता पर बढ़ते तापमान का प्रभाव; खेत में स्वतंत्र कार्बन डाइऑक्साइड समृद्धि (RACE) तापमान प्रवणता सुरंग (TGT) का परिशोधन; सरसों फसल उत्पादन पर जलवायु परिवर्तन का प्रभाव; मिट्टी से उत्सर्जित ग्रीन हाउस गैसों पर बढ़ते तापमान का प्रभाव; खाद्यान्न, दलहन तथा तिलहन फसलों की खेती के दौरान मीथेन तथा नाइट्रस ऑक्साइड प्रवाह का आकलन; ऊपरी व्यास बेसिन के जल संभर में वर्षा, बर्फ तथा ग्लेशियर के कारण वार्षिक निस्स्राव की दीर्घावधि विभिन्नता खेतों में उर्वरीकरण के सिंचाई के लिए औद्योगिक व्यर्थ जल की उपयोगिता; कृषि पारिस्थितिकी सेवाओं पर जैविक खेती का पारिस्थितिक तथा आर्थिक प्रभाव; निचले हिमालयी क्षेत्र में जमा होने वाली तलछट का आंकलन; पुनश्चक्रण योग्य कृषि अवशिष्ट तथा चयनित फसल गैर–खाद्य तिलहन खली का मूल्यांकन और बायोगैस उत्पादन हेतु उनकी उपयुक्तता, विभिन्न हॉटस्प्रिंग्स से सेलुलोलाइटिक थर्मोफाइल्स का विलगन एवं गुणधर्म निर्धारण; सतह ओज़ोन पर चावल की बढ़वार एवं उत्पादकता का प्रभाव; गेहूं की परागण बंध्यता पर बढ़े हुए ओजोन का प्रभाव; तथा उन्नत प्राकृतिक संसाधन गुणधर्म निर्धारण के लिए मल्टी/हाइपर–स्पेक्ट्रल सुदूर संवेदी तकनीकें।

फसल सुरक्षा के क्षेत्र में संस्थान द्वारा पादप रोगविज्ञान, कीटविज्ञान, सूत्रकृमिविज्ञान, कृषि रसायन तथा खरपतवार प्रबंधन में उल्लेखनीय परिणाम निकाले गए।

पादप रोगविज्ञान के क्षेत्र में संस्थान द्वारा गेहूं, चावल, मक्का, चना, उड़द, मूंग, मटर, अरहर, तोरिया व सरसों, सब्जियों तथा फलों को प्रभावित करने वाली कवकीय बीमारियों पर कार्य किया गया। ड्यूरम गेहूं की दो बौनी किस्मों नामतः एचडी 4672 तथा एचआई 8498 और चपाती गेहूं की एक किस्म एचआई 1500 में नई उभरी तना रतुआ प्रजाति *यूजी99* जो कि *एसआर31* पर उग्र थी, के विरुद्ध केन्या में खेत प्रतिरोधिता का उच्च स्तर प्रदर्शित हुआ। विषाण्विक तथा जैविक बीमारियों पर भी महत्वपूर्ण परिणाम प्राप्त किए गए। विषाण्विक जीनोमिक्स के अंतर्गत, मूंगफली कलिका ऊतकक्षय विषाणु (जीबीएनवी) के मध्यम आरएनए का अनुक्रमण; तरबूज कलिका ऊतकक्षय विषाणु (डब्ल्यूबीएनवी) के माध्यम से आरएनए का अनुक्रमण; पपीता छल्ला धब्बा विषाणु (पीआरएसवी) का संपूर्ण जीनोम अनुक्रमण; सिट्रस ट्रिस्टेजा विषाणु (सीटीवी) का आंशिक जीनोम अनुक्रमण; सिट्रस पीले चित्ती विषाणु (सीएमबीवी) का संपूर्ण जीनोम अनुक्रमण; रोगजनक में मूंगबीन पीले चित्ती भारत विषाणु (एमवाईएमआईवी) के आवरण पूर्व प्रोटीन (ओआरएफ एवी2) तथा आवरण प्रोटीन (ओआरआर एवी1) की भूमिका; तथा टमाटर बेगोमो विषाणु की संक्रमण क्षमता पर अध्ययन किये गये। आंध्र प्रदेश के चित्तूर जिले से एकत्रित सतगुडी संतरा के नमूनों में CMBV के साथ मंडारी विषाणु के सम्मिश्रित संक्रमण का पता चला। सिट्रस को संक्रमित करने वाले आरएनए तथा डीएनए की पहचान के लिए पीसीआर आधारित एक नैदानिक किट का विकास किया गया। आण्विक रोगनिदान; आनुवंशिक विविधता, पराजीनी प्रतिरोधिता आदि में अन्य बहुत से अध्ययन किए गए। पुणे में संस्थान के क्षेत्रीय केन्द्र द्वारा किए गए सर्वेक्षणों से पता चला कि संतरा, खट्टा और मौसम्बी मे हरितिमा रोग; खरबूजे में जैडवाईएमवी (10–15 प्रतिशत) तथा पॉटी वाइरस (80–100 प्रतिशत); और पॉलीहाउस में उगाए गए शिमला मिर्च की बाम्बे और लेरियो किस्मों में टोबेमो वाइरस (5–52 प्रतिशत) का प्रकोप हुआ। खरबूजे में व्यावसायिक रूप से उगाई गई सात किस्मों की विषाण्विक बीमारियों के लिए की गई जांच से पॉटी विषाणु के प्रभेद की उपस्थिति का पता चला जिसके कारण खरबूजे के बेल के झड़ने और फलों के चटकने के कारण किसानों को गंभीर नुकसान उठाना पड़ता है।

कीटविज्ञान के अंतर्गत खाद्यान्नों, सरसों, सोयाबीन, कपास तथा सब्जियों पर कीट नाशीजीव प्रबंधन अध्ययन आयोजित किए गए। अन्य किए गए अध्ययन में शामिल थे : जैविक नियंत्रण, कीट शरीरक्रियाविज्ञान तथा कीट विषालुताविज्ञान। सूत्रकृमिविज्ञान में जैवविविधता तथा सूत्रकृमि प्रबंधन पर महत्वपूर्ण अध्ययन किए गए। कृषि रसायन में प्राकृतिक तथा कृत्रिम कृषि रसायनों और उनके सह–उत्पादों; नाशीजीवनाशी फार्म्यूलेशन; तथा नाशीजीवनाशियों के जोखिम मूल्यांकन व पर्यावरणीय क्षति एवं उपचार पर उल्लेखनीय अनुसंधान आयोजित किए गए।

खरपतवार प्रबंधन के अंतर्गत किए गए अध्ययन इस प्रकार थे – गेहूं में *चेनोपोडियम एल्बम* एल. की आर्थिक सीमा; क्लोडीनाफॉप तथा मेटसल्फुरॉन के साथ गेहूं में जटिल खरपतवार वनस्पति का नियंत्रण; शाकनाशी टैंक मिश्रण बनाम खरपतवार प्रबंधन एवं सोयाबीन पैदावार के लिए अनवर्ती अनुप्रयोग; तथा *फेलरिस माइनर* रिटज बायोटाइप में क्रॉस प्रतिरोधिता के संबंध में क्लोडीनाफोप – प्रोपारगायल, सल्फोसल्फुरॉन तथा पाइनोक्साडेन का मूल्यांकन।

मूलभूत एवं नीतिगत अनुसंधान के तहत संस्थान द्वारा बहुत से उल्लेखनीय परिणाम हासिल किए गए। पादप जैवप्रौद्योगिकी के क्षेत्र में किए गए अनुसंधान इस प्रकार थे : संकर ओज के उपयोग से उत्पादकता में वृद्धि; पराजीनी विकास के लिए जीन तथा प्रमोटर्स का विलगन; जैविक तथा अजैविक प्रतिबल की प्रतिरोधिता के लिए पराजीनी फसलों का विकास; जीनोमिक्स एवं आण्विक मार्कर; प्रभावी सूक्ष्मजीव–पादप अंतरक्रिया के लिए आनुवंशिकीय रूप से अभियंत्रित सूक्ष्मजीवों का विकास;ऊतक संवर्धन द्वारा शाकीय फसलों का सूक्ष्म प्रवर्धन एवं सुधार तथा आम का आण्विक गुणधर्म निर्धारण।

जैवरसायनविज्ञान के अंतर्गत किए गए अध्ययन में शामिल थे : चावल में आर्द्रता प्रतिबल के अंतर्गत अलग–अलग नियंत्रित जीनों का विलगन एवं गुणधर्म निरीक्षण; तथा स्टार्च, घुलनशील शर्करा व पैदावार संबंधी पैरामीटरों के लिए गेहूं की किस्मों का विश्लेषण। संस्थान में किये गए पादप शरीरक्रियाविज्ञानी अध्ययन के तहत शामिल विषय थे : अनाजों में उत्पादकता को सीमित करने वाली शरीरक्रियाविज्ञानी बाधाएं; शरीरक्रियाविज्ञानी एप्रोच के माध्यम से फसलीय पौधों की अजैविक दबाव सहिष्णुता में सुधार; निरन्तर एवं सीमांत तापीय दबाव वातावरण में *ट्रिटिकम ऐस्टीवम* तथा *ट्रिटिकम* ड्यूरम गेहूं जीनप्ररुपों में तापीय दबाव सहिष्णुता का मूल्यांकन; जल विभिन्नता वाले पर्यावरण के अंतर्गत गेहूं के संकर डब्ल्यूएल 711×सी 306 की प्रगत पीढ़ी जनसंख्या में सूखा प्रतिरोधिता हेतु आकृति–शरीरक्रियाविज्ञानी गुणों का निर्धारण; गामा विकिरण संरोपित पादप प्रतिक्रिया, नाशीजीवनाशी अपघटन तथा कृषि उत्पादों का कटाई उपरांत गुणवत्ता परिरक्षण; कपास की किस्मों की प्रकाश–संश्लेषण दक्षता पर बढ़ते तापमान का प्रभाव; भारी धातुओं के फाइटोरीमेडिएशन में फाइटोसिडेरोफोर की भूमिका; नई गेहूं पादप किस्म (डीएल 1266–5) में परागोद्भव के उपरांत नाइट्रोजन स्वांगीकरण में पत्ती की विभिन्न स्थितियों का योगदान; लिलियम में अगेती पुष्पीकरण के लिए प्रबल तकनीक का मानकीकरण; फलों, सब्जियों एवं फूलों का कटाई उपरांत

शरीरक्रियाविज्ञान, तथा वैश्विक जलवायु परिवर्तन के प्रति फसल प्रतिक्रिया का गुणधर्म निर्धारण। आनुवंशिकी में संस्थान द्वारा किए गए ये अनुसंधान मुख्यतः गेहूं, चावल, जौ, मक्का, बाजरा, चना, मसूर, मटर, अरहर तथा *ब्रैसिका* पर केन्द्रित थे। *ड्रोसोफ़िला मेलानोगैस्टर* में 76 जीनों तथा 4 Wnt जीनों वाले गुणसूत्र 2L पर 725Kb जीनोमिक क्षेत्र का एक विस्तृत कार्यशील जीनोमिक विश्लेषण किया गया। 76 जीनों में से 19 में उत्परिवर्तन खोजे गए और महत्वपूर्ण यह था कि DWnt4 में 8 नए उत्परिवर्तन खोजे गए। wnt परिवार के सदस्यों के बीच कार्यशील संबंध तथा पारस्परिकता का अध्ययन किया गया।

कृषि भौतिकी के तहत मृदा भौतिकी; सुदूर संवेदन एवं जीआईएस; तथा कृषि मौसमविज्ञान विषयों पर अध्ययन किये गए।

कृषि अर्थशास्त्र के क्षेत्र में संस्थान द्वारा किए गए अध्ययन इस प्रकार थे : भारत के गंगा–यमुना के मैदानों में मजदूर देशांतरण का ग्रामीण अर्थव्यवस्था पर प्रभाव; भारतीय कृषि पर व्यापार उदारीकरण का प्रभाव; परि–नगरीय खेती, तथा भारत में गैर–खाद्य तिलहनों का आर्थिक विश्लेषण एवं संभावना। कृषि प्रसार में किए गए प्रमुख अध्ययन इस प्रकार थे : प्रसार संगठनों की दक्षता में सुधार; कृषि प्रौद्योगिकियों के सामाजिक, आर्थिक एवं पर्यावरणीय प्रभाव का मूल्यांकन; टिकाऊ विकास के लिए खेती प्रणाली अनुसंधान एवं प्रसार; सहभागिता प्रसार कार्यप्रणाली एवं अंतर–क्षेत्रीय सूक्ष्म–योजनाओं का विकास; कृषि प्रसार में सीएएस के अंतर्गत आयोजित प्रशिक्षण कार्यक्रमों के प्रभाव का विश्लेषण, ग्रामीण संसाधन प्रबंध में क्षमता निर्धारण मूल्यांकन तथा पहुंच से दूर एवं आदिवासी क्षेत्रों में गेहूं खेती प्रौद्योगिकी का प्रसार।

संस्थान द्वारा प्रौद्योगिकी मूल्यांकन एवं हस्तांतरण के क्षेत्र में किए गए प्रमुख अध्ययन में शामिल थे : विभिन्न कृषि–पारिस्थितिक क्षेत्रों में कृषि प्रौद्योगिकियों के अनुप्रयोग के लिए नए वृद्धि क्षेत्रों की संभावना; टिकाऊ फसल उत्पादन के लिए जल प्रबंधन प्रौद्योगिकियां; समेकित खेती प्रणाली तथा प्रौद्योगिकी मॉडल के माध्यम से आदिवासी प्रभुत्व वाले क्षेत्रों के निवासियों का जीवन निर्वाह एवं उनकी पोषण सुरक्षा; गेहूं, जौ तथा मक्का की खेती के अग्रिम पंक्ति प्रदर्शन और राज्य कृषि विश्वविद्यालयों व भा.कृ.अ.प. के संस्थानों के साथ सहयोगात्मक प्रसार कार्यक्रम।

भा.कृ.अ.सं., नई दिल्ली में 21–23 फरवरी, 2008 को तीन दिवसीय पूसा कृषि विज्ञान मेले का आयोजन किया गया जिसका मुख्य विषय था : ''भा.कृ.अ.सं. – उच्च उत्पादकता तथा व्यावसायीकरण की ओर अग्रसर''। मेले का उद्घाटन 21 फरवरी 2008 को कृषि अनुसंधान एवं शिक्षा विभाग (डेयर) के सचिव तथा भारतीय कृषि अनुसंधान परिषद के महानिदेशक डॉ. मंगला राय ने किया।

संस्थान द्वारा खेत दिवस/खेत परीक्षण, ऑफ कैम्पस प्रदर्शनियां, किसानों तथा प्रसार कर्मियों आदि के लिए प्रशिक्षण जैसी प्रसार संबंधी बहुत–सी गतिविधियों का आयोजन भी किया गया। संस्थान के कृषि प्रौद्योगिकी सूचना केन्द्र (एटिक) ने विभिन्न पणधारियों को उत्पादों, सेवा, प्रौद्योगिकियों और सूचना को प्रभावी रूप से प्रदान करने के उद्देश्य से 'एकल खिड़की आपूर्ति प्रणाली' के रूप में कार्य करना जारी रखा।

संस्थान के शिकोहपुर, गुड़गांव स्थित कृषि विज्ञान केन्द्र ने प्रौद्योगिकीय सशक्तीकरण के माध्यम से ग्रामीण युवाओं में बेरोजगारी की समस्या का सामना करने तथा विभिन्न प्रौद्योगिकियों के कार्यक्रमों के हस्तांतरण के माध्यम से किसानों में जागरूकता का सृजन करने और खेत उत्पादकता में सुधार लाने के प्रति उत्प्रेरक की भूमिका निभाना जारी रखा। संस्थान द्वारा महिला सशक्तीकरण और लिंग मुद्दों को मुख्य धारा में लाने के लिए बहुत–से कार्यक्रम चलाए गए।

संस्थान में दिनांक 8 फरवरी 2008 को स्नातकोत्तर विद्यालय का स्वर्ण जयंती वर्ष दीक्षांत समारोह–2008 आयोजित किया गया। दीक्षांत समारोह के मुख्य अतिथि भाभा परमाणु अनुसंधान केन्द्र, मुम्बई के निदेशक डॉ. एस. बनर्जी ने दीक्षांत भाषण दिया। उक्त समारोह में एम. एससी. तथा पीएच.डी. के क्रमशः 75 तथा 84 छात्रों को उपाधियां प्रदान की गईं। कु. रीता भाटिया (बागवानी) तथा कु. निशा एम. (आनुवंशिकी) को क्रमशः पीएच.डी. तथा एम.एससी. के लिए वर्ष 2007 का सर्वश्रेष्ठ छात्र पुरस्कार प्रदान किया गया। रिपोर्टाधीन अवधि के दौरान संस्थान द्वारा अनेक नियमित एवं अल्पावधि प्रशिक्षण पाठ्यक्रमों का आयोजन किया गया। जैवसूचना प्रणाली तथा कृषि सूचना प्रणाली संस्थान की उच्च प्राथमिकता वाली सूची में बने रहे। संस्थान के पुस्तकालय द्वारा छात्रों एवं वैज्ञानिक समुदाय को उत्कृष्ट सेवा प्रदान करना जारी रहा।

संस्थान की अधिदेशित गतिविधियों के सूचना प्रसार के उद्देश्य से संस्थान द्वारा हिन्दी तथा अंग्रेजी दोनों भाषाओं में अनेक नियमित एवं तदर्थ प्रकाशन निकाले गए। संस्थान ने रिपोर्टाधीन अवधि में कुल छह पेटेन्ट के लिए आवेदन प्रस्तुत किए तथा 11 समझौता ज्ञापनों पर हस्ताक्षर किए। चार पेटेंट हासिल किए गए अथवा उनका नवीनीकरण किया गया। संस्थान ने व्यावसायीकरण के लिए अपनी दो प्रौद्योगिकियों को राष्ट्रीय अनुसंधान एवं विकास परिषद् (एनआरडीसी) को सौंपा।

संस्थान द्वारा अनेक राष्ट्रीय एवं अंतरराष्ट्रीय संस्थानों के साथ सम्पर्क एवं सहयोग जारी रखा गया।

EXECUTIVE SUMMARY

The Indian Agricultural Research Institute (IARI) continued to provide leadership in its mandated areas of agricultural research, education and extension during the year 2008-2009.

In the area of crop improvement, several crop varieties were either released or identified. Many trials were also conducted successfully.

In wheat, a high yielding wheat variety HD 2894 with an average seed yield of 5.2 t/ha was released and notified for the national capital region (NCR), Delhi. Its seed yield was higher than that of the existing varieties over 21 environments and was in the range of 8.6% -17.1%. It carries a different APR *Lr13* gene that acts as a buffer against leaf rust. It has 12.9% protein and better *chapati* making quality with a high gluten score. A *durum* wheat variety HD 4713 with an average yield of 4.71 t/ha and a yield potential of 5.15 t/ha was released and notified for NCR, Delhi. It is resistant to brown rust under both natural and artificial conditions and is suitable for pasta products as the average yellow berry incidence is only 2.8%. The variety possesses the band 45 for γ-gliadin, which is a desirable trait. Another *durum* wheat variety HD 8638 was released for rainfed and limited irrigation conditions of Madhya Pradesh. It is the first "tall-dwarf" (medium tall and non-lodging) variety yielding 22.3% to 45.0% higher than the popular wheat cultivars, Sujata and Lok 1, in farmers' fields in Madhya Pradesh. In addition to high grain yield, it provides more fodder as well. Because of its high β-carotene (~5.0 ppm), high hectolitre weight (83 kg to 84 kg), high SDS sedimentation value (30 ml to 32 ml) and high protein content (~11.0 %), it can serve as a dual purpose *durum* wheat genotype for making nutritious *chapati* and semolina (*suji*). A new wheat variety Pusa Baker (HS 490) developed at IARI Regional Station, Tutikandi, Shimla was identified for release under late sown, restricted irrigation conditions of Northern Hills Zone (NHZ). This is the first variety in the country which meets international standard for biscuit quality with a 'spread factor' as high as 10.13 and a 'grain hardness index' value of 33. Its average seed yield is 3.1 t/ha with a yield potential of 5.0 t/ha. It combines resistance to all three rusts including the most virulent pathotype '46S119' of stripe rust.

In rice, Pusa Basmati 6 released in August 2008 performed better than Pusa 1121 in yielding ability, agronomy, semi-dwarf stature, non-lodging habit and cooking quality. For grain and cooking quality traits, it has significant improvement over Pusa 1121.

In pearl millet, an early maturing, and fast growing variety Pusa Composite 443, which is highly resistant to downy mildew disease and suitable for moisture stress condition, was released for cultivation in Rajasthan, Haryana, Gujarat and other areas, where the annual rainfall is less than 400 mm. It has an average yield of 1.8 t/ha.

In chickpea, a *Kabuli* bold seeded variety Pusa 2024 developed through a double cross (BG 261 × ICC 88503) × (GL 920 × BG 1003) was released and notified for NCR, Delhi. It is suitable for both normal and late plantings, and yields, on an average, 2.4 t/ha. It is moderately resistant to soil borne diseases and tolerant to moisture stress and high temperature. This variety having an excellent cooking quality is good for table purpose also. Two chickpea varieties, BG 5028 (*desi* extra large seeded) and BG 5023 (*Kabuli* extra large seeded), were identified by IARI Variety Identification Committee, and are in the process of release by the Delhi State Seed Sub-Committee for NCR, Delhi.

A medium tall variety of pigeonpea Pusa 2002 was released and notified for NCR, Delhi. The average seed yield of this variety is 1.77 t/ha with a maturity period of 143 days. It is a medium bold seeded variety with 8.7 g/100 seeds. It has better quality traits like protein value (20.2%), cooking time (20 minutes) and *dal* recovery (85%).

In *Brassicas*, four varieties, namely, LET 18 (Pusa Mustard 24), LET 17 (Pusa Mustard 22), NPJ 93 (Pusa Vijay), and EJ 13 (Pusa Tarak) were released. Pusa Mustard 24 is a low erucic acid (<2.0%) variety of Indian mustard released for zone II (Rajasthan, Punjab, Haryana, Delhi, plains of Jammu & Kashmir and western parts of Uttar Pradesh). The average seed yield of this variety is 2.11 t/ha with a yield potential of 2.9 t/ha. This variety is on a par in maturity (140 days) with the conventional mustard varieties. It is a small seeded variety (4 g/1000 seeds) with an oil content of 36.55%. Pusa Mustard 22 is a single zero erucic acid (<2%) variety of Indian mustard released for NCR, Delhi. The average seed yield of this variety is 2.07 t/ha, whereas, its yield potential is up to 2.75 t/ha. It is on a par in maturity (142 days) with the conventional mustard varieties. The mean 1000-seed weight of this variety is 3.6 g with an oil content of 36.0%. Pusa Vijay was released for NCR, Delhi and notified during 2008. The average seed yield of this variety is 2.5 t/ha. It is a bold seeded variety (6 g/1000 seeds) with an oil content of 38.51%. It is of medium maturity (145 days), and is tolerant to abiotic stresses, viz., high temperature at seedling stage, salinity up to 12 dS/m, and lodging and shattering. Pusa Tarak is an early maturing (100-120 days' maturity) bold seeded (6 g/1000 seeds) variety of Indian mustard, which was released for September sowing in NCR, Delhi. It has an average seed yield of 1.924 t/ha with a yield potential of 2.90 t/ha. The mean oil content of this variety is 40%, which is better than that of the prevailing checks. This variety will be useful in the multiple cropping system particularly during the period of September-December. DS 2207, a soybean genotype, which performed consistently better than the checks for three consecutive years in the coordinated trials was proposed for its identification and release in NCR, Delhi.

In vegetable crops, DC 5 (Pusa Shukti), a mid maturity group variety of cauliflower, was identified by IARI Variety Identification Committee. A knol khol variety, Pusa Virat (KKS 1) was identified for release in Himachal Pradesh by IARI Variety Identification Committee. In AICRP (VC) trials, the entry KKS 1 gave the highest yield of 66.0 t/ha in AVT I at Katrain. A luffa variety, DRG 2 (Pusa Nutan) was identified by IARI Variety Identification Committee for NCR, Delhi. It gave yields of 18.5 t/ha and 17.5 t/ha, which were 59.3% and 49.0% higher than those of the check Pusa Nasdar during spring-summer and *kharif* seasons, respectively. Two carrot varieties, viz., Pusa Rudhira (red) and Pusa Asita (black), were released for NCR, Delhi by the Delhi State Seed Sub-Committee. A promising temperate carrot hybrid KTCTH 7 (Pusa Nayanjyoti) was identified by IARI Variety Identification Committee on the basis of its superior performance in multilocation trials. Besides higher yield and desirable horticultural root traits, this hybrid also contained an appreciable content of β-carotene (7.552 mg/100 g fresh weight). Four mango hybrids, viz., H 1-1, H 1-6, H 2-6 and H 4-12 found to perform consistently well were identified for release.

In ornamental crops, twenty promising varieties of rose were evaluated in low cost polyhouse, of which two varieties, viz., Pusa Priya and Pusa Bahadur performed well with respect to flower quality. Twelve gladiolus varieties developed at IIHR, Bangalore were evaluated under Delhi conditions, of which Meera, Sagar, Poonam, Sapana, Shakti and Arka Kesar were found to be suitable for production under Delhi conditions. Gladiolus hybrids, Salmon Queen Open (Veerangana), Little Fawn Open (Kataksh), and Ave Open (Kiran) were found promising under continuous evaluation.

The Institute has made significant progress in hybrid seed production technology. An assessment of the plants possessing protogyny in Indian mustard [*Brassica juncea* (L.) Czern & Coss.] was undertaken during the past three years with the objective of examining the nature of protogyny, stigma receptivity, pollen viability and its self multiplication. The result has established that a protogynous self-incompatible line can be used as a base material for hybrid development. In continuation to earlier studies on synchronization in the flowering of parental lines of cauliflower hybrid Pusa Karthik Shankar, it was confirmed that sprays of IAA @ 50 ppm at curd maturity (CM), bolting (Bol), and bud initiation (BI) stages advanced the flowering of the late parent (female) by 13 days, thereby bridging the gap in flowering between the parental lines. However, there was a marginal reduction (2 days) in the duration of flowering of the seed parent. In conclusion, transplanting of parental lines in the first week of August and sprays of IAA @ 50 ppm at curd maturity, bolting, and bud initiation to the seed parent could be recommended in hybrid seed production of the early

group cauliflower hybrid Pusa Karthik Shankar. It was estimated that an average seed yield of 15 kg of hybrid cauliflower could be achieved from 500 m^2 area of hybrid seed production by spraying IAA @ 50 ppm at CM+Bol+BI or GA_3 @ 250 ppm at CI+ CM+Bol+BI stages. There was no adverse effect of these chemicals on seed viability at least up to one season.

A study on the effect of pre-sowing exposure of static magnetic field showed that magnetic field exposure enhanced shoots and root dry weights significantly compared to those of unexposed control. The root characteristics of the plants showed a dramatic two-fold increase in root length and root surface area of one month old plants. The improved root parameters suggest that this technique could be profitably exploited as chickpea is generally grown without irrigation and the enhanced root growth will be useful in extracting moisture from deeper layers. A study on the effect of pre-sowing exposure of static magnetic field on seed water distribution and germination related enzymes during germination in maize showed that dehydrogenase activity was 46% higher than that of the control, and α-amylase ctivity was higher by 17-22% in treated seeds. Higher activity of these enzymes coincided with higher relaxation time of cytoplasmic water fraction observed from the component analysis after measuring T_2 relaxation times. Early hydration of macromolecules and membranes and greater activities of germination related enzymes are responsible for quicker germination and early seedling vigour of magnetically treated seeds in maize.

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.

WR 95 (INGR 08070), a genetic wheat stock carrying newly identified gene apd_1 for apical lethality was registered with NBPGR as a tester stock for gene apd_1. Two wheat genotypes, viz., HS 424 (INGR No. 08006) and HS 431 (INGR No. 08007) developed by IARI Regional Station, Tutikandi, Shimla were registered with NBPGR as resistance sources against leaf and stem rusts. Two wheat genotypes, viz., HS 491 and HS 492 were identified for biscuit quality and are under registration with application and national identity numbers 08116 (IC 566222) and 08117 (IC 566223), respectively. A *durum* wheat genotype HI 8591 was registered with NBPGR, New Delhi as a genetic stock with high yield and resistance to all three rusts. A maize genetic stock SC-24-92-3-2-1-1 for *maydis* leaf blight resistance was registered with NBPGR (INGR 08117).

Under the research on microbial genetic resources, BGA germplasm was strengthened. At present, a total of 550 cyanobacterial isolates are housed in the repository and maintained in unialgal condition.

Seven hundred seventy-two diseased fungal specimens of different groups including fifty type specimens were accessioned in HCIO raising the total number of specimens to 48, 222.

Many new species added towards fungal biodiversity include: *Alternaria palmivora*, *Asterina ardisiicola*, *A. cassiae*, *A. emciciana, Asteridiella emciciana, Cercospora atylosiae, C. michnigena, C. nymphaegena, Meliolaster aporusae*, *Meliola vatsavayai*, *M. lophopetaliilola*, *M. cayratiae, Passalora cesalpinicola, Pseudocercospora ampilocisicola, P. bischofigena, P. caesalpiniana, P. cocculigena, P. thunbergiana, Schiffnerula wedeliae, Sarcinella limoniae, Stenella pentatropidicola* and *S. schleicherioliosa.*

About 3663 fungal cultures belonging to Mastigomycotina, Zygomycotina, Ascomycotina and Deuteromycotina were maintained at Indian Type Culture Collection (ITCC). The ITCC was further enriched with 143 different fungal cultures. Some noteworthy plant pathogens accessioned include: *Acremonium roseogriseum Curvularia fallax, C. aragrostidis, C. clavata, Fusarium fusaroides, Telaromyces flavus, Stemphylium vesicarium,* and *Sclerotium delphini*.

Under insect identification service, 529 insect specimens were identified. *Scutellera perplexa* and *Chrysocoris* sp. (Hemiptera: Pentatomoidea: Scutelleridae) were recorded as serious and regular pests of *Jatropha* sp. grown in and around Delhi. A new species, viz., *Priassus punctata* was described with a key for the identification of various species. Four pentatomoid species, viz., *Coridius obscurus, Eurydema pulchrum, Priassus exemptus* and *Priassus punctata* (new

species) were recorded for the first time from Himachal Pradesh. Under nematode biosystematics and identification service, the Institute submitted 7 new gene sequences of the ITS region of ribosomal DNA – four of *Steinernema*, two of *Heterorhabditis*, and one of asymbiotic bacterium *Leucobacter iarius* sp. n. from *S. thermophilum* to the GenBank vide accession Nos. FJ 418046; FJ 715947; FJ 715946; FJ 418045; FJ 744544; FJ 751864; and AM 040493, respectively. The National Nematode Collection was maintained and augmented by the addition of 35 type specimens on 21 type slides representing 7 new species, thus bringing the total strength to 2232 type accessions. The database of wet collections was updated from 625 to 1830 records.

Several important studies were conducted by the Institute under the research on crop and resource management and environment. These covered studies on the effect of incorporation of summer green manuring, crops residue and zinc fertilization on the productivity of aromatic rice; intercropping of mungbean in cotton; studies on *Jatropha* (*Jatropha carcus*) and castor (*Ricinus communis*) de-oiled cakes as a nutrient source in spring sunflower (*Helianthus annuus*) and their residual effect on succeeding maize (*Zea mays)*; response of soybean to sulphur and boron nutrition; organic farming of rice-based cropping systems with respect to nutrient management; effect of planting systems and fertility levels on pigeonpea and mungbean intercropping system under rainfed condition; suitable cropping system for conservation tillage; performance of wheat genotypes at different nitrogen levels under rainfed condition; effect of boron application on the productivity of wheat in NEPZ; evaluation of wheat varieties under conventional tillage and zero tillage conditions; effect of seed treatment with *azatobactor* and PSB culture on wheat; agronomy of improved Pusa Basmati 1 (Pusa 1460); effect of agronomic manipulations on synchronization and seed yield of parental line of PRH 10; and new technique for raising weed free and healthy rice nursery. In soil management, studies were conducted on the effect of temperature and moisture on the carbon mineralization in soil amended with various organic materials and urea; nanoclay-polymer composite as a slow release fertilizer; profile distribution of humus and DTPA-extractable micronutrients in clay-humus complexes under long-term cultivation of rice-wheat and maize-wheat systems; relative efficacy of soil and foliar application of iron in correcting iron deficiency under aerobically-grown rice; phosphorus dynamics in wheat-based cropping systems with varying tillage and crop residue management practices; effect of sewage sludge and rice straw incorporation on wheat yield and mineralization of nutrients; effect of enriched rice straw compost on nutrition of wheat and cowpea and soil health; and impact of heavy metal contamination on soil biota and its remediation. In water management, the major studies covered were: meteorological studies to identify the existence of any trend in the data series related to long term rainfall at IARI farm; surface runoff estimation and groundwater monitoring in IARI campus; estimation of surface runoff by the use of SCS curve number (CN) method, remote sensing and GIS from Manesar Nala watershed in Gurgaon (Haryana); effect of planting method and intercropping on the yield of maize and peanut under maize-based cropping system; effect of poor quality water on dripper clogging; sub-surface drip system for summer tomato; effect of micro-irrigation systems on okra production; performance of groundnut (*Arachis hypogaea* L.) under drip irrigation and rainfed conditions; modeling evapotranspiration and root-zone soil water balance for cropping system analysis in the trans-Gangetic plains (TGP) region of India through remote sensing and GIS techniques; groundwater studies; water quality studies; and evaluation of institutional role and organizational set-up in irrigation water management.

Under integrated nutrient management, the studies covered the long-term effects of fertilizers and manures on crop productivity and soil fertility under maize-wheat sequence; integrated nutrient supply and management in pigeonpea-wheat cropping system; integrated nutrient supply and management in pearl millet-mustard cropping system; biofertilizers in integrated nutrient management (INM) in rice-wheat cropping system; evaluation of value-added composts on sustainable crop production and their impact on soil quality under wheat-maize cropping system; and development of basic data and soil test based fertilizer recommendations for pigeonpea and wheat. Other studies in nutrient management were on the appraisal of multi-nutrient deficiencies in soils and their redress through site-specific nutrient management, and soil organic carbon and available

nutrient content in rice-wheat cropping system under conservation tillage.

Under orchard management, studies were conducted on: epidemiology of mango malformation; response of AMF on Kinnow; micronutrient management in Kinnow; effect of paclobutrazol on NACl stress in mango; effect of paclobutrazol and putrescine on citrus rootstock under salt stress; and the effect of biofertilizers and micronutrients on the growth, yield and quality of papaya. The studies under protected cultivation technology were on the evaluation of semi-climate controlled greenhouse for parthenocarpic cucumber cultivation during peak summer period; techno-economic suitability of low cost insect proof net house for virus free and off-season nursery raising in vegetables; evaluation of seed spices (cumin and coriander) under different protected conditions; techno-economic evaluation of lemon grown with drip fertigation technology; standardization of crop water productivity and fertigation scheduling of cucumber grown in naturally ventilated greenhouse; and photoperiodic regulation of flowering in chrysanthemum grown with drip fertigation.

The Institute developed several farm related equipment and technology for optimizing crop production. During the year, an onion digger operated by a 45-horse power (hp) tractor, was designed and developed. An onion detopper developed earlier was modified for simplicity of design. A 2-hp motor driven vegetable seed extractor was designed and fabricated. A grain polisher developed earlier was modified for polishing grains by removing sticky dust from the grain surface.

The Farm Operation Service Unit (FOSU) catered to the needs of the divisions, project directorates or establishments at the Institute for conducting field experiments.

Under post harvest technology and management, a new formulation of *jamun* drink without sugar was developed. Other studies included quality retention of sapota fruits through standardization of harvest maturity and packaging; varietal evaluation of *aonla* fruits during ambient and low temperature storage; PA biosynthesis gene expression studies with respect to post harvest quality attributes of transgenic tomatoes; modified atmosphere packaging of broccoli florets; standardization of shrink-wrapping technique for apples; microbial antagonists for the control of post-harvest diseases of apple; quality evaluation of citrus juice with added hydrocolloids; standardization of method of flaking for pigeonpea *dal*; nutritional evaluation of corn varieties; and standardization of growth regulator treatments to delay flower senescence in *Alstroemeria.*

In microbiology, major studies were conducted on recycling of agricultural residues and their utilization for sustainable and organic agriculture; exploitation of microorganisms for crop production; microorganisms as biocontrol agents; and exploration and exploitation of cyanobacterial genetic resource for agriculture and industry.

Protection of environment has been one of the Institute's major concerns in research. The important studies related to environmental sciences were on the impact of elevated temperature and CO_2 on chickpea yield; effect of elevated temperature on quality characters of crops; calibration of free air carbon dioxide enrichment (FACE) and temperature gradient tunnel (TGT) in field; impact of climate change on mustard crop production; effect of elevated temperature on greenhouse gases emissions from soil; estimation of methane and nitrous oxide flux from soils under cereals, pulses and oil seed crops; long term variability of annual discharge in a rain, snow and glacier fed watershed of the upper Beas basin; utilization of industrial wastewaters for ferti-irrigation in agricultural fields; ecological and economic impact of organic farming on agroecosystem services; sediment yield estimation in the lesser Himalayan region; evaluation of recyclable agri-residue and selected crop non-edible oilseeds cakes for their suitability for producing biogas; isolation and characterization of cellulolytic thermophiles from different hotsprings; impact of surface ozone on the growth and productivity of rice; impact of elevated ozone on the pollen sterility of wheat; and innovative multi/hyper-spectral remote sensing techniques for improved natural resource characterization.

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

In plant pathology, findings were made on fungal diseases affecting wheat, rice, maize, chickpea, urdbean, mungbean, pea, pigeonpea, rapeseed and mustard, vegetables, and fruits. Two *durum* wheat varieties, HD 4672 and HI 8498, and a bread wheat variety HI 1500 showed high levels of field resistance in Kenya to the newly emerged stem rust race *Ug99*, virulent on *Sr31*. Important findings were also made on viral and bacterial diseases. Under viral genomics, studies were conducted on sequencing of medium (M) RNA of *Groundnut bud necrosis virus* (GBNV); sequencing of medium (M) RNA of *Watermelon bud necrosis virus* (WBNV); complete genome sequencing of *Papaya ring spot virus* (PRSV); partial genome sequencing of *Citrus tristeza virus* (CTV); complete genome sequencing of *Citrus yellow mosaic virus* (CMBV); role of pre-coat protein (ORF AV2) and coat protein (ORF AV1) of *Mungbean yellow mosaic India virus* (MYMIV) in pathogenicity; and infectivity of tomato begomoviruses. Mixed infection of a *Mandarivirus* with CMBV was observed in Sathgudi sweet orange sample collected from Chittoor district of Andhra Pradesh. A PCR based diagnostic kit for the detection of RNA and DNA pathogens affecting citrus was developed. Several other studies were also conducted in molecular diagnosis; genetic diversity; transgenic resistance, etc. Surveys conducted by the Institute's regional station at Pune revealed the occurrence of : greening disease in sweet orange, acid lime and mandarin; ZYMV (10-15%) and a strain of poty virus (80-100%) in muskmelon; and tobamovirus (50-52%) in polyhouse grown capsicum varieties, Bomby and Lario. In muskmelon, seven commercially grown varieties screened for viral diseases revealed the occurrence of a strain of poty virus causing severe losses to farmers due to the decline of muskmelon vines and cracking of fruits.

In entomology, insect pest management studies were conducted on cereals, mustard, soybean, cotton and vegetables. Other studies covered biological control, insect physiology and insect toxicology. In nematology, important studies were made on biodiversity and nematodes management. In agricultural chemicals, significant research was conducted on the development of natural and synthetic agrochemicals and their adjuvants; pesticide formulations; and risk assessment and environmental fate of pesticides and remedies.

In weed management, studies were conducted on the economic threshold of *Chenopodium album* L. in wheat; control of complex weed flora in wheat with clodinafop and metsulfuron; herbicide tank-mixes *versus* sequential application for weed management and soybean yield; and evaluation of clodinafop-propargyl, sulfosulfuron and pinoxaden towards cross-resistance across *Phalaris minor* Retz. biotypes.

Under basic and strategic research, the Institute made several significant findings. In plant biotechnology, studies were conducted on the enhancement of productivity through exploitation of heterosis; isolation of genes and promoters for the development of transgenics; development of transgenic crops for resistance to biotic and abiotic stresses; genomics and molecular markers; development of genetically engineered microbes for effective microbe-plant interaction; micro-propagation and improvement through tissue culture of vegetable crops; and molecular characterization of mango.

In biochemistry, the studies covered the isolation and characterization of differentially regulated genes under moisture stress in rice; and analysis of wheat cultivars for starch, soluble sugar and yield parameters. In plant physiology, the studies conducted at the Institute covered the physiological constraints limiting productivity in cereals; improvements in abiotic stress tolerance in crop plants through physiological approaches; evaluation of heat stress tolerance in *Triticum aestivum* and *Triticum durum* wheat genotypes under continual and terminal heat stress environments; morpho-physiological traits for drought resistance in advanced generation population of the wheat cross WL 711 × C 306 under water variable environments; *gamma* radiation induced plant responses, pesticide degradation and post-harvest quality preservation of agri-products; effect of growing temperatures on photosynthetic efficiency of cotton varieties; role of phytosiderophore in phytoremediation of heavy metals; contribution of leaves at different positions towards N-assimilation after anthesis in new wheat plant type (DL 1266-5); standardization of forcing technique for early flowering in lilium; post-harvest physiology of fruits, vegetables and flowers; and characterization of crop responses to global climate change. In genetics, the studies conducted at the Institute mainly

covered wheat, rice, barley, maize, pearl millet, chickpea, lentil and fieldpea, pigeonpea, and *Brassica*s. In *Drosophila melanogaster*, a detailed functional genomic analysis of a 725 kb genomic region on chromosome 2L housing 76 genes and four Wnt genes was carried out. Mutations were discovered in 19 of the 76 genes, and importantly 8 new mutations in DWnt4 were discovered. The functional relation and interactions between the members of the wnt gene family were studied.

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

In agricultural economics, the Institute conducted studies on labour migration and its implications on rural economy of Indo-Gangetic plains of India; impact of trade liberalization on Indian agriculture; peri-urban agriculture; and economic analysis and prospects of non-edible oilseeds in India. The major studies conducted in agricultural extension were on enhancing the efficiency of extension organizations; assessing the socio-economic and environmental impact of agricultural technologies; farming systems research and extension for sustainable development; 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; and taking wheat cultivation technology to unreached and tribal areas.

The major studies conducted by the Institute for technology assessment and transfer were on the prospects of new growth areas for application of agricultural technologies in different agro-eco regions; water management technologies for sustainable crop production; livelihood and nutritional security of tribal dominated areas through integrated farming system and technology models; front line demonstrations on wheat, barley and maize; and collaborative extension programme with SAUs/ICAR institutes.

A three-day *Pusa Krishi Vigyan Mela* was held at IARI, New Delhi, from February 21 to 23, 2008 on the theme "IARI Marches Towards Higher Productivity and Commercialization". The *mela* was inaugurated by Dr. Mangala Rai, Secretary, Department of Agricultural Research and Education (DARE) and Director-General, Indian Council of Agricultural Research (ICAR) on February 21, 2008.

The Institute also conducted several other extension related activities like field day/field trial, off-campus exhibition, training for farmers and extension workers, etc. The Agricultural Technology Information Centre (ATIC) continued to serve as a 'Single Window Delivery System' to effectively provide products, service, technologies and information to different stakeholders.

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

The Golden Jubilee Year Convocation 2008 of the Post Graduate School of IARI was held on February 8, 2008. Dr. S. Banerjee, Director, Bhabha Atomic Research Centre, Mumbai, who was the chief guest, delivered the convocation address. At this convocation, 75 M.Sc. and 84 Ph.D. students were awarded degrees. Ms. Reeta Bhatia (Horticulture) and Ms. Nisha M. (Genetics) were awarded the Best Student of the Year 2007 Award for Ph.D. and M.Sc., respectively. The Institute also conducted several regular and short-term training courses. Bioinformatics and agri-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 six patents and signed nineteen MoUs. Four patents were either granted or renewed. The Institute also assigned two 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

HD 2894 (Pusa Wheat 109). A high yielding wheat variety HD 2894 with an average seed yield of 5.2 t/ha was released and notified for NCR, Delhi. Its seed yield was higher than that of the existing varieties over 21 environments and was in the range of 8.6% -17.1%. Its seed yield was 10.6% higher than that of PBW 343. It carries a different APR *Lr13* gene that acts as buffer against leaf rust. Further, it is a non IB/1R line and, therefore, has no sticky dough. It has 12.9% protein and better *chapati* making quality with a high gluten score.

HD 4713 (Pusa Wheat 110). A *durum* wheat variety HD 4713 with an average yield of 4.71 t/ha and a potential of yield of 5.15 t/ha was released and notified for NCR, Delhi. It is resistant to brown rust under both natural and artificial conditions and is suitable for pasta products as the average yellow berry incidence is only 2.8%. The variety possesses the band 45 for γ-gliadin, which is a desirable trait.

HI 8638 (Malav Kranti). A *durum* wheat variety HD 8638 was released for rainfed and limited irrigation conditions of Madhya Pradesh. It is the first "tall-dwarf" (medium tall and non-lodging) variety yielding 22.3% to 45.0% higher than popular wheat cultivars, Sujata and Lok 1, in farmers' fields in Madhya Pradesh. In addition to high grain yield, it provides more fodder as well. Because of its resistance to leaf and stem rusts, it joins HD 4672 and HI 8627 in eliminating the danger of early build-up of rust inoculum in Madhya Pradesh, which serves as a secondary source of infection for the northern wheat belt. Because of its high β-carotene (~5.0 ppm), high hectolitre weight (83 kg to 84 kg), high SDS sedimentation value (30ml to 32 ml) and high protein content

A field view of *durum* wheat variety HI 8638 released for rainfed and limited irrigation conditions of Madhya Pradesh

(~11.0 %), it can serve as a dual purpose *durum* wheat genotype for making nutritious *chapati* and semolina (*suji*).

1.1.1.2 Varieties identified

A new wheat variety Pusa Baker (HS 490), developed at IARI Regional Station, Tutikandi, Shimla was identified for release under late sown, restricted irrigation conditions of Northern Hills Zone (NHZ). This is the first variety in the country which meets international standard for biscuit quality with 'spread factor' as high as 10.13 and 'grain hardness index' value of 33. Its average seed yield is 3.1 t/ha with a yield potential of up to 5.0 t/ha. The variety is superior to all the checks under late sown condition of NHZ for yield. It combines resistance to all three rusts including the most virulent pathotype '46S119' of stripe rust.

1.1.1.3 Entries in pipeline

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

Improved lines of wheat under testing in coordinated trials

Trials	Entry name/numbers
Advance Varietal Trials (AVTs)	**AVT II:** HD 4719 (CZ), HD 2982 (NEPZ), HD 2985 (NW/NEPZ), HD 2987 (PZ), HD 2967 (NWPZ & NEPZ), HD 2983 (NEPZ) **AVT 1:** HD 2969 (NWPZ), HD 2993 (SHZ), HD 2996 (SHZ), HD 3007 (NWPZ), HD 3013 (All zones), HD 3014 (All zones), HD 3016 (All zones), HD 2998, HD 2997, HD 3002, HD 3003, HD 3012
National Initial Evualation Trials (NIVTs)	HD 2999, HD 3000, HD 3001, HD 3005, HD 3008, HD 3011, HD 3015, HD 3018, HD 3030, HD 3033, HD 4722, HD 3043, HD 3044, HD 3045, HD 3023, HD 3024, HD 3027. HD 3028, HD 3031, HD 3037, HD 3039, HD 3041, HD 3042. HD 3046, HD 3047, HD 3051, HD 3052

A promising culture HP 1913 was promoted to AVT 1 (LS) under irrigated condition in Peninsular Zone showing fair degree of resistance against black, brown and yellow rusts.

Four cultures, viz., HP 1925, HP 1926, HP 1927 and HP 1928 deriving resistance genes from diverse genetic backgrounds were found promising and are under evaluation in different NIVTs.

Under quality wheat breeding programme, five entries, viz., HP 1913, HP 1925, HP 1926, HP 1927 and HP 1928 were found promising and sent for QCSN conducted by DWR, Karnal.

HW 1095 is a high yielding and rust resistant semi-dwarf *dicoccum* wheat variety, with best *dicoccum* grain quality developed through mutation breeding. This genotype is under process for its release in Tamil Nadu in collaboration with TNAU, Coimbatore.

The wheat lines HW 5204 and HW 5205 were tested in AVT II for cultivation in Southern Hills Zone. The best performing genotypes, HW 5207 and HW 5209 were promoted to AVT II. A high yielding disease resistant wheat genotype HW 5207-1 carrying *Sr24, Lr24* and *Yr15* developed for protection against the predominant pathotypes of three rusts was promoted to AVT I in Central Zone. Two high yielding disease resistant dwarf *dicoccum* wheat varieties, HW 1096 and HW 1097 were entered as new test entries in IVT special *dicoccum* trials.

HS 502, a consistently performing wheat genotype was promoted to AVT II. Two genotypes, viz., HS 512 and HS 513 were promoted to AVT I under late sown, restricted irrigation conditions, while one more genotype, HS 511 was promoted to AVT I under early sown, rainfed conditions of NHZ. Three genotypes, viz., HS 505, HS 507 and HS 508 found their place for testing under AVT I for timely sown condition of NHZ.

HS 490 was promoted to the final year of testing under summer season of very high altitude of NHZ. In addition, 9 genotypes, viz., HS 514, HS 515, HS 516, HS 517, HS 518, HS 519, HS 521, HS 522, and HS 523 were included in the All India Coordinated Trials for further evaluation under different production conditions of NHZ on the basis of their yield potential and high degree of rusts resistance.

Three *durum* wheat varieties, including HI 8680 and HI 8682 for Peninsular Zone, and HI 8681 for North Western Plains Zone (NWPZ), were tested in the coordinated trials and would be proposed for identification.

Wheat genotypes under testing in AVT 1

Genotype (s)	Zone (s)	Cultivation conditions
***Durum* wheats**		
HI 8690, HI 8691	Central & NWPZ	Timely sown, high fertility, irrigated
HI 8693	Central irrigated	Timely sown, high fertility,
HI 8696, HI 8699	Central	Rainfed & restricted irrigation
HI 8692, HI 8694	NWPZ	Timely sown, high fertility, irrigated
Bread wheats		
HI 1560	Central	Timely sown, high fertility, irrigated
HI 1563	NEPZ	Late sown, high fertility, irrigated

Ten entries each of *durum* wheat, viz., HI 8700, HI 8701, HI 8702, HI 8703, HI 8704, HI 8705, HI 8706, HI 8707, HI 8708 and HI 8709; and bread wheat, viz., HI 1565, HI 1566, HI 1567, HI 1568, HI 1569, HI 1570, HI 1571, HI 1572, HI 1573 and HI 1574, were contributed to National Initial Varietal Trials (NIVTs).

1.1.1.4 Development of quality genetic stocks

Extensive intraspecific hybridization involving identified quality germplasm over the years was carried out by using single, three-way and complex cross schemes. Around 916 single and complex crosses were made for genetic studies of traits, incorporation of different traits and mapping populations. The promising lines with quality parameters were evaluated for their yield potential in different trials and, specifically, the following materials were developed after thorough screening:

- PW31 [VEE/PJN//2*TUI/3/PFAU/Bow//VEE#9/3/PASTOR//CBW12/DBW14]
- PW 32 [HUW 468/HD2402//PBW373/CPAN3004]
- PW 34 (CBW12/NW2034//DBW14/HUW468)

Resistance to *Ug99* pathotype of black rust pathogen in Indian wheat germplasm was strengthened by pyramiding *Sr24* and *Lr19+Sr25* along with *Sr26* and *Sr27* in 12 popular Indian bread wheat cultivars, viz., Kalyansona, HD 2687, HUW 234, HD 2285, HS 240, WH 147, Lok 1, HD 2329, J 24, C 306, UP 2328 and PBW 226 through simultaneous molecular confirmation by using SSR primers listed below:

Sr24	-	*Sr24*#12-F *Sr24*#12 R
Lr19+ Sr25	-	Gb-F Gb-R
Sr26	-	*Sr26* #43-F *Sr26* #43-F
Sr27	-	Based on field response and phenotypical marker – apical claw

Genetic stocks carrying effective stem rust resistance genes *Sr25, Sr36, Sr26, Sr27, Sr38,*and *Sr39* in combination with *Sr31, Sr24* and *Sr2* in the background of wheat varieties, Kalyansona, C 306, HD 2009, HD 2285, HD 2402, HD 2687, J 24, LOK 1, MACS 2496, NI 5439, PBN 51, PBW 226, RAJ 3077, UP 262, WH 147, and WH 542 were developed to combat the threat from pathotype *Ug99*.

Pyramiding of *Yr10* and *Yr15* was completed in wheat genotypes HD 2285, HD 2329, HD 2402, Lok 1, PBN 51, HI 977, PBW 226 and HD 2687 for combating the widely prevalent yellow rust pathotypes virulent on gene *Yr9* (present in majority of the popular Indian wheat cultivars with Veery parentage). For simultaneous protection against predominant brown rust virulences, these lines were additionally incorporated with brown rust resistance genes *Lr35, Lr39, Lr40, Lr41, Lr42, Lr44* and *Lr45* and advanced to BC_3F_2 stage.

1.1.1.5 Breeding material

Over 10000 segregating progenies (F_2-F_6) generated from more than 2000 crosses were subjected to selection according to the different objectives of the programme. Nearly 1200 fresh crosses and backcrosses were attempted successfully.

1.1.1.6 Varieties tolerant to heat stress

Early heat. Good grain quality (grain weight: 47-60 g/1000 grains) was observed both in *durum* and bread wheat under very early (28th September 2007) sown conditions. More than 5.00 t/ha grain yield was obtained in HI 8627, HI 8663, V 21-23 and HW 2004 when the crop was sown on 2nd October, 2007. HI 8627 gave 5.52 t/ha grain yield with 11.4% protein, HW 2004 headed 16 days earlier than the 17th October sown crop. Under mid-October sown (17th October 2007) conditions, V 21-28 gave a grain yield of 5.79 t/ha, followed by HD 4672 (5.73 t/ha), V 21-74 and V 21-79 (5.69 t/ha), S 16-91 (5.46 t/ha) and HI 8627 (5.30 t/ha) with only three irrigations. However, with four irrigations, HI 8627 gave maximum grain yield of 6.67 t/ha, followed by HD 4672 (6.27 t/ha), HI 8663 (6.25 t/ha) and V 21-79 (6.10 t/ha). Potential yield of more than 7.0 t/ha was recorded by HI 8627 and HI 8663. The harvest index varied from 27.11 in HW 2004 to 44.86 in S 16-19. Under early heat, β-carotene ranged from 3.3 ppm in HI 8381 to 6.8 ppm in V 21-79.

Terminal heat. Under late sown (4th Jan. 2008) conditions, HI 1544 (Purna) gave 5.43 t/ha grain yield, followed by advanced *durum* lines HI 8671 (5.31 t/ha), HI 1418 (4.87 t/ha) and S 16-91 (4.77 t/ha). HI 8671 gave a better combination of yield (5.31 t/ha), 1000-grain weight (50.6 g) and harvest index (42.5%) compared to that of normal sown crops. Minimum grain weight loss (17%) was observed in HD 4672 followed by that in HI 1531 (20.37%) and in HI 8671 (22.10%). Under terminal heat, V 21-79 gave 9.92 ppm β-carotene and 41.5 SDS.

1.1.1.7 Evaluation of advance generation material for timely sown condition

Out of 120 bulks evaluated under timely sown, irrigated conditions against the standard check, PBW 343, PBW 502, DBW 17, and DBW 21 were retained on the basis of their grain yield and disease resistance for further evaluation. Some of the promising selected bulks were: DL 788-2/DBW 14, CBW 12/RWP 9912, CBW 09/RWP 9924, WH 542/ PBW 226, PJN/BOW//OPATA/MILAN, WEBILL 2*V1V1TS1, CBW 23/PBWN 142, DBW 14/WH 730, and FLW 4/BPW 892.

1.1.1.8 Analysis for quality traits

Testing of germplasm for quality traits. Around 1355 germplasm lines were grown at three locations in North Western Plains Zone and tested for kernel hardness, micronutrients, dough quality, protein and sedimentation traits. None were soft grained for farinographic traits (to judge rheological suitability of a strain). Germplasm belonging to both the strong and the weak classes were identified.

Micronutrient content in Indian and exotic germplasm. By analyzing iron and zinc contents in wheat varieties, germplasm and exotic lines from single and multilocations, potential sources were identified. While the varieties had lower micronutrient content, the highest levels of iron and zinc were found in wild relatives such as speltas and synthetic derivatives from crosses between different species. These lines were used as donor parents, in crosses, with the aim to transfer this trait in cultivated lines to address the problem of malnutrition.

1.1.1.9 Heterosis breeding

Diversity analysis of eight newly developed fertility restorers was done by using SSR primers. These restorers were genetically diverse from the original restorers 4099R and 4101R. Several other putative fertility restorers are being tested for fertility restoration. About eighty CMS lines at various stages of development including those of *T. araraticum*. *T. timopheevi*. *Ae. speltoides*, *Ae. kotschyii* and *Ae. Variabilis,* were backcrossed with their respective maintainers.

1.1.2 Rice

1.1.2.1 Variety released

A *basmati* rice variety, Pusa Basmati 6 (Pusa 1401) released in August 2008 performed better than Pusa 1121 in yielding ability, agronomy, semi-dwarf stature, non-lodging habit and cooking quality. This variety was developed from the cross of Pusa Basmati1 with Pusa 1121. For grain and cooking quality traits, it has significant improvement over Pusa 1121 with uniform shape of cooked grain as against the tapering end in Pusa 1121, in addition to strong aroma and less than 4% chalky grains.

Cooked grains of Pusa 1401

1.1.2.2 Improvement of Pusa 1460 (Improved Pusa Basmati 1) for resistance to blast disease

For combining the blight resistance of this variety (having genes *xa13* and *Xa21*) with blast resistance gene from a donor line Tetep carrying gene *PiKh,* BC_1F_5 progenies from selected plants were evaluated during *kharif* 2008. Some of the selected families showed yield superiority of up to 39.4% over Improved Pusa Basmati 1.

1.1.2.3 Promising entries in National Basmati Trial

Three *basmati* rice entries, namely, Pusa 1301, Pusa 1221 and Pusa 2530, were entered in the Initial Varietal Trial (IVT-BT) for evaluation during *kharif* 2008.

1.1.2.4 Advanced *basmati* breeding lines

Approximately 700 single plant selections (F_3-F_5) across 78 different cross combinations were made for the improvement of quality and resistance to BB. These single plant selections were evaluated for quality parameters such as grain dimensions, L/B ratio, length and breadth after cooking, elongation ratio (ER) and ASV. The best entries with high quality traits are: P1366-06-1-22, Pusa1460-03-75-6-118-1-5, Pusa1460-08-45, P1485-06-83, P1485-06-88, P1485-06-94, P1486-06-5-122, P1486-06-5-134, P1509-03-1-7-2-184, P1509-03-1-7-2-185, P1509-03-1-7-2-188, P1526-04-25-59-2-192, P1560-06-2-364, P1560-06-2-371, P1560-06-2-372, P1560-06-2-409, P1560-06-2-411, P1560-06-2-413, P1561-06-2-416, P1537-06-3-228, P1554-06-3-298 and P1561-06-2-424.

1.1.2.5 Hybrids with new plant type (NPT) parental lines

As the NPT, derived from *indica* × *japonica* crosses exhibits high order of heterosis, some of the NPTs developed through complex crosses involving a wide range of parental lines were used for conversion into CMS lines, and a number of perfect restorers in the NPT background with *basmati* quality were identified. During *kharif* 2008, nearly 120 test crosses involving CMS lines Pusa 5A, Pusa 6A and Pusa 9A, and NPT restorers were made. Of these, 17 promising test crosses involving the above male sterile sources were identified in terms of restoration ability and heterosis for yield and yield components. The utilization of NPT based *basmati* CMS and restorer lines in hybrid development is likely to raise the level of heterosis manifold.

Heterosis for panicle size and grain number in a test hybrid developed by using NPT Basmati restorer line

1.1.2.6 Evaluation of non-*basmati* NPT lines

Non-*basmati* station evaluation trial consisted of 17 NPT restorer lines derived from *indica* × *japonica* crosses with two checks, namely, Pusa 44 and IR 64 during *kharif* 2008**.** Six lines showed yield advantage in the range of 23.97% - 42.20% over the national check IR 64. However, only two lines showed more than 10% yield advantage over the local check Pusa 44.

1.1.3 Barley

BHS 380, a hulled genotype developed by IARI Regional station, Tutikandi, Shimla performed outstandingly under both grain and dual purpose trials and promoted to AVT II. Three genotypes, viz., BHS 383, BHS 384 and BHS 386 are in second year of testing under the all India coordinated trials. Four genotypes, viz., BHS 387, BHS 388, BHS 389, and BHS 391 are in AVT I for evaluation for both grain and dual purposes.

1.1.4 Maize

1.1.4.1 Evaluation of hybrids in station trials

Around 300 experimental hybrids involving both field corns (normal) and specialty corns evaluated in ten station trials constituted field corn, pop corn, sweet corn, elite inbreds, diverse parentage, diverse population derived lines with specialty corn, and extant OPVs for multiple conditions of moisture regimes and planting dates.

Further, various maize genotypes (including specialty corns) with various degrees of inbreeding and stages of development were advanced and assessed for productivity, quality as well as biotic (disease) and abiotic (moisture stress) conditions.

1.2 MILLET

1.2.1 Pearl Millet

1.2.1.1 Variety released

An early maturing, fast growing pearl millet variety Pusa Composite 443, which is highly resistant to downy mildew disease and suitable for moisture stress condition, was released for cultivation in Rajasthan, Haryana, Gujarat and other areas where the annual rainfall is less than 400 mm. It has an average yield of 1.8 t/ha.

A newly released pearl millet composite variety Pusa Composite 443

1.2.1.2 Hybrids and composites in coordinated trials

Hybrids. A hybrid Pusa 768 (MS 411 A × PPMI 69) that performed well in Advanced Hybrid Trial II A, completed three years of testing, and showed good resistance against downy mildew disease qualified for identification. Another hybrid Pusa 782 (MS411 A × PPMI 964) was promoted from IHT II to AHT II A and AHT II B in two different trials for the 2nd year of testing. Four new hybrids MS 841 A × PPMI 647 , MS 841 A × PPMI 451, MS 411 A × PPMI 708 and MS a × PPMI 721, which out yielded the best check Pusa 605 by 9.1 % to 20.6% were included in Initial Hybrid Trial (IHT II) conducted by AICPMIP during *kharif* 2008.

Composites. A high yielding composite population MP 480 (Pusa Composite 612) that performed well in Zone B in the Advanced Population Trial (APT B) and completed 3 years of testing qualified for identification. Pusa Composite 621 (MP 495) performed well in the Initial Population Trials and was promoted to AHPT A_1 (for Zone A_1) for the second year of testing during *kharif* 2008. A new population, namely, Pusa Composite 637 was included in the Initial Population Trials (*kharif* 2008) for the first year of testing.

1.2.1.3 Hybrids in station trials

A total of 236 new hybrids involving different sets of CMS lines and restorer lines were generated and evaluated in initial and advanced station trials during *kharif* 2008.

1.3 FORAGE CROP

1.3.1 Forage Sorghum

1.3.1.1 Promising material in coordinated trials

Two single cut entries PC 1002 (SPV 1849) and PC 1003 (SPV1853) were evaluated in AVT. Based on the mean performance in Zone I, PC 1002 and PC 1003 produced 32.6 t/ha and 31.1 t/ha of green fodder yield, respectively, in comparison to 29.3 t/ha of check HC 306.

1.4 GRAIN LEGUMES

1.4.1 Chickpea

1.4.1.1 Variety released

A *Kabuli* bold seeded chickpea variety Pusa 2024 developed through a double cross (BG 261 × ICC 88503) × (GL 920 × BG 1003) was released and notified for NCR, Delhi. It is suitable for both normal and late plantings and yields, on an average, 2.4 t/ha. It is moderately resistant to soil borne diseases and tolerant to moisture stress and high temperature. This variety having an excellent cooking quality is good for table purpose also.

1.4.1.2 Varieties identified

Two chickpea varieties BG 5028 (*desi* extra large seeded) and BG 5023 (*Kabuli* extra large seeded), were identified by the IARI Variety Identification Committee, and are in the process of release by the Delhi State Seed Sub-Committee for the NCR, Delhi.

1.4.1.3 Varieties in pipeline

Kabuli extra bold seeded lines BG 2085, BG 2086 and BG 2087 with test weight 40 g and above were promoted to AVT 1 in NWPZ. Two entries BG 2083 and BGM 564 were promoted to AVT I (Kabuli) in NEPZ and SZ, respectively. An entry BGM 562 was also promoted to AVT I (late sown) in NEPZ.

1.4.1.4 Entries in coordinated trials

Seventeen promising genotypes BG 2088, BG 2089, BG 2090, BG 2091, BGM 565, BG 2092, BG 2093, BGM 567, BG 2094, BG 2095, BG 2096, BG 2097, BG 2098, BGM 568, BG 3000, BG 3001 and BG 3002 were contributed to coordinated trials on the basis of their superior performance in station trials.

1.4.1.5 Breeding short duration varieties

The IARI Centre for Pulses Improvement, Dharwad has initiated intensive research on development of short duration chickpea genotypes with enhanced genetic yield potential. BGD 9617, BGD 9812, BGD 9920 and BGD 132 are some of the short duration genotypes developed. An evaluation of advanced generation breeding lines showed that it is possible to combine earliness and high grain yield in chickpea. The best short-duration (< 90 days) genotype produced 3.4 t/ha grain yield and exceeded that of best check JG 11.

1.4.2 Mungbean

1.4.2.1 Entries in coordinated trials

New mungbean entries Pusa 0831 and Pusa 0832 were entered in IVT (*kharif*), and Pusa 0871 and Pusa 0872 in IVT (Spring).

1.4.3 Lentil and Fieldpea

1.4.3.1 Entries in coordinated trials

Two lentil entries (L 4584 and L 4585) belonging to small seeded group and one entry L 4594 belonging to bold seeded group were tested in IVT (all zones).

Fieldpea entry DDR 82 was evaluated in AVT-1 Dwarf of NEPZ while two entries each were entered into IVT Dwarf (DDR 85 and DDR 86) and IVT Tall (DMR 61 and DMR 62) of all zones.

1.4.4 Pigeonpea

1.4.4.1 Variety released

A pigeonpea variety Pusa 2002 is a medium tall variety released and notified for NCR, Delhi. The average seed yield of this variety is 1.77 t/ha with a maturity period of 143 days. It is a medium bold seeded variety with 8.7 g/100 seeds. *Arhar*-wheat can fit well in the double cropping system and as a timely sown crop can be harvested by the second week of November vacating the field for *rabi* crops. It has better quality traits like protein value (20.2%), cooking time (20 minutes) and *dal* recovery (85%).

1.4.4.2 Entries in coordinated trial

Pusa 2008-1 and Pusa 2008-2 were entered into IVT (Early).

1.5 OILSEED CROPS

1.5.1 *Brassicas*

1.5.1.1 Varieties released

LET 18 (Pusa Mustard 24). Pusa Mustard 24 is a low erucic acid (<2.0%) variety of Indian mustard released for zone II (Rajasthan, Punjab, Haryana, Delhi, plains of J&K and western parts of U.P.). The average seed yield of this variety is 2.11 t/ha with a potential seed yield up to 2.9 t/ha. This variety is on a par in maturity (140 days) with the conventional mustard varieties. It is a small seeded variety (4 g/1000 seeds) with 36.55% oil content.

LET 17 (Pusa Mustard 22). Pusa Mustard 22 is a single zero (<2% erucic acid) variety of Indian mustard

A low erucic acid mustard variety Pusa Mustard 22 (LET 17) released for NCR, Delhi

released for NCR, Delhi. The average seed yield of this variety is 2.07 t/ha, whereas, potential seed yield is up to 2.75 t/ha. It is on a par in maturity (142 days) with the conventional mustard varieties. Mean 1000-seed weight of this variety is 3.6 g with 36.0% oil content.

NPJ 93 (Pusa Vijay). Pusa Vijay was released for NCR, Delhi and notified during 2008. The average seed yield of this variety is 2.5 t/ ha. It is a bold seeded variety (6 g/1000 seeds) with 38.51% oil content. It is of medium maturity (145 days). It is tolerant to abiotic stresses, viz., high temperature at seedling stage, salinity up to 12 dS/m and lodging and shattering resistance.

EJ 13 (Pusa Tarak). Pusa Tarak is an early maturing (100-120 days' maturity) bold seeded (6 g/ 1000 seeds) variety of Indian mustard which was released for September sowing in NCR, Delhi. It has an average seed yield of 1.924 t/ha with a potential of up to 2.90 t/ha. The mean oil content of this variety is 40%, which is better than that of the prevailing checks. This variety will be useful in the multiple cropping system particularly during the period of September – December.

1.5.1.2 Elite entries in coordinated trials

A large number of entries were promoted/contributed to different coordinated trials and ecological situations.

1.5.1.3 Breeding for low erucic strain of mustard

Three thousand five hundred single plants and bulks of various released/identified varieties, advanced breeding lines of F_6/F_7 generation and segregating breeding material wise analysed. The range of erucic acid (%) in different materials was: 0-2.0% (1724), 2.1-5.0% (842), 5.1-10.0% (557), 10.1-20.0% (353), and >20.0 (24)

1.5.1.4 Breeding for white rust and *Alternaria* blight resistance

BC_4 was attempted to three inter specific crosses, viz., Varuna × BCEF-1-00-18-1, Bio-902 × BCEF-1-00-18-1 and Laxmi × BCEF-1-00-18-1 for introgression of white rust resistance. *Brassica juncea* × *B. carinata* cross is being advanced for the development of mapping population for *Alternaria* blight resistance gene(s).

Elite mustard entries in pipeline

Name of trial	Entry/entries	Zone (s)
AVT- II *toria*/early mustard	NPJ 112	II
AVT- I *toria*/early mustard	NPJ117, EJ 17, EJ 19	II,III
IVT- *toria*/early mustard	NPJ 124, EJ 20	II,III,IV
IVT- timely sown irrigated mustard	HYT 8, HYT 33	II,III,IV, V
AVT- I late sown mustard	NPJ 113	II
IVT- late sown mustard	NPJ 125	II,III,IV
AVT- I quality mustard	LET 14-1	II,III
IVT- quality mustard	LET 3, LET 36	II,III
Salinity/alkalinity screening nursery	NPJ 119, NPJ 126	All India
Agronomical trial	NPJ 112	All India
Pathological, entomological and physiological screening	*B. juncea*: NPJ 99, NPJ 107, NPJ 109, NPJ 112, NPJ 113, NPJ 114, NPJ 117, NPJ 120, NPJ 121, NPJ 124, NPJ 125, NPJ 127, NPJ 128, EJ 13, EJ 14, EJ 17, EJ 19, LET 3, LET 36, LET 14-1, LET 17, LET 18, LES 1-27, LES 39 *B. carinata*: BCS 3, BCS 4, NPC 12, NPC 16, NPC 17, DLSC 1	

1.5.2 Soybean

1.5.2.1 Variety proposed for identification

DS 2207, a soybean genotype which performed consistently better than the checks for three consecutive years in the coordinated trials was proposed for its identification and release in the NCR, Delhi.

1.5.2.2 Entries in pipeline

A soybean entry DS 2309 was tested in AVT II in Northern Plains Zone and another entry DS 2410 was tested in AVT I in North Eastern Zone. Both the entries ranked first in their respective zones.

1.6 FIBRE CROP

1.6.1 Cotton

1.6.1.1 Entries in coordinated trials

Advanced Varietal Trial (Br 04a). A cotton variety Pusa 72-9-37 was under evaluation for the second year in CVT Br 04 (a) in Central Zone under irrigated conditions. It showed 27.6 mm span length, 22.0 g/tex fibre strength and 4.2 micronaire fibre fineness.

Initial Varietal Trial (Br 02 a&b). A cotton variety Pusa 57-6 was promoted to Br 03 (a) for evaluation in all (North, South and Central) zones. Varieties Pusa 1752 and Pusa 8608, were entered in national trials Br 02 (a) and Br 02 (b), respectively.

1.6.1.2 Effect of different planting dates on fibre quality of cotton (*Gossypium hirsutum* L)

Impact of six dates of sowing, i.e., February 23, March 19, April 13, May 8, June 2 and June 28, 2007 on cotton fibre quality was evaluated in four cotton varieties, namely, H 1117, P 56-4, P 1752 and RS 2013 by the use of high volume instrument (HVI). Environment influenced various fibre quality parameters like 2.5% span length, uniformity ratio, fibre strength, elongation %, reflectance, color and short fibre index except micronaire and maturity ratio. Fibre quality, but not the yield, improved significantly under late sown conditions. RS 2013 was more adapted to different growth environments as evidenced from a high yield stability when compared with H 1117, P 1752 and P 56-4.

1.7 VEGETABLE CROPS

1.7.1 Cole Crops

1.7.1.1 Cauliflower

DC 5 (Pusa Shukti), a mid maturity group variety of cauliflower, was identified by IARI Variety Identification Committee.

BC_1 population of the sterile cytoplasms being introgressed into cauliflower from *Brassica canarianse* and *B. tournefortii* were raised and BC_2 was attempted using embryo rescue. For resistance to black rot and downy mildew, 16 advance generation populations were found promising

DC 5 (Pusa Shukti), a cauliflower variety identified by IARI Varietal Identification Committee

with respect to horticultural traits with a maturity range from October to January. Fifteen recombinant inbred lines (RILs) and nine near isogenic lines (NILs) developed for resistance to black rot and downy mildew were advanced to F_4 generation to develop mapping populations. For resistance to black rot, three accessions each from *Brassica carinata* and *B. campestris* were screened under artificial epiphytotic conditions in field as well as laboratory. Out of these, two accessions, viz., NPC 9 and NPC 17 of *Brassica carinata* showed high level of resistance. Pusa Meghna, Pusa Kartik Sankar and DC 23000 were found promising for spring-summer season.

In snowball group of cauliflower, 50 CMS based hybrids were developed by the use of three male sterile lines, viz., Call B1, Sera K1 and Sera K 25. Consistent superiority for yield and other horticultural traits was found in four hybrids, viz., KTH 44 (26.5 t/ha), KTH 28 (26.2 t/ha), KTH 40 (23.6 t/ha) and KTH 22 (23.2 t/ha). Three new hybrid combinations, KTH 45 (27.6 t/ha), KTH 36 (27.2 t/ha) and KTH 38 (26.5 t/ha) were also found to be promising.

Sterile cytoplasm ("*Ogu*") from three CMS lines, viz., Sera K1, Sera K25 and Call B1 are in the process of transfer in the ten promising lines with good combining ability. They are at advanced stages of backcrossing (BC_2 to BC_3). Two entries, viz., KTH 1 and KTH 2 under AICRP (VC) in AVT II trial are in progress. Seventy-one lines (segregating generation/selections) including CMS lines along with the

respective maintainers were maintained after positive selection. Four new lines were collected and are being maintained.

Cauliflower lines, identified earlier for tolerance against diamondback moth (DBM) under field conditions, were screened further under the controlled conditions. On the basis of their 60 days exposure from the date of transplanting, maximum leaf damage and minimum plant survival were recorded in the case of PSBK 1, followed by PSB 1. However cultivars, PHJ and PSBK 25 followed by DB 187-1 and DB 1305 showed tolerance to DBM.

1.7.1.2 Cabbage

Six self-incompatible lines of cabbage were utilized to produce 24 cross combinations. The hybrids KCH 9836 (52.2 t/ha) and KCH 9835 (47.5 t/ha) were found promising for yield and other horticultural traits. Selection C 6 performed consistently better among the eleven promising selections evaluated over the years. Conversion of promising varieties/ lines of cabbage into CMS lines is in progress.

Cabbage lines were exposed against diamondback moth (DBM) from the date of their transplanting to head formation to assess their tolerance on the basis of yield. Thus, on the basis of gross and net head yield, maximum tolerance was recorded in the cross GA × AC-204 (Pl-1-4) followed by KIRC 8, KIRC 9, and KIRC 10.

1.7.1.3 Knol-khol

A knol-khol variety, Pusa Virat (KKS 1) was identified for release in Himachal Pradesh by the IARI Variety Identification Committee. In AICRP (VC) trials, the entry KKS 1 gave the highest yield of 66.0 t/ha in the AVT I at Katrain location.

1.7.2 Cucurbitaceous Crops

1.7.2.1 Ash gourd

Twelve lines of ash gourd were purified, evaluated, maintained and passport data prepared. Two promising selections, DAG 12 and DAG 13 were high yielding both in summer and *kharif* seasons with 48.0 t/ha and 54.0 t/ha, respectively, and earlier in maturity compared to Pusa Ujwal (Check). The fruits of these selections are oblong in shape and medium in size. The average fruit weight is 10.5 kg for DAG 12 and 9.2 kg for DAG 13. Out of 8 F_1 hybrids tested, the yields of two promising hybrids, DAGH 16 and DAGH 46 were 5.15 t/ha and 5.80 t/ha, respectively, which were 29.0% and 45.0%, respectively, higher than that of the check Pusa Ujwal, under large scale yield trial.

1.7.2.2 Bitter gourd

Thirty-eight genotypes from NBPGR and 29 lines from AVRDC, Taiwan were collected. A white fruited promising selection DBTG 1 was observed under large scale yield trial. It gave 16.7 t/ha yield, which was 8.0% higher than that of the check Pusa Do Mausami. This variety was contributed to AICRP (VC) trial.

The nutrient content of 20 genotypes (including the commercial varieties and hybrids) showed no difference in the N, P and K contents but the minor elements such as Ca, Mn, Zn, Fe and Cu varied. The Ca and Fe contents were the highest in small fruited varieties, WBBG 24 and WBBG 48, respectively, whereas, Zn and Cu were maximum in cultivated types, Arka Harit, Pusa Hybrid 2 and VNR 22. The best stage for the preparation of better quality of dehydrated bitter gourd rings for retention of high content of total chlorophyll, ascorbic acid, drying and rehydration ratio and sensory characteristics was 13-16 days after fruit set (DAFS). A fruit slice thickness of 1.5 cm was found to be the best for maximum retention of nutritional quality parameters like drying and rehydration ratio and sensory score of dehydrated bitter gourd rings. Pusa Hybrid 2 was found to be the best for the preparation of better quality dehydrated bitter gourd rings.

1.7.2.3 Cucumber

Cucumber selections, DC 82, DC 54 and DC 6 yielded 21.2 t/ha, 20.7 t/ha and 19.8 t/ha, respectively, showing an increase of 22.0%, 20.3% and 15.2%, respectively, over that of the check Pusa Uday (17.2 t/ha). DC 6 was advanced to AVT 1 of AICRP (VC) trial. Twenty-eight new F_1 hybrid combinations were made utilising monoecious and gynoecious parents. Out of 34 F_1 hybrids tested, monoecious F_1 hybrid DCH 6, gynoecious F_1 hybrids, DCHG 5 and DCHG 10 gave yields of 23.9 t/ha, 22.2 t/ha and 21.8 t/ ha, respectively, which were 38.9%, 29.0% and 26.7%,

respectively, higher than that of the check Pusa Uday. Fifteen genotypes of cucumber were screened artificially for salinity stress under two salt concentrations (0 and 4 dsm^{-1}) of NaCl, Na_2CO_3 and K_2SO_4 (1:1:1). The genotypes CRC 8, G 338 and Poinsette were found moderately tolerant to salinity and showed higher germination percentage, longer vine length, retention of maximum number of leaves and lowest defoliation percentage at 4 dsm^{-1}. Higher proline, and phenol contents, and Na/K ratio of the leaves further confirm the salinity tolerance of these genotypes.

1.7.2.4 Luffa

Variety identified. A luffa variety, DRG 2 (Pusa Nutan) was identified by IARI Variety Identification Committee for NCR Delhi. It gave yields of 18.5 t/ha and 17.5 t/ha which were 59.3% and 49.0% higher than those of the check Pusa Nasdar during spring-summer and *kharif* seasons, respectively.

A luffa variety DRG 2 (Pusa Nutan) identified by IARI Varietal Identification Committee for NCR, Delhi

Sponge gourd Selection DSG 43 gave 17.5 t/ha yield which was 34.6 % higher than that of the check Pusa Sneha. It was advanced to AVT II of AICRP (VC) trial. Selections, DSG 6 and DSG 7 gave 16.4 t/ha and 15.5 t/ha yields, respectively, which were 26.1% and 19.2%, respectively, higher than that of the the check Pusa Sneha and showed consistent and highly tolerant reaction to *Luffa yellow mosaic virus* during rainy season.

1.7.3 Solanaceous Crops

1.7.3.1 Brinjal

In round fruited hybrid trial, the hybrids DBHR 49 and DBHR 98 yielded 50.2 t/ha and 49.1 t/ha, which were 13.0% and 10.5%, respectively, higher than that of the national check Pusa Hybrid 6 (44.4 t/ha). Among long fruited hybrids, DBHL 20 (52.2 t/ha) and DBHL 115 (50.5 t/ha) were found promising with yield increases of 15.7% and 11.8%, respectively, over that of the national check Pusa Hybrid 5 (45.2 t/ha). One small round fruited hybrid, DBHSR 66 was found to be the best with a yield of 36.2 t/ha followed by DBHSR 58 (34.5 t/ha) and the check ABH 1 (30.4 t/ha). Sixty-one varieties and hybrids were evaluated under nine different trials of AICRP (VC). Of the sixty genotypes and forty-five crosses screened against *Phomopsis* blight, two hybrids DBHL 161 and DBHL 147 were found tolerant. Fifty-five genotypes and forty-five crosses were screened against shoot and fruit borer under field conditions and the hybrids, DBHL 91 and DBHL 150 were found tolerant to this disease.

1.7.3.2 Tomato

Two entries of cherry tomato, viz., DCT 1 and DCT 2 were entered in the initial evaluation varietal trial of AICRP (VC). Two tomato hybrids, DTH 5 and DTH 6 are being evaluated under IET AICRP (VC) trials. In TLCV resistant varietal trial, the lines PH 348, N 5, N 1, H 86-2, Sel. 6-11-7 and H 88-1 were found resistant to TLCV with good fruit yield. The genotypes, FEB-2, Megha and their combination FEB 2 × Megha were found resistant to early blight while Pusa 120 and its F_1 combinations showed resistance to root-knot nematode. The genotypes, Pusa Sadabahar, NW and Booster, and their combinations (Pusa Sadabahar × Pusa Sheetal, Pusa Sheetal × Pusa 120 and Pusa Sheetal × Booster) were found promising for setting fruits at low temperature during December-January and the varieties Booster and Pusa Sadabahar, and their F_1 combinations (Pusa Sadabahar

× FEB 2, N 5 × Pusa Sadabahar, Pusa Sheetal × Labonita and Pusa Sheetal × Pusa Sadabahar) were found promising for setting fruits at high temperature during May-June.

1.7.3.3 Capsicum

The source of genetic male sterility was crossed with 12 lines of capsicum and paprika in 2007-08. The resulting F_1 progenies were grown this year and compared for pungency. The least pungent hybrid, viz., ms-12 × YC was selfed and F_2 seeds were harvested. The F_2 generation was planted in glasshouse for advancing generation.

1.7.4 Root and Bulbous Crops

1.7.4.1 Carrot

Two carrot varieties, viz., Pusa Rudhira (red) and Pusa Asita (black) were released for NCR, Delhi by the Delhi State Seed Sub-Committee.

A released carrot variety Pusa Rudhira

Out of 28 lines evaluated for spring summer crop from March sowing, seven lines, viz., IPC Ht_1, IPC Ht_2, IPC 25, IPC 120, IPC 7, Nantes and Pusa Yamdagini formed good roots and showed promise for this season. IPC Ht_2 and Pusa Vrishti were identified by IARI Variety Identification Committee for July sowing. Other genotypes, viz., IPC Ht_1, IPC 106, IPC 7, IPC 11 and IPC 109 were also found promising for August sowing. Total carotenoids were found to be the highest in IPC 13 (4887 µg/100 g) followed by IPC 122 (3354 µg/100 g), IPC 4 (2895 µg/100 g) and IPC 8 (2884 µg/100 g). IPC 25 (378 µg/100 g), however, had the highest content of lutin. Lycopene content was also found to be the highest in IPC 13 (3030 µg/100 g) followed by IPC 122 (2211 µg/100 g), IPC 4 (1818 µg/100 g), IPC 8 (1767 µg/100g) and IPC 30 (1598 µg/100 g). β-carotene was found to be maximum in the genotype, IPC 122 (994 µg/100 g) followed by IPC 7 (926 µg/100 g) and IPC 13 (865 µg/100 g). The genotypes, IPC 17, Purple Shoulder Cream and Pusa Kesar (0.05 mg/100 g) recorded the highest thiamine content. The highest niacin content was estimated in IPC 31 (0.80 mg/100 g) followed by Purple Shoulder Cream (0.73 mg/100 g) and IPC 11 (0.72 mg/100 g).

A promising temperate carrot hybrid, KTCTH 7 (Pusa Nayanjyoti) was identified by IARI Variety Identification Committee on the basis of its superior performance in multilocation trials. Besides higher yields and desirable horticultural root traits, this hybrid also contained an appreciable content of β-carotene (7.552 mg/100 g fresh weight).

Seventy-two F_1 hybrids involving nine CMS (A) lines and eight pollinator lines were developed and evaluated. The two highest yielding hybrids, KTCTH 7 (59.4 t/ha) and KTCTH 8 (55.3 t/ha), showing consistent superior performance for yield and other desirable root traits, exhibited 84.5% and 71.4% economic heterosis, respectively, over that of the check Pusa Yamdagni (32.2 t/ha). These two hybrids are under testing in AICRP (VC) trials.

1.7.4.2 Onion

Four selections were included in AICRP (VC) varietal trials at IET (Sel. 157 and Sel. 397) and AVT I (Sel. 126 and Sel. 153). Among CMS based hybrids, H 13, H 9 and H 19 yielded 47.2 t/ha, 44.6 t/ha and 43.6 t/ha, respectively, showed yield increases of 22.5%, 15.8% and 13.2%, respectively, over that of the hybrid H 44 (38.5 t/ha). In *kharif* onion trial, net bulb yield was found to be best in L 355, Sel. 126 and Sel. 157 yielding 15.9 t/ha, 14.8 t/ha and 14.0 t/ha, respectively. The genotype B line, Sel. 126 and RO-597 were found superior in dehydration ratio. The genotype Early Grano was found promising for Mg and K contents, Sel. 153 for Cu content and Sel. 397 for Mn and Fe contents and antioxidant activity.

1.8 FRUIT CROPS

1.8.1 Mango

1.8.1.1 Evaluation of new mango hybrids

Fifty-seven mango hybrids were evaluated for different physico-chemical attributes. The hybrids, viz., H 1-1, H 1-6, H 2-6 and H 4-12 found to perform consistently well were identified for release. The hybrid H 11-2 had intense red colouration on peel and had bigger fruits (376.3 g) with high pulp (79.9%) and moderate TSS (16.4%).

1.8.1.2 Potential mango hybrids

Hybrid H 1-1. Mango hybrid H 1-1 is a unique hybrid regular in bearing, and semi-vigorous, having attractive oblong fruit shape with uniform size, bright red peel on golden yellow background and orange fibreless pulp. This hybrid showed moderate tolerance to major pests of mango and also had less malformation incidence in comparison to Dushehari and Amrapali. It has 7 to 8 days' shelf life at room temperature after ripening, which is twice that of Dushehari. The average fruit weight is 186.5 g, which is significantly higher than that of Amrapali (165.0 g). This new hybrid is comparable to Dushehari and Amrapali in terms of pulp (72.78%), β-carotene (11,474 µg/100 g pulp) and ascorbic acid (34.89 mg/100 g pulp).

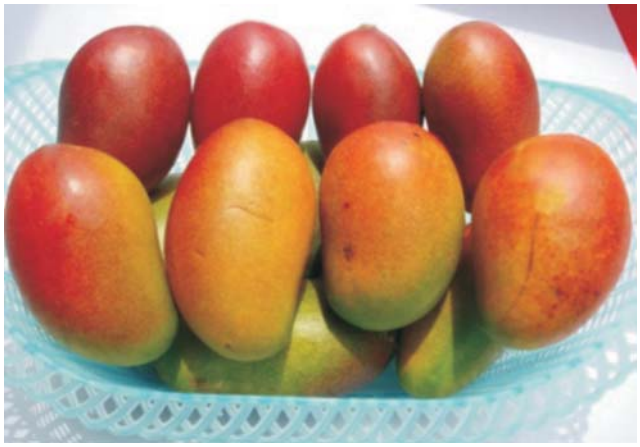
Hybrid H 1-6. Mango hybrid H 1-6 is an improved hybrid having regularity in bearing, attractive elongated fruits having bright red peel colour and orange fibreless pulp. Owing to its elongated shape, it is suitable for uniform packaging. This hybrid also showed moderate tolerance to major pests of mango and also had less malformation incidence in comparison to Dushehari and Amrapali. This hybrid has all the desirable characters inherited from its parents, Amarpali and Sensation, like red colour peel, good sugar: acid blend and, above all, uniformity in fruit size. The

Mango hybrid H 1-1

Important mango hybrids under evaluation

Parameter	H 1-1	H 1-5	H 1-6	H 2-6	H 2-14	H 4-12	H 11-2	H 13-7	H 13-8
Plant height (m)	5.60	3.70	4.50	3.00	3.50	-	2.90	7.90	6.30
Plant spread									
E-W	3.40	2.10	3.90	3.60	3.50	-	2.30	3.70	5.10
N-S	3.60	2.60	3.20	3.80	3.70	-	2.20	3.60	3.60
Yield (number of fruits/plant)	273	53	97	120	57	295	44	165	98
Average fruit weight (g)	186.5	226.6	237.3	252.4	278.8	174.8	376.3	207.3	217.4
Peel thickness (mm)	0.98	1.49	1.40	1.23	1.25	1.27	1.07	1.34	1.73
Pulp %	72.78	73.23	71.70	75.71	70.28	67.32	79.90	68.37	60.00
Pulp colour	Yellow	Uniform yellow	Orange yellow	Yellow	Yellow	Orange yellow	Yellow	Orange yellow	Orange yellow
Total soluble solids (%)	19.79	19.67	21.6	19.3	19.4	20.8	16.4	18.3	18.5

Mango hybrid H 1-6



Mango hybrid H 4-12

average fruit weight is 237.3 g. The variety is comparable to Dushehari and Amrapali in terms of pulp (71.70%), β-carotene (10,964 µg/100 g pulp) and ascorbic acid (40.26 mg/100 g pulp).

Hybrid H 2-6. Mango hybrid H 2-6 is a unique hybrid having regularity in bearing and attractive oblong fruit shape. Owing to its oblong shape, it is suitable for uniform packaging. The yellow fruit colour at ripening makes it very

Mango hybrid H 2-6

appealing to the buyers. It has 5 to 6 days' shelf life at room temperature after ripening. Further, the plants are semi-vigorous and about 278 plants of this hybrid can be accommodated in a hectare.

Hybrid H 4-12. Mango hybrid H 4-12 has regularity in bearing, attractive fruit shape, bright red peel and orange pulp. The red peel colour on yellowish green background makes it very appealing to the buyers. It has oblong shape and uniform sized fruits. It has 5 to 6 days' shelf life at room temperature after ripening. This hybrid has good sugar: acid blend and uniformity in fruit size.

1.8.2 Grape

Thirty grape cultivars were evaluated for their fruit characteristics on Head, Kniffin and Bower systems of training. The cultivars Tash-e-Ganesh and Centennial Seedless performed well again on Head and Kniffin systems of training under yield trials. Out of 90 hybrids assessed and evaluated for their yield, quality and fruit characters, Banqui Abyad × Perlette 75-32 and Hur × Cardinal 76-1 performed well on Head and Bower systems of training under yield trial. Potential grape hybrids, viz., Selection 2005-6-17, Selection 2006-11-8 and Selection 2006-12-1 were observed to have early ripening and good quality seedless grapes.

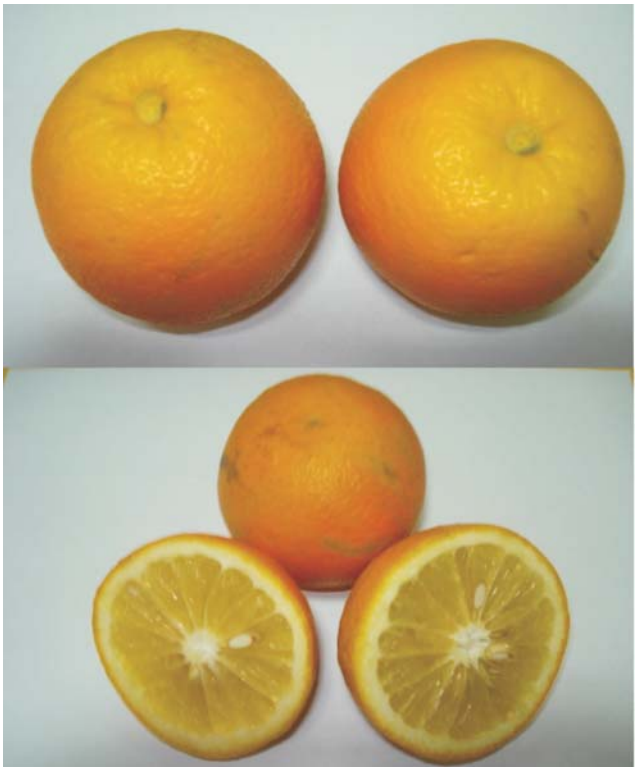
1.8.3 Citrus

1.8.3.1 Citrus germplasm evaluation

Different collections of malta, mosambi, lime and galgal were evaluated under Delhi conditions. In malta collection, MS 5 had the heaviest fruit (331 g) followed by MS 16 (212.6 g) and MS 17 (200.7 g) as compared to that of the standard variety Valencia (107 g). All three malta collections had 10.2-18.2 seeds/fruit. The highest juice recovery was in MS 5 (43.3%), whereas the highest TSS was recorded in MS 16. The peel thickness varied from 3.58 mm in MS 16 to 5.54 mm in MS 5.

Malta collection: MS 17

Among different collections of mosambi, MOS 1 had larger fruit (233.2 g), 13 segments, 1.4 seeds/fruit, 43.93% juice recovery, and 10.68% TSS. In acid lime collections, ALC 4 bore the heaviest fruit (70.9 g) followed by ALC 1 (59.5 g). However, the number of seeds per fruit was found to be the lowest in ALC 2 (4.8 seeds) followed by ALC 1 (9.4 seeds). Juice recovery varied from 41.13% in ALC 4 to 48.08% in ALC 1. ALC 4 registered maximum TSS (8.28%).



Mosambi collection: MOS 1

Among galgal collections, GS 2 had registered maximum fruit weight (358.2 g), fruit length (84.1 mm) and fruit diameter (94.5 mm). It also recorded maximum number of seeds (42.4 seeds /fruit), juice recovery (41.68%) and TSS (9.06%).

Acid lime collection: ALC 4

Four cultivars of grapefruit were evaluated for physico-chemical parameters to find out suitable cultivar (s) for north Indian conditions. Imperial had maximum fruit weight (387.6 g) whereas the highest juice recovery (47.28%) was found in Red Blush. The number of seeds varied from 2.4 seeds in Red Blush to 48.6 seeds in Walter. The maximum peel thickness (6.62 mm) was recorded in Red Blush and minimum in Foster (4.65 mm). TSS varied from 8.08% in Red Blush to 11.23% in Walter.

1.8.4 Papaya

1.8.4.1 Papaya improvement

A papaya line, PP 2-8 was selected from cultivar Pusa Dwarf having pink flesh with TSS content of 10° Brix. The stature of the plant is very short (112 cm) with low fruiting height (40 cm), medium fruit size of 550 g and 34 number of fruits/ plant.

1.8.5 Temperate Fruits

1.8.5.1 Apricot

The dried apricots among 12 cultivars, viz., Charmagz, St. Ambriose, Suffaida Oblonga, Nari Kinnaur and Kaisha Kinnaur were rated the best in organoleptic tests. These cultivars were also evaluated for their suitability for jam

making. The cultivar Charmagz was not particularly suitable for jam making as it is very light coloured and lacks the characteristic apricot fruit acidity that makes apricot jam unique. *Prunus japonica* could be used as a dwarfing rootstock for apricot and cherry in addition to use as an ornamental shrub.

Fourteen cultivars of apricot fruited, of which cultivar St. Ambriose exhibited fruits with highest fruit weight (44.05 g) and fruit volume (67.96 cc) followed by cultivar Suffaida Oblonga (43.60 g/fruit weight) and (36.98 cc /fruit volume), whereas the lowest fruit weight (11.45 g) and fruit volume (10.44 cc) were recorded in Shipley Early. TSS varied from 7.80° brix in EC 168342 to 18.47° brix in Shipley Early.

Foliar spray of NPK (15:15:15) at 12.5 g/l concentration at monthly intervals from March to August, 2008 gave higher per cent increase in shoot length and yield in apricot plants.

1.8.5.2 Kiwifruit

CPPU [N-(2-chloro-4-pyridyl)-N-phenylurea] greatly stimulates fruit growth indicating that it can be a powerful tool for improving kiwifruit (Chinese goose berry) cropping. Ten days after anthesis/two weeks after full bloom, CPPU at 10 ppm was applied to fruits by dipping them for about 10 seconds in aqueous solution of the compound. CPPU applied fruits increased in size by 20-70 g over that of control. A higher proportion of the crop was in large size grade and there was no loss of response as the crop load on the vine increased. CPPU produced a darker skin colour and some changes in appearance, increased fruit size, advanced ripening by one week, reduced flesh firmness, increased soluble solids and decreased titrable acidity. The average fruit weight has been further increased by light summer pruning in intervals along with CPPU application.

1.8.5.3 Pear

Foliar spray of NPK (15:15:15) at 5 gm/l concentration at monthly intervals from May to August, 2008 gave higher per cent increase in shoot length and yield in pear plants.

Pyrus pyrifolia (serotina), Pyrus pashia and *Pyrus pashia* var. Kumaonii are vigorous rootstocks for pear. *Pyrus calleryana* shows signs of delayed incompatibility and trees on this stock may not be long lived.

1.8.5.4 Strawberry

A total of 97 strawberry cultivars were being evaluated for their horticultural traits. Under the programme for evaluation of strawberry cultivars in different agro-climatic regions, cultivars were supplied to various ICAR institutes, SAUs and state governments. Some promising varieties were identified. The average fruit weight of these varieties varied from 3.5 g to 30 g.

The use of polyethylene in commercial cultivation of strawberry can play a pivotal role in minimizing winter injury and plant mortality and increasing productivity. Covering the strawberry beds with low clear plastic tunnels induced one month early cropping, prevented bed erosion and increased total yield by 20%. The black polyethylene mulched beds did not require any weeding. During summer (in hills), the polyethylene sheets of the tunnels were replaced by plastic anti-hail nets or anti-bird nets, which resulted in advanced harvest, increased yield and improved fruit quality.

1.8.5.5 Walnut

Pusa Khor, an early bearing variety of walnut, started bearing in the second year of its grafting, unlike other varieties of walnut, which normally take 10-12 years to come into bearing. The fruit appears to be borne laterally as well as terminally. The plant started bearing fruits in 2002 when

Fruit characteristics of Pusa Khor, an early bearing walnut variety

it bore two fruits. Presently, it is bearing 290 fruits. It is vigorous in growth with 514 cm plant height and its spread varies from 310 cm to 410 cm with an annual shoot increment of 105 cm. The fruit weight with husk and without husk (nut) was 53.95 g and 21.55 g, respectively. Likewise, the length of fruit with husk and without husk has been 56.47 cm and 42.23 cm, respectively. The nut is thin shelled with light yellow kernel of 12 g having good taste. It is an early, regular, and heavy bearing walnut with good quality. The rate of photosynthesis and transpiration was significantly higher in Pusa Khor compared to that in other seven clones under testing. A scrutiny of the bearing habit revealed that Pusa Khor bore 65.0% laterally and 35.0% fruits terminally, while all the fruits borne by other four clones under testing were borne terminally. Another characteristics of Pusa Khor is self cracking husk, which enables the nut to drop automatically after maturity.

1.9 ORNAMENTAL CROPS

1.9.1 Rose

1.9.1.1 Assessment of IARI roses under polyhouse conditions

Twenty promising varieties of rose developed were evaluated in low cost polyhouse, of which two varieties, viz., Pusa Priya and Pusa Bahadur performed well with respect to flower quality.

Rose variety Pusa Priya

Rose variety Pusa Bahadur

1.9.2 Gladiolus

1.9.2.1 Germplasm evaluation

Twelve gladiolus varieties developed at IIHR, Bangalore were evaluated under Delhi conditions, of which Meera, Sagar, Poonam, Sapana, Shakti and Arka Kesar were found to be suitable for production under Delhi conditions. The hybrids, Salmon Queen Open (Veerangana), Little Fawn Open (Kataksh), and Ave Open (Kiran) were found promising under continuous evaluation.

A promising gladiolus hybrid Veerangana

A promising gladiolus hybrid Kataksh

1.9.3 Chrysanthemum

For ratoon cropping the chrysanthemum cultivars, viz., Gulmohar, Flirt, Shyamal, TERI and Ravi Kiran are best suited.

Altered flower forms in irradiated chrysanthemum cultivar Thai Chen Queen

Chrysanthemum cultivars, Yellow Bangla and Thai Chen Queen were subjected to irradiation and could induce a large number of mutants in cultivar Thai Chen Queen. Rooted cuttings of cultivar Thai Chen Queen were subjected to a dosage of 20 Gray γ rays. This higher dose resulted in alteration of flower form, resulting in fluted, frilled and spider flower forms.

1.9.4 Marigold

1.9.4.1 Evaluation of interspecific hybrids

The interspecific hybrids derived from 33 cross combinations utilizing 11 parents of French marigold and three male sterile lines of African marigold were evaluated for various characters. The inter-specific hybrids showed superior plant spread, flower yield, flower size, number of flowers per plant and duration of flowering.

1.9.5 Tuberose

Rested bulbs of two cultivars of tuberose, viz., Phule Rajani and Sikkim Selection were planted at monthly intervals from January to June. March and April plantings produced better results. Tuberose cultivars, Hyderabad Single and Phule Rajani, can be uprooted in 7 to 8 months after planting to obtain daughter bulbs for next season planting. Root knot nematode infestation reduced with carbofuran (2 kg a.i./ha) treatment.

1.9.6 Lilium

Different intervarietal crosses were made among Asiatic lilium hybrid cultivars. Earliest seed germination was recorded in a cross combination of Shiraj × Sumplon, while maximum percentage seed germination was observed in Pollyanna × Shiraj cross combination.

1.10 SEED SCIENCE AND TECHNOLOGY

1.10.1 Hybrid Seed Production Technology

1.10.1.1 Mustard

Self-incompatibility in Indian mustard. An assessment of plants possessing protogyny in Indian mustard [*Brassica juncea* (L.) Czern & Coss.] was undertaken during the past three years with the objective of examining the nature of protogyny, stigma receptivity, pollen viability and its self multiplication. The results indicated that the protogynous interval, i.e., the period between stigma exsertion and anther dehiscence in flower was up to seven days. This is significant in relation to restriction of inbreeding, thereby facilitating out crossing. The average percentage of pod set in natural self-pollination and natural cross-pollination was very low. However, there was significantly higher seed set in cross pollinated treatments both at bud stage and in freshly opened flowers, which confirmed that the plants possessing protogyny were self-incompatible. Microscopic examination revealed the viability of pollens and cross compatibility with other genotypes of Indian mustard. A protogynous self-incompatible line can be used as a base material for hybrid development.

1.10.1.2 Cauliflower

Synchronization of flowering. In continuation to earlier studies on synchronization in the flowering of parental lines of cauliflower hybrid Pusa Karthik Shankar, it was confirmed that sprays of IAA @ 50 ppm at curd maturity (CM), bolting

(Bol), and bud initiation (BI) stages advanced the flowering of the late parent (female) by 13 days, thereby bridging the gap in flowering between the parental lines. However, there was a marginal reduction (2 days) in the duration of flowering of the seed parent. In conclusion, transplanting of parental lines in the first week of August and sprays of IAA @ 50 ppm at curd maturity, bolting, and bud initiation to the seed parent could be recommended in hybrid seed production of the early group cauliflower hybrid Pusa Karthik Shankar.

Seed yield. It was estimated that an average seed yield of 15 kg of hybrid cauliflower could be achieved from 500 m^2 area of hybrid seed production by spraying IAA @ 50 ppm at CM+Bol+BI or GA_3 @ 250 ppm at CI+ CM+Bol+BI stages. There was no adverse effect of these chemicals on seed viability at least up to one season.

Effect of chemical treatments on hybrid seed yield/plant (g) in cauliflower

Treatments	Stages				
	BI	Bol+ BI	CM+ Bol+BI	CI+CM+ Bol+BI	Mean
GA_3 250 ppm	12.53	11.91	13.21	16.75	13.60
GA_3 500 ppm	12.28	11.55	19.46	15.16	14.61
IAA 50 ppm	12.36	11.67	14.42	10.58	12.26
IAA 100 ppm	13.19	12.63	13.14	9.89	12.22
Mean	12.59	11.94	15.06	13.10	
S.E.(d) (P<0.05)	Treatment= 1.30		Stage= 1.16	Interaction= 2.60	

BI= bud initiation, Bol= bolting, CM=curd maturity (Harvest), CI= curd initiation

Multiplication of female line. Female line of Pusa Karthik Shankar, being self-incompatible (SI) in nature, is multiplied through bud pollination, which is time consuming and costly. It was observed that the application of 4% or 6% NaCl solution at 4 days and 8 days interval improved the seed set by 5-6%. Thus, NaCl treatment, a cheaper and easy method could be an alternative to bud pollination for multiplication of the SI lines of cauliflower.

1.10.1.3 Tomato

Hybrid seed production studies were undertaken in three tomato hybrids, viz., Pusa Hybrid 1, Pusa Hybrid 2 and Pusa Hybrid 4 in temperature controlled polyhouse, ventilated polyhouse and net house conditions. Pollen viability studies taken in the two male parents, viz., Chikoo and Pusa Gaurav showed very high pollen viability (above 90 per cent) both in polyhouse and field conditions. Reduced pollen fertility was observed when the mean temperature fell below 12-15 ºC. Pollens stored in ambient and refrigerated conditions remained viable up to 4 days of storage. The hybrid seed yield was compared under different growing conditions in Pusa Hybrid 4 and was found to be the highest in temperature controlled polyhouse (3.16 kg/100 m^2), followed by ventilated polyhouse (1.87 kg/100 m^2) and net house (0.59 kg/100 m^2) conditions, respectively.

1.10.1.4 Capsicum

Hybrid seed production of capsicum hybrid KTCPH 3 under open field was compared with that under the net house and low cost polyhouse. Polyhouse seed production technology proved more profitable than the other two technologies.

1.10.2 Effect of Bulb Size on Seed Yield of Onion

In a study on the effect of bulb size on seed yield of onion, it was found that seed yield is directly correlated to bulb size. It was also found that long day varieties had better storability under ambient conditions of Kullu valley. Among the short day varieties, red cultivars had better storability compared to white varieties.

1.10.3 Effect of Sowing Dates on Flowering Phenology, Seed Development and Seed Yield in Senna

Studies on the effect of different sowing dates on flowering phenology and seed yield in senna (*Cassia angustifolia*) revealed that the crop exhibited long day requirement for flowering. Therefore, delayed sowing inhibited the flowering and adversely affected the seed yield. Time required for seed maturation was about 40 days from flowering. The onset of germination took place after 20 days of flowering while the imposition of physical dormancy started after 30 days of seed maturation, and the onset of desiccation tolerance occurred after 34 days of flowering.

1.10.4 Characterization of Farmers' Rice Varieties by the Use of Morphological and Molecular Markers

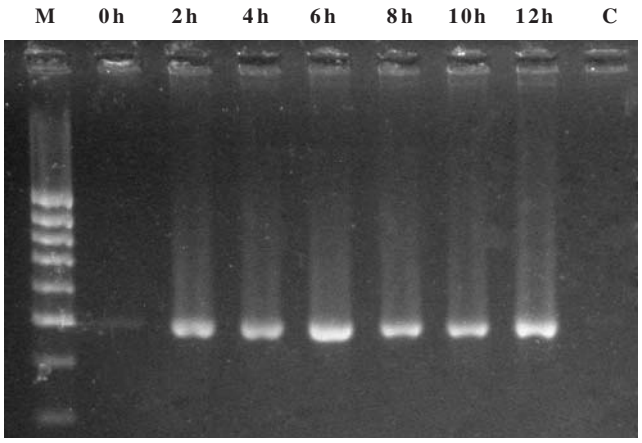
Farmers' varieties and land races of rice are grown across the country, which are also used for the development of improved varieties as donors for various traits. The PPV & FR Act 2001 provides for the protection of farmers' varieties, both as extant and new varieties. For protection of such varieties it is necessary to differentiate them by the use of molecular characteristics.

A rice variety, Patel 3, popularly known as HMT, developed at JNKVV, Jabalpur is widely grown by the farmers in many areas. An analysis of variations of this variety (grown at different locations) for various morphological and molecular traits indicated minor differences in some of the characteristics. The variety HMT collected from Orissa and Akola did not show differences for any of the characteristics, while Patel 3 (IC- 86557) and the same variety produced and maintained at Jabalpur was different for only 3 characteristics, viz., leaf: pubescence of blade surface, leaf: auricles and culm: attitude. Characterization based on molecular markers using 16 SSR markers did not show any difference between HMT varieties, grown in Orissa and Akola. However, Patel 3 could be differentiated from HMT based on SSR markers namely, RM 202, RM 204 and RM 205. Therefore, studying such varieties by the use of molecular markers is important for validating the similarity and differences among them.

1.10.5 Seed Invigoration and Quality Enhancement

Three seed lots of Bt hybrid NCH 74 exhibiting high, medium and low vigour were chosen for the molecular basis of seed priming. Hydro-priming was most effective in enhancing the germination and field emergence percentage in medium vigour seed lot from 77% to 95% and 73% to 82%, respectively. Priming treatment also enhanced the seedling dry weight significantly.

The globulin profile of primed and dried seeds, which were hydrated for 2 - 24 h, showed a prominent 29 kDa polypeptide fraction, induced by the priming treatment. Another fraction of 110 kDa also appeared during the priming



RT-PCR of control and primed seed of cotton primer sequence Psst-2 (M: 100bp, C: negative control, 0h-controlled condition for priming)

of seeds. The reverse transcriptase PCR (RT-PCR) analysis was performed with 12 nucleotide sequences picked up from *Arabidopsis* database of priming-induced nucleotide sequences which revealed 100% complementarity with cotton ESTs. This was further confirmed by the amplification of genomic DNA of cotton with these 12 primer sequences. RT-PCR analysis with Psst-2 corresponding to Actin-7 revealed a clear amplification, the intensity of which increased from 2 h to 14 h of priming. This is the first report on priming induced gene expressed in cotton.

Onion and soybean are two of the poor storer crops, which rapidly lose viability and vigour during storage. Therefore, seed quality enhancement protocols were developed to maintain high germination and vigour of seeds of these crops.

Solid matrix priming, halopriming, priming with celomic fluid/vermiwash and coating with Royalflow, a liquid formulation of Thiram or with synthetic polymer (Polykote + 0.25% thiram) were most effective in enhancing the germination and vigour in onion. The seeds dried to about 6% moisture content after the treatment and packed in 700 gauge polythene bags retained more than 70% germination up to 12 months of storage under ambient conditions.

In soybean, coating with Polykote + thiram @ 0.25% or with liquid formulation of thiram (Royalflo) were effective, which maintained more than 75% germination up to 9 months of storage. Hydropriming or halopriming were found to be detrimental. However, solid matrix conditioning, followed

by hydration and treatments with common bleach (0.2% NaOCl) or dry chilli powder were effective as mid-storage corrective treatments both in onion and soybean, which improved germination as well as field emergence.

1.10.6 Assessment of Seed Vigour

Based on a 3-year study, methods were standardized for reliable assessment of the planting value of onion and soybean seeds. In the case of onion, it was found that the final germination count of ~ 80% could result in >50% field emergence. Similarly, the first count of germination after accelerated ageing test (AAT) of >60% or germination after multiple stress test of >80% could predict a germinability of >70% after 9 months of storage under Delhi conditions. In the case of soybean, >80% germination after multiple stress test could result in >50% field emergence, whereas >50% first count of germination after AAT or >80% germination after multiple stress test could predict >70% germination after 9 months of ambient storage.

1.10.7 Standardization of Vigour Tests and Seed Enhancement

Preliminary observations on seed quality enhancement treatment with polymers in cotton showed higher field emergence. Seed treatment with thiram alone or in combination with polymer (PVP or PEM) had significant effect in enhancing first count, germination and field emergence percentage in chickpea genotypes. The electrical conductivity test could be suggested as the vigour test for chickpea. The germination was significantly reduced by osmopriming whereas Thiram @ 2 g/kg increased it significantly. All other seed enhancement treatments, viz., control, polymer-1, polymer-1+neem oil, polymer-2, neem oil, polymer2+neem oil, halopriming, polymer-2+thiram and polymer-1+thiram were on a par with thiram and osmopriming individually in chickpea.

1.10.8 Seed Testing Protocols in Medicinal Crops

***Standardization of topographical tetrazolium test for muskdana* (*Abelmoschus moschatus*).** Procedure of quick viability test was standardized for muskdana. The seeds were treated with boiling water and then soaked overnight at 20 ºC. The soaked seeds were prepared for biochemical test by cutting a thin slice opposite to micropile without damaging the folded embryo. The prepared seeds were soaked in 1% tetrazolium chloride salt at 30 ºC for 16 h and the embryos were prepared for microscopic examination by removing the seed coat and by excising the embryos from the seed coat. Stained, partially stained and unstained embryos were evaluated on the basis of staining pattern of embryonic axis and categorized into viable and non-viable seeds. The results were subsequently confirmed by correlating with germination results.

TZ staining pattern in muskdana showing viable and non-viable embryos

1.10.9 Effect of Pre-sowing Exposure of Static Magnetic Field on Shoot and Root Characteristics of One Month Old Chickpea Plants

Seeds of chickpea (*Cicer arietinum* L.) cultivar Pusa 1053 were exposed in batches to static magnetic fields of strength 50 mT for 2 h, 100 mT for 1 h and 150 mT for 2 h, and their effect on shoot and root characteristics of field grown one month old plants was studied. Results showed that magnetic field exposure enhanced shoots and root dry weights significantly compared to those of unexposed control. The root characteristics of the plants showed a dramatic two-fold increase in root length and root surface area of one month old plants. The improved root parameters suggest that this technique could be profitably exploited as chickpea is generally grown without irrigation and enhanced root growth will be useful in extracting moisture from deeper layers.

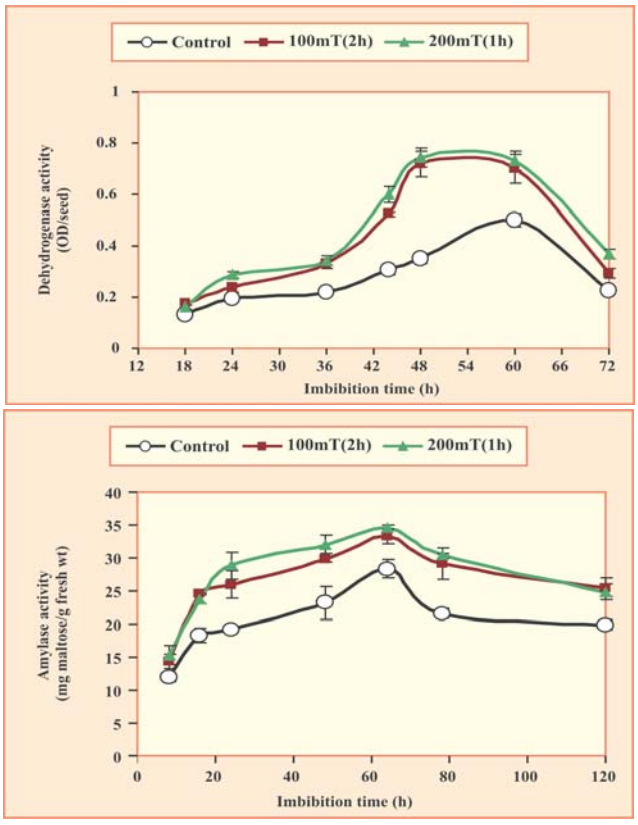
Effect of magnetic field on shoot and root growth characteristics of chickpea

Magnetic field (mT)	Shoot height (cm)	Branch no./ plant	Shoot dry weight (g)	Root dry weight (g)	Root dry weight/ shoot dry weight	Total root length (cm)	Root surface area (cm^2)
Control	15.22	4	0.282	0.030	0.106	94.1	8.29
50 (2h)	17.82**	5**	0.431**	0.090**	0.208**	197.7**	17.88**
100 (1h)	19.77**	5**	0.422**	0.098**	0.233**	170.9**	16.44**
150 (2h)	19.50**	5**	0.430**	0.093**	0.216**	207.0**	18.38**
LSD at 5%	0.896	0.385	0.0199	0.0065	0.0247	13.9	1.32

*** Significant at 5% level of probability, ** Significant at 1% level of probability**

1.10.10 Effect of Pre-sowing Exposure of Static Magnetic Field on Seed Water Distribution and Germination Related Enzymes during Germination in Maize

Experiments were conducted to evaluate the change in enzyme activity of the house keeping enzymes, viz., dehydrogenase and α amylase in maize (*Zea mays* L*)* cultivar Ganga Safed 2 seeds exposed to static magnetic fields of 100 mT and 200 mT for 2 h and 1 h, respectively. Dehydrogenase activity was 46% higher than that of the control, and α amylase activity was higher by 17-22% in treated seeds. Higher activity of these enzymes coincided with higher relaxation time of cytoplasmic water fraction observed from the component analysis after measuring T_2 relaxation times. Early hydration of macromolecules and membranes and greater activities of germination related enzymes are responsible for quicker germination and early seedling vigour of magnetically treated seeds in maize.



Activities of dehydrogenase and α amylase during germination in magnetically treated and untreated (control) seeds of maize

1.10.11 Impact of Implementation of Mega Seed Project on Seed Production

Farmers' Participatory Seed Production Programme was undertaken for wheat and gram during *rabi* 2007-08; and for mungbean and rice during summer/*kharif* 2008.

With the implementation of the Mega Seeds Project, the total seed production of the Regional Station, Karnal increased more than double.

Area and production for different crops under Mega Seed Project

Crop	No. of varieties	Area (ha)	Seed produced (t)
Rabi 2007-08			
Wheat	4	27.2	11.013
Gram	1	0.4	0.058
Summer-2008			
Mungbean	1	3.6	0.396
Kharif 2008			
Rice	5	50.8	18.111
Total	**11**	**82.0**	**29.578**

1.10.12 Seed Production

At the Seed Production Unit of the Institute (Delhi) and at the Institute's regional stations at Karnal, Indore, Pusa, Katrain, and Dharwad, nucleus, breeder and IARI seeds of different varieties of cereals, pulses, oilseeds, vegetables, fruit and tobacco were produced during the year under strict quality control. Apart from seed production, 1221 fruit plants were produced at the Seed Production Unit (Delhi). At the Regional Station, Karnal, about 4000 horticultural plants were produced.

Seed production (tonnes)

Crop	Nucleus seed	Breeder seed	IARI seed	Total seed
Seed Production Unit (Delhi)				
Cereals	-	26.18	134.18	160.36
Pulses	2.02	-	3..50	5..52
Oilseeds (mustard)	0.02	1.73	12.41*	14.16
Vegetables	0.009	0.108	0.739	0.856
Regional Station, Karnal				
Cereals	2.07	104.41	297.72	404.20
Pulses	0.03	7.25	3.96	11.24
Oilseeds	0.02	3.29	1.98	5.29
Forage	0.07	1.83	0.97	2.87
Vegetables	0.029	4.658	0.719	5.406
Regional Station, Indore (Breeder seed produced under farmers' participatory programme)				
Cereals	-	255.60	-	255.60
Oilseed (soybean)	-	1.20	-	1.20
Fruit (papaya)	-	14 (kg)	-	14 (kg)
Regional Station, Pusa				
Cereals	-	69.96	-	69.96
Pulse (mungbean)	-	0.44	-	0.44
Oilseeds (*toria*)	-	0.55	-	0.55
Tobacco	-	0.70	-	0.70
Papaya	-	15 (kg)	-	15 (kg)
Regional Station,Katrain				
Vegetables	0.107	0.729	1.246	2.082
IARI Centre for Pulses Improvement, Dharwad				
Pulses	0.45	-	-	0.45

***Including the mustard seed produced under participatory seed production programme (ORP) at the Seed Production Unit (Delhi)**

2. GENETIC RESOURCES

2.1 CROP GENETIC RESOURCES

2.1.1 Wheat

2.1.1.1 Novel genetic stocks

WR 95 (INGR 08070), a genetic stock carrying newly identified gene apd_1 for apical lethality was registered with NBPGR as a tester stock for gene apd_1.

Two genotypes, viz., HS 424 (INGR No. 08006) and HS 431 (INGR No. 08007) developed by IARI Regional Station, Tutikandi, Shimla were registered with NBPGR as resistance sources against leaf and stem rusts. Two genotypes, viz., HS 491 and HS 492 were identified for biscuit quality. An application was submitted for their registration with application and national identity numbers 08116 (IC 566222) and 08117 (IC 566223), respectively.

2.1.1.2 Germplasm registered with NBPGR

A *durum* wheat genotype HI 8591 was registered with NBPGR, New Delhi as a genetic stock with high yield and resistance to all three rusts.

2.1.1.3 Screening of exotic and indigenous material for late heat tolerance

Nine hundred fifty indigenous and exotic materials were evaluated for resistance to late heat tolerance, rust resistance and desirable agronomic attributes with PBW 343, HD 2329, DBW 14 and DBW 16 as standard checks. Some of the promising lines were Halna/DBW 14, 1st SAMNYT 1011, 1017, 1036, 39th IBWSN 1219, 1217, 1221, 38th IBWSN 11, 30, 94, 212, 239, 9th SRSN 13.

2.1.1.4 Identification of rust resistance germplasm against virulent pathotypes of leaf and stripe rusts

Eight genotypes, viz., IND 179, IND 181, IND 184, IND 195, IND 201, IND 214, IND 217 and HS 484 were identified as sources of resistance against two virulent pathotypes (46S119 and 78S84) of stripe rust and 77-5 pathotype of leaf rust at seedling stage. These germplam lines could prove useful in wheat improvement programme.

2.1.1.5 Maintenance and characterization of wild wheats

Nearly three thousand accessions of wild species received from USDA- Small Grain Centre and preserved in cold storage were retrieved and their viability was tested. Simultaneous phenotyping and characterization was also undertaken. The interspecific crosses with wheat and *Aegilops geniculata, Ae. longissima, Ae. squarrossa*, *Triticum timopheevi* were attempted.

2.1.1.6 Quality germplasm consolidation and purification

About 118 germplasm lines including indigenous, exotic and related species were consolidated and purified by single plant harvest along with other germplasm lines.

2.1.2 Rice

2.1.2.1 Nucleus seed production of Pusa 6A and paired crosses

Nearly 200 panicle to pair rows for nucleus seed production of Pusa 6A were grown and after careful examination, about 100 true to type progenies were selected and the rest removed at the onset of flowering. From the selected progenies 4 kg nucleus seed of Pusa 6A was produced for production of breeder seed. Twenty paired crosses each were made for maintenance of CMS lines, Pusa 4A, Pusa 5A, Pusa 6A, Pusa 7A, Pusa 8A and Pusa 11A.

2.1.3 Barley

2.1.3.1 New sources of resistance against rust

BHS 369 was identified as new source of resistance against all the pathotypes of stripe rust at seedling and immune to stripe rust at adult plant stage and registered with NBPGR (INGR 08010).

2.1.4 Maize

2.1.4.1 Registration of genetic stock

A maize genetic stock SC-24-92-3-2-1-1 for *maydis* leaf blight resistance was registered with NBPGR (INGR 08117).

2.1.4.2 Maize for diversified end-uses

Promising landraces and specialty corn populations/ composites were used as source germplasm for the creation of six specialty corn pools, including two baby corn pools, one sweet corn pool, one pop corn pool and two high carotenoid pool, and were advanced to cycles 4/5. Besides, two NEH pools (one flint and one semi-flint pool) were advanced to cycle 5 and an inbred line derivation was initiated. In addition, inbred lines for early generation baby corn, pop corn and high carotenoid were derived. Twenty-five sweet corn inbred lines (carrying *su* and *sh2* genes) were generated in the genetic background of six elite lines (CM 135, CM 136, CM 137, CM 138, CM 139 and CM 140). Eight inbred lines with phenotypic contrast for baby corn traits were crossed with a set of seven testers for undertaking genetic analysis of baby corn traits.

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 seventy-two pairs of A and B lines involving 53 downy mildew resistant male sterile lines, 34 pairs of MS lines which belonged to A2, A3, A4, A5 & A6 sources, 282 inbred lines suitable for moisture stress conditions were grown, maintained, and crosses made to exploit heterosis.

Fifty-two pairs of male sterile lines belonging to different cytoplasmic backgrounds (A1, A2, A4, A5) received from ICRISAT were maintained. The restorer lines for thick panicle, high head volume and dual purpose types (grain and fodder) were obtained from ICRISAT for their utilization in the ongoing breeding programme. Lines with short duration were used in crossing programme.

2.1.6 Chickpea

2.1.6.1 Genetic stock

About 150 prominent lines including mutant entries and varieties, having variability for different genetic traits in chickpea, were raised. Eight pea recombinant fixed lines of advanced generation ($F_{8/9}$), containing important morphological markers were sown for evaluation. Genetically stable lines can serve as multi-marker genetic stock for various genetic/ molecular studies in pea.

2.1.7 Mungbean

2.1.7.1 Germplasm evaluation and maintenance

Four hundred mungbean germplasm lines were evaluated and multiplied. Thirteen accessions of wild species were also maintained.

2.1.8 Pea and Lentil

2.1.8.1 Germplasm evaluation and maintenance

One hundred five germplasm lines of lentil were evaluated for yield and related agronomic traits. Eight hundred germplasm lines of fieldpea were evaluated for yield and related agronomic traits.

2.1.9 Pigeonpea

2.1.9.1 Germplasm resources

About 195 germplasm lines were selfed for maintenance and 402 germplasm lines received from NBPGR were evaluated and maintained.

2.1.10 *Brassica*s

2.1.10.1 Maintenance of germplasm and RILs

Six hundred forty-one germplasm lines of *Brassica* (*juncea*, *napus*, *carinata*, *campestris*, *nigra*, *oleracea*, *tournifortii*, *caudatus*), *Raphanus* (*sativa*, *caudatus*), *S. alba*,

E. sativa, Crambe, Camellina and, Lapidium were being maintained as core set of germplasm. In addition, 192 recombinant lines including parents from a cross Varuna × BEC 144 were selfed to advance next generation. These RILs have a wide variability for plant height, maturity, seed colour, and plant type in terms of basal branching, siliquae length, seed size, main shoot length, primary and secondary branches, etc.

2.1.10.2 Maintenance of zero erucic varieties

Seven hundred single plants of *Brassica* selected from selfed plots of four released varieties and eighteen advance cultures were screened for erucic acid content. Zero erucic acid single plants of four released varieties were multiplied under nylon nets to avoid out crossing.

2.1.11 Soybean

2.1.11.1 Maintenance and evaluation of germplasm

About 200 germplasm of soybean were screened for resistance to charcoal rot resistance. Screening was done both in earthen pots as well as in paper towel. About 30 genotypes were screened for iron deficiency chlorosis resistance under hydroponics system. About 190 germplasm were scored for YMV resistance. Eighty resistant/tolerant germplasm were identified for further testing. About 5 entries were involved in crosses to transfer the gene for YMV resistance and to develop mapping population.

2.1.12 Vegetables

In addition to sixty germplasm lines of cabbage, six new germplasm lines were obtained from different sources, which were evaluated and maintained for further use. Wax 1 has a distinct waxy coloured four lobed large size fruit. Another line Goldmine has a green blocky fruit, which turns golden on ripening. However, Bangalore 30 was the highest yielder with 1.25 kg fruits/plant.

Five new germplasm lines of paprika were collected, evaluated and maintained. The highest fruit yield/plant was recorded in Indu (800 g), which is an indeterminate type of paprika. Naga Jolokiya, which is the world's most pungent chilli, was also collected. Seven cabbage and three cauliflower lines, tolerant to DBM, were maintained.

2.1.13 Fruits

Marssonina blotch of apple was observed in severe form in some of the genotypes such as *Malus eseltine, M. orientale, M. baccata* (Dhack), and *M. baccata* (Srinagar), whereas in MM 26 (root stock), MM106 (root stock), *M. simcoe*, *M. baccata* (Kharot) and *M. baccata* (Rohru), the disease was observed in traces. However, the remaining genotypes, viz., M 7 (root stock), *M.E.M. Wilson*, *M. pumilla*, *M. sargentii*, *M. kindsomer*, *M. baccata* (Shillong), *M. baccata* (Lahaul), *M. micromalus* (Nagasaki zumi), *M. baccata* var. *Mandachurica,* and *M. prunifolia* (Maruba) were free from this disease. These genotypes were also evaluated for other foliar diseases such as *Alternaria* leaf spot, powdery mildew, sooty blotch and fly speck. The genotype *M. baccata* var. *Mandachurica,* showed good resistance to almost all the foliar diseases. This observation needs further investigation. *Cydonia oblonga,* which was reported to be resistant to root rot, showed susceptibility during the second year (2007) evaluation trial also. Similarly, *Pyrus* species, *Py. pashia* var. *Kumaonii* were found resistant to *Dematophora necatrix*.

Pusa Sev Moolvrinth 1 (PSM 1) recently developed wooly aphid, and powdery mildew resistant apple rootstock was grafted with spur type and delicious group varieties to study the transmission of powdery mildew resistance to scion wood. The artificial inoculation of the pathogen was done immediately after unfolding of the leaves. The initial observations during 2007 revealed that the contribution of powdery mildew resistance by rootstock to scion wood was negligible. However, next year, it would be evaluated again for confirmation.

2.1.14 Flowers

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, Wellington.

2.1.15 Tobacco

Seventy-six germplasm lines of chewing and *rustica* tobacco were evaluated, out of which many promising entries meant for total cured leaf, first grade leaf yield, puckering score and spangling score were screened and will be utilized in the ensuing crop season.

2.2 MICROBIAL GENETIC RESOURCES

2.2.1 Strengthening of BGA Germplasm

The Centre for Conservation and Utilisation of Blue Green Algae is an important repository and service centre for fresh water blue green algae. At present, a total of 550 cyanobacterial isolates are housed in the repository and maintained in unialgal condition. The cultures are maintained on slants and regularly subcultured following microscopic examination and purity check. Cyanobacterial strains obtained from Sambhar Salt Lake belonging to the genera *Nostoc*, *Calothrix*, *Cylindrospermum*, *Anabaena*, *Westiellopsis* and *Hapalosiophon* were added to the collection. These form an important genetic stock and can be used for research in the area of biofertilizer and, value addition, and as a source of important genes. The cultures were supplied to various organizations on request.

2.3 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

2.3.1 *Herbarium Cryptogamae Indiae Orientalis* (HCIO)

Enrichment of repository of fungal biodiversity. Seven hundred seventy-two (772) diseased fungal specimens of different groups including fifty type specimens were accessioned in HCIO raising the total number of specimens to 48, 222.

New species proposed. Many new species added towards fungal biodiversity include: *Alternaria palmivora*, *Asterina ardisiicola*, *A. cassiae*, *A. emciciana, Asteridiella emciciana, Cercospora atylosiae, C. michnigena, C. nymphaegena, Meliolaster aporusae*, *Meliola vatsavayai*, *M. lophopetaliilola*, *M. cayratiae, Passalora cesalpinicola, Pseudocercospora ampilocisicola, P. bischofigena, P. caesalpiniana, P. cocculigena, P. thunbergiana, Schiffnerula wedeliae, Sarcinella limoniae, Stenella pentatropidicola* and *S. schleicherioliosa.*

2.3.2 Indian Type Culture Collection (ITCC)

Maintenance and new additions. About 3663 fungal cultures belonging to Mastigomycotina, Zygomycotina, Ascomycotina and Deuteromycotina were maintained at ITCC. The ITCC was further enriched with 143 different fungal cultures. Some noteworthy plant pathogens accessioned include: *Acremonium roseogriseum Curvularia fallax, C. aragrostidis, C. clavata, Fusarium fusaroides, Telaromyces flavus, Stemphylium vesicarium,* and *Sclerotium delphini*.

Culture supply and identification services. Three hundred and five authentic cultures belonging to Zygomycetes (38), Hyphomycetes (91), Ascomycetes (22), Penicilli(17), Aspergilli (27), Coelomycetes (12) and Fusaria (98) were supplied. Besides 345 culture specimens belonging to Hyphomycetes, Coelomycetes and Zygomycetes were identified up to species level.

Characterization of Chaetomium and Aspergillus. Eighteen different species of *Chaetomium* were morphologically characterized and preserved at ITCC. Twenty isolates of *Aspergillus* obtained from fruits/seeds collected from Delhi market were sorted into five groups based on their colony characters and microscopic observations, viz., conidial head, conidiophore, vesicle, sterigmata and conidia. The group 1 was referred to as *A. flavus*, group 2 as *A. parasiticus*, group 3 as *A. ochraceus*, group 4 as *A. terreus* and group 5 as *A. niger.*

2.3.3 Insect Biosystematics

Under the insect identification service, 529 insect specimens were identified. Field diagnostics including seasonal history and activity of shot hole borer *Scolytis nitidus* (Coleoptera: Curculionoidea: Scolytidae) on apple in Kashmir was worked out. Further the host plant phenology was correlated with these to integrate ecological aspects towards its evolution and biosystematics.

In species of *Apanteles* (Hymenoptera: Braconidae), which are often very difficult to identify, molecular

characterisation was attempted. PCR amplification of the entire Internal Transcribed Spacer (ITS) of rDNA was done for *Apanteles angaleti.* The sequence comprised of 849 bp. The sequence was analyzed by Blast and deposited in the NCBI GenBank (Accession No. EU 938530).

Monitoring of formicids (Hymenoptera: Formicidae) revealed 12 species of three subfamilies, viz., Formicinae: *Camponotus compressus*, C. *sericeus, C. parius, Cataglyphis setipes, Acantholepis frauenfeldi;* Myrmicinae: *Pheidole spathifera*, *P. indica, Melanoplus bicolor. M. indica, Monomorium scabriceps, Messor himalayanum*; and Ponerinae: *Anochetus madraszi. Messor himalayanum* was recorded as a seed harvester in the mustard agroecosystem.

Scutellera perplexa and *Chrysocoris* sp. (Hemiptera: Pentatomoidea: Scutelleridae) were recorded as serious and regular pests of *Jatropha* sp. grown in and around Delhi. A new species, viz., *Priassus punctata* was described with a key for the identification of various species. Four pentatomoid species, viz., *Coridius obscurus, Eurydema pulchrum, Priassus exemptus* and *Priassus punctata* (new species) were recorded for the first time from Himachal Pradesh.

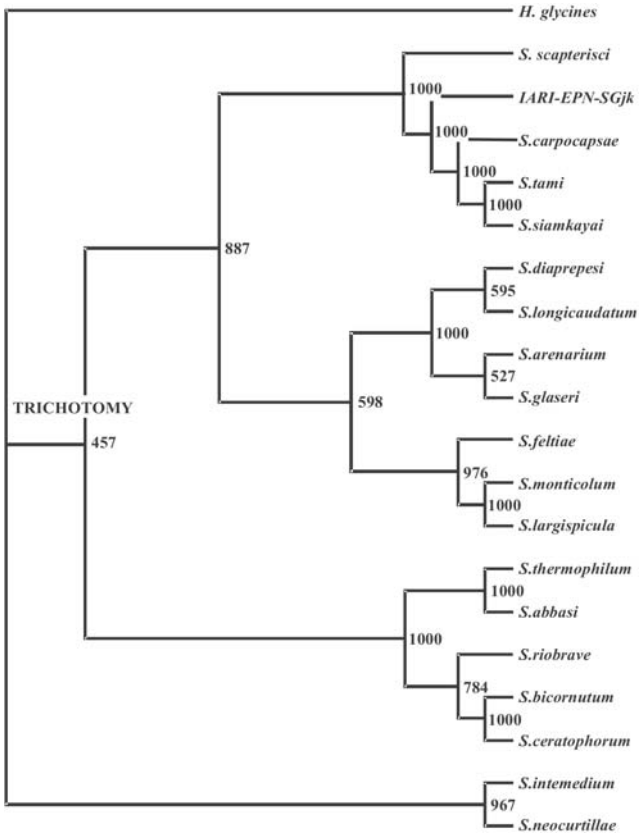
2.3.4 Nematode Biosystematics and Identification Services

New nematode species. Described three new nematode species, one each of the genera *Tylenchorhynchus* and *Xiphinema*, from the rhizoshere of bamboo in Jorhat, Assam; and one of *Helicotylenchus* from rice in Chhattisgarh.

New EPN strains isolated. Isolated two new strains of *Steinernema,* one each from Orissa and Assam. Based on the morphological and morphometrical features of the infective juveniles and males and females of two generations, the strains were identified as *S. carpocapsae* from Orissa, and *Steinernema bicornutum* from Assam. *S. bicornutum* was characterized by paired horn-like structure on the lip regions of its infective juveniles; the presence of additional pair of papillae on its males and the presence of tail mucro only in second generation females. In *S. carpocapsae,* horn like structures were absent, and tail mucro was present in adults of both the sexes of all the generations.

Molecular characterization of Steinernema* sp. *from Jammu & Kashmir. Amplified and sequenced the complete ITS region of rDNA of its infective juvenile, which was found to have 653 base pairs. A phylogenetic tree was obtained by maximum parsimony by the use of default parameters of Clustal X. Tree evaluation was made using a heuristic search (simple stepwise addition, tree bisection reconnection branch swapping). The phylogenetic relationships of Jammu and Kashmir strain *Steinernema* sp. JK with *S. thermophilum* showed that the species were grouped in three main clusters, wherein the two Indian species – *S. thermophilum* and *Steinernema* sp. Jammu & Kashmir strain were located in different clusters, the former forming a clade in *bicornutum* group, and the latter in *carpocapsae* group.

NCBI GenBank depositions. The Institute submitted 7 new gene sequences of the ITS region of ribosomal DNA



Phylogenetic relationships of *Steinernema* from J&K (IARI-EPN-SG*jk*) with closely related species based on ITS region of rDNA

– 4 of *Steinernema* (strains from J & K, Kerala, Assam and West Bengal), 2 of *Heterorhabditis* (strains from Gujarat and Meghalaya), and one of asymbiotic bacterium *Leucobacter iarius* sp. n. from *S. thermophilum* to the GenBank, vide accession Nos. FJ 418046; FJ 715947; FJ 715946; FJ 418045; FJ 744544; FJ 751864; and AM 040493, respectively.

National Nematode Collection of India (NNCI). The National Nematode Collection was maintained and augmented by the addition of 35 type specimens on 21 type slides representing 7 new species, thus bringing the total strength up to 2232 type accessions. The database of wet collections was updated from 625 to 1830 records.

Nematode identification service. Identified 107 nematode specimens of plant parasitic, free-living and entomopathogenic nematodes received from Uttar Pradesh, Manipur, Arunachal Pradesh and Orissa. The important species identified were: *Meloidogyne incognita, Rotylenchulus reniformis, Pratylenchus thornei, Tylenchorhynchus* spp., *Helicotylenchus* spp., *Hoplolaimus* sp., *Hirschmanniella* sp., *Tylenchus* sp., Tylenchidae, *Criconemoides* sp., *Criconema* sp., *Hemicriconemoides* sp., *Paratylenchus* sp., *Caloosia* sp., *Xiphinema* sp., *Longidorus* spp. *Aphelenchus avenae*, *Ditylenchus* sp., *Seinura* sp., *Ecphyadophora* sp., Belondirids, Wilsonematids, Dorylaimids, *Chronogaster* sp., *Leptonchus* sp., mononchids, *Cephalobus persegnis,* Rhabditids and *Steinernema* spp.

3. CROP AND RESOURCE MANAGEMENT AND ENVIRONMENT

3.1 AGRONOMY

3.1.1 Effect of Incorporation of Summer Green Manuring Crops Residue and Zinc Fertilization on Productivity of Aromatic Rice

A field experiment was conducted to study the effect of incorporation of summer green manuring crops residue and zinc fertilization on productivity of aromatic rice (cv. Pusa 1121) in split plot design during 2008 on a sandy clay-loam soil. Summer green manuring crops and zinc fertilization treatments were allocated to main and sub- plots, respectively.

Maximum yields of aromatic rice were recorded when the crop was grown after *Sesbania aculeata* green manuring, and this treatment was found superior to summer mungbean green manuring and summer fallow treatments. However, cowpea residue incorporation remained statistically on a par with *Sesbania* green manuring. In general, residue incorporation improved the grain yield of rice ranging from 0.25 to 0.40 t/ha over that of control. Higher values of harvest index were also found with the incorporation of mungbean and cowpea residues compared to those of summer fallow. Zinc fertilization, irrespective of the method of its application, had a significant effect on the grain and straw yields as well as harvest index of aromatic rice. Zn enriched urea application through 2.0% zinc sulphate ($ZnSO_4.H_2O$) recorded significantly higher yields of aromatic rice compared to the yields obtained with 5.0 kg Zn/ha as soil application, and ZnO as slurry for dipping the roots of rice seedlings before transplanting, and remained statistically on par a with the yields obtained with other Zn application treatments. Between two sources of zinc, sulphate ($ZnSO_4.H_2O$) was superior to zinc oxide (ZnO) irrespective of their method of application. Harvest index of aromatic rice was significantly influenced by zinc application only as against absolute control (no N and no Zn) but remained statistically on a par with the rest of the treatments. There was no significant interaction between summer green manure crop and zinc fertilization.

Effect of summer green manuring crops and zinc fertilization on yields and harvest index of aromatic rice

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Summer green manuring crops			
Cowpea (5.3 t/ha)**	3.51	15.46	18.5
Mungbean (4.96t/ha)	3.44	15.24	18.4
Sesbania aculeata (7.34t/ha)	3.59	16.33	18.0
Summer fallow	3.19	14.61	17.9
SEm±	0.03	0.07	0.08
CD (*P*=0.05)	0.12	0.23	0.29
Zinc fertilization for aromatic rice			
Absolute control (no N and no Zn)	2.66	12.84	17.1
Control (120 kg N/ha Only)	3.40	14.92	18.5
2.0% Zn-enriched urea as $ZnSO_4.H_2O$	3.67	16.75	18.0
2.0% Zn-enriched urea as ZnO	3.61	16.11	18.3
5.0 kg Zn/ha as $ZnSO_4.H_2O$	3.58	16.04	18.2
5.0 kg Zn/ha as ZnO	3.51	15.61	18.4
Using ZnO slurry for dipping of rice seedling roots before transplanting of rice	3.45	15.29	18.4
0.2% foliar spray application of $ZnSO_4.H_2O$*	3.54	15.72	18.4
SEm±	0.05	0.14	0.11
CD (*P*=0.05)	0.13	0.40	0.32

***At maximum tillering, pre-flowering and flowering stages, respectively**

****Crop residue on dry weight basis (shoot & root)**

3.1.2 Intercropping of Mungbean in Cotton

A field experiment was conducted to find out the suitability of mungbean intercropping in cotton during the

Performance of cotton in sole and intercropping system

Cropping system	Yield (t/ha)			LER	Net return (x 10^3 Rs/ha)
	Seed cotton	Mungbean grain	Cotton equivalent yield of system		
Sole cotton	2.05	-	2.05	1.00	36.25
Cotton + mungbean (1:2)*	2.07	0.70	2.41	1.53	48.47
Sole mungbean	-	1.35	1.20	1.00	19.09
SEm±	0.02	0.10	0.10		
CD (P=0.05)	NS	0.23	0.40		

*100% population of base crop of cotton and $^2/_3$ population of mungbean

summer season, 2008. Spring cotton intercropped with mungbean cv. Pusa Vishal (1:2 additive series) recorded higher total productivity in terms of cotton equivalent without affecting the yield of cotton. Intercropped mungbean yielded 52 % of its sole crop yield. An additional net return of Rs 12,220/ha was obtained in intercropping system compared to that of sole cotton. The land equivalent ratio (LER) of intercropping system (1.53) also revealed the beneficial effect of intercropping system.

3.1.3 Studies on *Jatropha* (*Jatropha carcus*) and Castor (*Ricinus communis*) De-oiled Cakes as a Nutrient Source in Spring Sunflower (*Helianthus annuus*) and their Residual Effect on Succeeding Maize (*Zea mays*)

A field experiment was carried out on spring sunflower-maize sequence to evaluate the effect of *Jatropha* cake, castor cake and FYM as a source of nutrients in sunflower and their effect on nitrification and microbial properties of soil and also their residual effects on succeeding maize crop during 2008. The experiment was carried out in three times replicated randomized block design with 11 treatments.

Application of 50% of the recommended dose of fertilizer (RDF) + 50% recommended dose of nitrogen (RDN) through *Jatropha* cake to sunflower was the best integrated nutrient management practice in terms of both direct effect on sunflower (3.43 t/ha) and residual effect on maize (2.89 t/ha) . The highest system productivity in terms of sunflower grain equivalent yield and system net returns was also recorded with the application of 50% RDF + 50% RDN through *Jatropha* cake closely followed by 50% RDF + 50% RDN through castor cake. The system agronomic nitrogen use efficiency was recorded maximum with 50% RDF + 50% RDN through *Jatropha* cake followed by 50% RDF + 50% RDN through castor cake. With reference to RDF application to sunflower, maximum nitrification inhibition was observed with 50% RDF + 50% RDN through *Jatropha* cake followed by 50% RDF + 50% RDN through castor cake. The RDN through FYM, *Jatropha* cake and castor cake recorded higher dehydrogenase activity and FDA hydrolysis activities compared to those of control and RDF through inorganic source. Organic carbon content recorded marginal increase due to organic sources of nutrients over the initial value and the effect was more pronounced under application of organic alone to supply recommended dose of nitrogen.

3.1.4 Response of Soybean to Sulphur and Boron Nutrition

A field trial was conducted to work out the optimum dose of sulphur and boron for soybean in factorial RBD and replicated thrice during *kharif* 2008.

Application of sulphur to soybean elicited good response up to 30 kg S/ha. Further increases in the level of sulphur did not influence the performance of soybean greatly and were found to be on a par with 30 kg S/ha. Among different levels of boron application, 1.0 kg and 1.5 kg boron recorded significant influence on yield as compared to other levels. Further, all the levels of both sulphur and boron recorded improvement in growth and yield attributes of soybean as compared to those of control. The uptake of S and B were also influenced by these levels of S and B. The response equations with different levels of sulphur and boron were quadratic in nature with 31.15 kg S and 1.34 kg B/ha being the optimum dose. The yields at optimum dose were 1728kg/ha and 1718 kg/ha from S and B, respectively.

3.1.5 Organic Farming of Rice-based Cropping Systems with respect to Nutrient Management

A field experiment was conducted on different rice-based cropping systems with special reference to nutrient management. Fourteen treatment combinations of nutrient sources, viz., control, farm yard manure (FYM) equivalent to 60 kg N/ha to rice and wheat, vermicompost (VC) equivalent to 60 kg N/ha to rice and wheat, FYM + crop residue (CR), VC+CR, FYM+ CR+ biofertilizer (B) and VC+CR+B and two cropping systems, viz., rice-wheat and rice-wheat-mungbean cropping systems were laid out in strip plot design with three replications.

In general, the application of FYM, VC, FYM+CR, VC+CR, FYM+CR+B and VC+CR+B improved the total productivity to the tune of 35.9%, 46.2%, 51.1%, 61.4%, 65.9% and 73.0%, respectively over that of control. Statistically, the application of VC+CR+ B being on a par with the application of FYM+CR+ B and VC+CR gave significantly higher productivity compared to that of the remaining treatments with more residual soil organic carbon content. Between two cropping systems, rice-wheat-mungbean system was more sustainable than rice-wheat system in terms of both productivity and residual soil organic carbon content.

Performance of rice-based cropping systems under different organic nutrient management practices

Treatment	Grain yield (t/ha)			Total productivity (t/ha)	Organic carbon in soil (%) after the system
	Rice	Wheat	Mungbean		
Cropping systems					
R-W	4.51	4.47	-	8.41	0.59
R-W-M	4.91	4.83	-	10.91	0.67
SEM±	0.12	0.18	-	0.25	0.011
CD (P=0.05)	NS	NS	-	1.52	0.067
Nutrients					
Control	3.45	2.64	0.72	7.15	0.42
FYM	4.28	4.32	0.84	9.72	0.61
VC	4.61	4.65	0.90	10.45	0.65
FYM + CR	4.77	4.86	0.91	10.81	0.65
VC + CR	5.15	5.19	0.94	11.54	0.68
FYM + CR + B	5.23	5.37	0.98	11.86	0.68
VC + CR + B	5.47	5.55	1.04	12.37	0.72
SEM±	0.09	0.11	0.0005	0.41	0.02
CD (P=0.05)	0.60	0.36	0.002	1.27	0.07

3.1.6 Effect of Planting Systems and Fertility Levels on Pigeonpea and Mungbean Intercropping System under Rainfed Conditions

Intercropping of mungbean in pigeonpea improved the system productivity in terms of pigeonpea equivalents (1.71 t/ha) over sole pigeonpea (1.5 t/ha). In the planting system, broad bed and furrow planting, being on a par with paired row planting remained superior to uniform row planting. Broad bed and furrow planting system produced 17.07 per cent higher pigeonpea equivalent yield compared to that of

Effect of cropping system, planting systems and fertility levels on pigeonpea equivalent yield

Treatment	Pigeonpea yield (t/ha)	Mungbean yield (t/ha)	Pigeonpea equivalent yield (t/ha)
Cropping system			
Pigeonpea sole (50 cm)	1.45		1.45
Pigeonpea + mungbean	1.48	2.48	1.71
S.Em+	0.02	-	0.06
CD (P=0.05)	NS	-	0.18
Planting system			
Uniform row planting system	1.34	1.97	1.46
Broad and furrow (BBF)	1.57	2.43	1.71
Paired planting system	1.51	2.36	1.65
S.Em+	0.02	0.05	0.02
CD (P=0.05)	0.07	0.16	0.08
Fertility level			
Control	1.18	1.53	1.27
40 kg P_2O_5/ha	1.43	2.10	1.55
40 kg P_2O_5+PSB+VAM	1.60	2.60	1.76
80 kg P_2O_5/ha	1.68	2.79	1.83
S.Em+	0.02	0.06	0.02
CD (P=0.05)	0.07	0.19	0.07

uniform row planting system. Among the fertility levels, the application of 80 kg P_2O_5/ha (1.83 t/ha) and 40 kg P_2O_5 + PSB + VAM/ha (1.76 t/ha) gave equal yields of pigeonpea, mungbean and pigeonpea equivalents, but both the fertility levels remained superior to control and 40 kg P_2O_5/ha.

3.1.7 Suitable Cropping System for Conservation Tillage

A field experiment was conducted on mungbean -mustard – cowpea cropping system to study the effect of conservation tillage and crop establishment practices. The crops were grown with 4 tillage practices, viz., conventional tillage (flat sowing), narrow bed, broad-bed and zero tillage in main plot; and 4 combinations of residue and fertilizer application, viz., no fertilizer application combined with no residue and residues application, and application of recommended fertilizers combined with no residue and residues application. The residues of the previous crop were applied to the succeeding crop in the respective treatments @ 2.0 t/ha for mungbean and cowpea and 2.5 t/ha for mustard.

Mungbean performed significantly better in narrow bed in comparison to zero-tillage, while mustard yields were similar in zero-tillage and flat sowing. Cowpea also performed significantly better in bed system of planting compared to zero-tillage. System productivity in terms of mustard equivalent yield was the highest with bed system with 4.20t to 4.28 t/ha followed by flat sowing (4.14 t/ha) and zero-tillage (3.89 t/ha). Fertilizer application supplemented with residues resulted in significantly higher yield of all the three crops. All the crops responded positively to the application of residues with varying levels of improvement in grain yield. The highest system productivity of 4.76 t/ha was recorded in the treatment receiving fertilizer supplemented with crop residues. Conservation tillage (zero-tillage followed by fertilizer and residue application) produced the highest mustard yield (1.712 t/ha) showing that mustard performed better or equally well under conservation tillage system. Economics data revealed that zero-tillage produced the highest net return (Rs.47,582/ha) among the tillage and crop establishment practices while in fertility levels, the treatment receiving residue and fertilizer resulted in the highest net return (Rs. 53,851).

System productivity due to tillage and residue management effects in mungbean–mustard–cowpea cropping system

	Mungbean (t/ha)	Mustard (t/ha)	Cowpea* (t/ha)	MEY (t/ha)	Net return (Rs/ha)
Tillage					
Flat sowing	0.72	1.38	2.79	4.14	41,177
Narrow bed	0.80	1.24	2.92	4.20	32,357
Broad bed	0.77	1.33	2.99	4.28	43,871
Zero tillage	0.67	1.33	2.59	3.89	47,582
CD (P=0.05)	0.05	NS	0.17		
Residue/fertilizer					
No fertilizer + no residue	0.66	1.05	2.55	3.56	32,661
No fertilizer + residue	0.71	1.17	2.75	3.88	38,449
Fertilizer + no residue	0.76	1.45	2.87	4.32	40,028
Fertilizer + residue	0.84	1.62	3.13	4.76	53,851
CD (P=0.05)	0.04	0.065	0.184		

***Green pod yield; MEY: mustard equivalent yield**

3.1.8 Performance of Wheat Genotypes at Different Nitrogen Levels under Rainfed Condition

Under rainfed condition, only two genotypes, viz., UP 2691 and HUW 609 were tested against four checks for North Eastern Plains Zone. HUW 609 performed better than all other checks for grain yield at lower nitrogen level, i.e., 40 kg N/ha.

3.1.9 Effect of Boron Application on the Productivity of Wheat in NEPZ

Since the yield of wheat crop in NEPZ is prone to boron deficiency, and the problem of non-seed setting is reported from pockets, the studies on the effect of boron application were considered important. To estimate the performance of wheat with boron application as borax, three most promising wheat varieties of this zone were evaluated with six main treatments of boron application.

The level of available boron in soil was observed to be in low range, and the results of the experiment showed that the application of FYM in plots produced significantly higher grain

yield (3.746 t/ha) as compared to other treatments. All levels of soil application of borax were observed to increase the yield as compared to that of control, but the overall increase in yield was not significant; the maximum mean yield (3.156 t/ha) was obtained in 10 kg borax/ha applied treatments, followed by a comparatively low mean grain yield of 2.619 t/ha in 0.2% spray of borax/ha as against 2.656 t/ha in control plots.

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

During the year, under conventional tillage, HD 2824 was observed to be the highest yielder (5.10 t/ha) followed by HP 1761 (5.00 t/ha), HUW 468 (4.18 t/ha), PBW 373 (4.08 t/ha) and HP 1731 (4.06 t/ha). Under zero tillage condition, HD 2824 (4.4.0 t/ha) followed by HP 1761 (4.09 t/ha) performed better. The varieties, PBW 373 (3.86 t/ha), HUW 468 and HP 1731 (3.65 t/ha) were other varieties in the order of performance.

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

The results of third year of experimentation on seed treatment of wheat with PSB and *Azatobactor* culture revealed that seed treatment with PSB culture and *Azatobactor* in plots, where 50% dose of the recommended N and P was applied, yielded 3.11 t/ha as against the yield obtained from the plots where the recommended dose of N and P was applied (3.87 t/ha).

Results of this year also indicated that the application of these fertilizers can compensate about 50% of recommended nitrogen and phosphate chemical fertilizer requirements in wheat crop with only a marginal loss in net grain yield component but major gain in economy of wheat crop production.

3.1.12 Agronomy of Improved Pusa Basmati 1 (Pusa 1460)

3.1.12.1 Transplanting date

A field experiment was conducted during *kharif* 2007 and 2008 at IARI Regional Station, Karnal with six transplanting dates, viz., June 22, June 30, July 8, July 16, July 24 and August 1 to evaluate its effect on seed yield and quality. The effect of transplanting dates on yield attributes, viz., plant height, panicle length, seed weight/panicle, filled seed/panicle and 1000-seed weight was significant. There was considerable reduction of more than 20% when transplanting was done on 16th, 24th and 31st July or 1st August compared to transplanting done on 22nd June.

3.1.12.2 Nitrogen fertilizer and spacing

Seed yield increased significantly up to 100 kg N/ha, and maximum seed yield was observed with 20 × 15 cm^2 spacing, which was significantly higher than that observed with 30 × 15 cm^2 and 25 × 15 cm^2 spacings.

3.1.13 Effect of Agronomic Manipulations on Synchronization and Seed Yield of Parental Line of PRH 10

Synchronisation of 6A (seed parent) and 6B (pollen parent) of PRH 10 was studied by staggered nursery sowing and plant density of female line. Nursery sowing of pollen parent was done on the jute bags 3, 6, 9 and 12 days after

Effect of staggered sowing of parental lines and spacing on flowering and seed yield

Staggered nursery sowing (days)	Days to flowering		Early/ late (in days)	Seed yield (t/ha)	Filled seed (%)
	Male (6B)	Female (6A)			
Male 17th June: Female 14th June (3)	60.7	60.6	0	0.974	48.3
Male 20th June: Female 14th June (6)	60.4	59.3	+1	0.984	49.7
Male 23rd June: Female 14th June (9)	62.8	60.3	+2	0.985	47.3
Male 26th June: Female 14th June (12)	64.5	59.8	+5	0.798	41.1
CD at 5%	**0.43**	**0.48**		**0.078**	**4.5**
Spacing (female)					
30x30 cm^2 (1,11110/ha)	62.5	60.8	+2	0.909	46.1
25x25 cm^2 (1,60000/ha)	62.0	60.4	+2	0.965	45.5
20x20 cm^2 (2,50000/ha)	62.1	59.8	+3	0.936	47.0
15x15 cm^2 (4,44000/ha)	61.7	59.1	+2	0.931	47.9
CD at 5%	**0.43**	**0.48**		**NS**	**NS**

Female (+) Early (-) late with reference to male flowers

sowing of seed parent. Transplanting of 6A with varying densities was done in square pattern following the system of rice intensification (SRI) technique. Synchronization in flowering was achieved when pollen parent was transplanted 3 to 9 days after seed parent. Number of panicles were significantly higher in 30 × 30 cm^2 and 25 × 25 cm^2 spacings. Filled seed (%), seed weight/panicle and seed yield was not influenced by female parent densities suggesting that more than double the area can be brought under the same amount of quality seed. This reduces the labour requirement and cost of production of parental line seed production.

3.1.14 New Technique for Raising Weed Free and Healthy Rice Nursery

For the production of robust and weed free nursery, A new method of raising nursery was found to be less labour consuming, while it also enhanced seedling growth, and minimized weed competition. It is more economical than the conventional method. Details regarding the new method are elaborated below:

- Soak 12.5 kg seed for 12 hours in 20 liters of water. Keep the seed in wet gunny bags after draining excess water for another 24 hours to allow sprouting.
- Make beds of 0.6 m width and 20 m length and 2" raised.
- Soak gunny bag in water for 4-6 hours.
- Spread 5 kg FYM along with 200 g NPK and 25 g zinc beneath the gunny bag and 3 kg FYM on upper side of the gunny bag. Pre-germinated seeds are spread on the wet gunny bags.
- Special care must be taken to prevent bird damage until seedlings become green.
- Care must be taken for termite control. Chloropyriphos @ 3.10 l/ha can be used at first and second irrigations.

Economics of Nursery raising with new technique and conventional practice (Rs./ha)

	Nursery with gunny bags		Conventional method	
	No. of labours	Cost (Rs.)	No.of labours	Cost (Rs.)
Seed bed preparation	3	300.00	3	300.00
Cost of weeding	1	100	20	2000
Irrigation	5	500	10	1000
Uprooting of seedlings	2	200	6	600
Cost of old gunny bags	200(no.)	1600.00	-	-
Total		**2700**		**3900**

Note: Cost of old gunny bag: Rs. 8/bag; labour cost: Rs.100/day

3.2 SOIL MANAGEMENT

3.2.1 Effect of Temperature and Moisture on the Carbon Mineralization in Soil Amended with Various Organic Materials and Urea

In the integrated plant nutrition system (IPNS), environmentally sound and productivity - sustaining management of N should rely on matching the rate of N release from organic sources with the crop demand. However, there is a practical difficulty in predicting the pattern and amount of N released particularly from organic sources during the growing season of crops as N release process involves a biological decomposition controlled by chemical composition of organic and soil environment, particularly temperature and moisture. In view of inadequate information available on the release kinetics of CO_2 during decomposition of various organic sources, experiments were conducted to study the release kinetics of CO_2 and nitrogen from different integrated sources (organics and synthetic) at varying levels of moisture and temperature. For this purpose, a laboratory incubation experiment with Typic Haplustepts (IARI farm) was conducted at two levels of moisture (field capacity and 2.5 cm standing water) and two levels of temperature (20 °C and 35 °C). Two levels each of moisture and temperature were selected to simulate the field conditions for rice and other upland crops; and winter and summer temperatures, respectively. Nitrogen was applied @ 60 mg kg^{-1} soil through urea, organic and integrated sources. Urea-N was substituted by farmyard manure (FYM), *Sesbania*, rice and wheat straw to the extent of 25%, 50% and 100%. Carbon di-oxide liberated in incubation experiment was collected in vials containing NaOH solution and the amount of CO_2 was determined by back titration with HCl. Results after twelve weeks of incubation showed that 13.2% reduction in carbon mineralization, as measured in terms of CO_2 evolved, occurred

Effect of water regime on the carbon mineralization (CO_2 evolved mg $100g^{-1}$) in soil amended with urea and organics

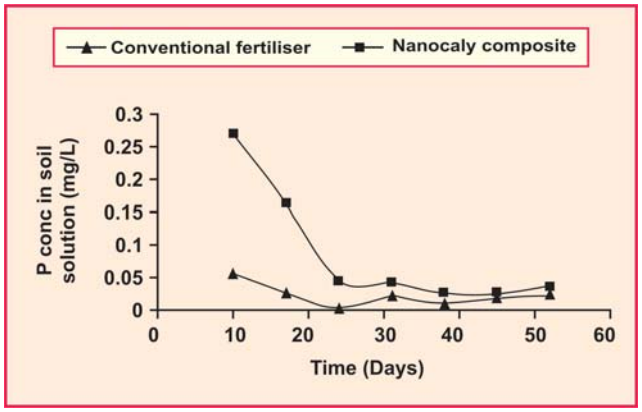
Sources of N	Water regime		Mean
	W_1	W_2	
Control	148	141	144
$Urea_{100}$	166	114	140
*FYM_{25}	162	122	142
FYM_{50}	183	130	157
FYM_{100}	180	144	162
$Sesbania_{25}$	182	137	159
$Sesbania_{50}$	241	168	205
$Sesbania_{100}$	294	233	263
$Rice\text{-}straw_{25}$	280	247	264
$Rice\text{-}straw_{50}$	327	287	307
$Rice\text{-}straw_{100}$	419	448	434
$Wheat\text{-}straw_{25}$	237	174	205
$Wheat\text{-}straw_{50}$	250	227	238
$Wheat\text{-}straw_{100}$	340	395	367
Mean	243	211	
LSD (P = 0.05)	N=14	W=5	N×W=20

*Subscripts indicate the percentage of urea-N substituted

under standing water (W_2) as compared to that under field capacity (W_1). There was a significant increase in C mineralization from 185 to 270 mg CO_2 $(100g)^{-1}$ with the increase in temperature from 20 °C to 35 °C. Among 100% organic treatments, rice straw recorded the highest C mineralization, followed by wheat straw, *Sesbania* and FYM. Almost similar trends were observed in the case of integrated nutrient management treatments also at both 25% and 50% levels of substitution.

3.2.2 Nanoclay-Polymer Composite as a Slow Release Fertilizer

Nanoclay fraction (Equivalent diameter < 80 nm) was isolated from soil clay. Mineralogical composition of this nano-clay was 31% vermiculite, 18% chlorite, 38% mica and 12% kaolinite. This fraction was incorporated into the partially neutralized acrylic acid and acrylamide at 10% rate during the process of polymerization to form the nanoclay-polymer



Phosphorus concentration in soil solution in a black soil due to application of conventional P fertilizer and nano-clay composite containing P

composite. Behaving like a hydragel, the composite had less permeability and finer pore space compared to those of the pure hydragel. Unlike hydragel, nanoclay-polymer composite was also not sensitive to variations in electrolytic concentration and could withstand salt solution without suffering a collapse in its structure. Nitrogen and phosphorus were uploaded in this nanoclay-polymer composite by dipping it in the fertilizer solution for 48 hours. This fertilizer-loaded- nano-composite was dried and ground to pass through a 2 mm size. This slow release material contained 13% N and 10% P and was tested for release of N and P into the soil for a period of eight weeks. When compared with the standard dose of N and P fertilizers, it was observed that P added in the form of nanonclay fertilizer to the soil at a dose of half the prescribed rate of a conventional inorganic fertilizer, the nanonclay fertilizer could maintain a reasonably higher P concentration in soil solution showing less adsorption and fixation of P by the soil colloids. Further this product has the advantage because the rate of P release from nanonclay fertilizer can be adjusted by varying the amount and nature of nanonclay in the polymer matrix.

3.2.3 Profile Distribution of Humus and DTPA-Extractable Micronutrients in Clay-Humus Complexes under Long-term Cultivation of Rice-Wheat and Maize-Wheat Systems

The objective of this study was to investigate the long-term effect of rice-wheat and maize-wheat cropping systems

on the distribution of humus and DTPA-extractable micronutrients, viz., Zn, Cu, Fe and Mn, in the clay-humus complex of the soil profile and work out their inter-relationships. Naturally occurring clay-humus complexes were isolated by ultrasonification of the soil samples collected from different depths of two soil profiles of Inceptisols from Ludhiana (one under long-term rice-wheat cropping system and the other under maize-wheat, cropping system). Isolated clay-humus complexes were analyzed for total organic carbon and DTPA-extractable Zn, Cu, Fe and Mn both before and after removal of adsorbed humus by treating them with 30% H_2O_2. After the H_2O_2 treatment, the samples were not washed. Extractability of the released nutrient in the absence of humus was studied to test the hypothesis that while after the removal of humus, the increase in micronutrient release might be due to additional release from the exposed inorganic surfaces, the decrease in the same might be due to the refixation of released cations by the exposed inorganic surface.

Results from this study showed that the soil profile under rice-wheat system had, in general, higher levels of adsorbed humus and DTPA-extractable Zn, Cu, Fe and Mn in the profile. Even after repeated treatment with 30% H_2O_2, humus carbon could not be depleted to less than 1% in the clay from both the systems which showed the existence of a strong bonding between clay and humus. The highest contents of the extractable micronutrients and organic carbon were obtained in 7.5-15 cm soil layer. Removal of humus from clay humus complex decreased the extractability of micronutrients, and most of the extracted micronutrients, in general, were associated with the humus component.

3.2.4 Relative Efficacy of Soil and Foliar Application of Iron in Correcting Iron Deficiency under Aerobically-grown Rice

In order to confirm the results reported last year, a field trial on diagnosis and amelioration of iron (Fe) deficiency under aerobically grown rice was conducted by using Pusa Sugandh 3, IR 64, IR 55419 and IR 55423 as test rice cultivars. Apart from control, Fe management treatments consisted of soil (150 kg $FeSO_4$ ha^{-1}) and foliar application of 3% $FeSO_4$ solution. Results indicated that two foliar sprays of Fe (3% $FeSO_4$; 30 kg $FeSO_4$ ha^{-1}) at 30 and 45 days after sowing (DAS) were more effective and economical than soil application of 150 kg $FeSO_4$ ha^{-1} in augmenting the grain yield of rice. Soil application of 150 kg $FeSO_4$ ha^{-1} and one foliar spray at 30 DAS were equally effective in maintaining Fe^{2+} in plant at 35 DAS. On an average, two foliar sprays at 30 and 45 DAS proved to be superior to soil application in maintaining Fe^{2+} in rice plants as measured at 60 DAS. The Fe^{2+} content of

Effect of methods of Fe application on the grain yield (Mg ha^{-1}) of different rice cultivars grown aerobically

Method of Fe application (Fe)	Cultivar (C)				
	Pusa Sugandh 3	IR 64	IR 55419	IR 55423	Mean
Control	1.35	0.61	1.85	1.93	1.43
Soil (150 kg $FeSO_4$/ha)	1.56	0.81	2.08	2.51	1.74
Four foliar sprays (3% $FeSO_4$)	1.90	1.18	2.89	2.84	2.20
Two foliar sprays (3% $FeSO_4$)	2.15	0.98	2.95	2.78	2.21
Mean	1.74	0.89	2.44	2.51	
LSD (5%)	Fe	C	Fe × C		
	0.19	0.19	0.39		

Effect of methods of Fe application on the Fe^{2+} content (mg kg^{-1}; on dry weight basis) at 35 days after sowing in different rice cultivars grown aerobically

Method of Fe application (Fe)	Cultivar (C)				
	Pusa Sugandh 3	IR 64	IR 55419	IR 55423	Mean
Control	43.2	28.1	45.3	41.0	39.4
Soil (150 kg $FeSO_4$/ha)	46.8	41.2	58.0	55.3	50.3
Four foliar sprays (3% $FeSO_4$)*	51.7	43.3	60.5	48.0	50.9
Two foliar sprays (3% $FeSO_4$)*	50.7	41.0	54.9	49.1	48.9
Mean	48.1	38.4	54.7	48.3	
LSD (5%)	Fe	C	Fe × C		
	2.7	2.7	5.5		

***At 30 DAS, both the treatments received only one foliar spray**

≥49 mg kg^{-1} in plants (on dry weight basis) appeared to be an adequate level at 35 days after sowing for direct seeded rice. Among the rice cultivars, Pusa Sugandh 3, IR 55419 and IR 55423 performed better than IR 64 under aerobic condition. The trends with respect to Fe^{2+} content and yield of different cultivars were almost similar to those obtained last year.

3.2.5 Phosphorus Dynamics in Wheat-based Cropping Systems with Varying Tillage and Crop Residue Management Practices

Phosphorus dynamics was studied on soil samples collected from a long-term on-going field experiment started during *kharif* 2004 on a sandy loam Typic Haplustept of IARI farm, New Delhi. The experiment was laid out in a split plot design in which crops (pigeonpea, cotton, soybean, maize and groundnut) constituted the main plot treatments and the combination of tillage and crop residue management, i.e., zero tillage with residue (ZT+R), zero tillage without residue (ZT-R), conventional tillage with residue (CT+R) and conventional tillage without residue (CT-R) constituted the sub-plot treatments. Results showed that the available P content of surface soil was more under cotton (18.3 kg ha^{-1}) than under all other crops except pigeonpea. Tillage and crop residue management (sub-plot treatments) caused a significant change in the $NaHCO_3$-P content and NaOH-P fraction of the surface soil with the highest content observed under ZT+R. Conventional tillage with crop residue was statistically on a par with zero tillage without crop residue treatment. The NaOH-P fraction of surface soil was significantly influenced by both *kharif* crops and tillage with crop residue management and was significantly higher under pigeonpea (76.9 kg ha^{-1}) than under other crops. Olsen-P and $NaHCO_3$-P (0.5 M $NaHCO_3$, 16 h shaking) of surface soil showed a significant positive relationship with total P uptake of *kharif* crops. A significant positive relationship was observed between biological yield and total P uptake with sub-surface soil $NaHCO_3$-P. Findings of this investigation show that soil P management decisions may differ according to the nature of cropping system, tillage and crop residue management practices.

3.2.6 Effect of Sewage Sludge and Rice Straw Incorporation on Wheat Yield and Mineralization of Nutrients

Cowpea was grown with treatments of rice straw (RS), sewage sludge (SS) alone and their mixtures, SS:RS (1:3), SS:RS (1:6) and SS:RS (1:9) along with 50% NPK; recommended NPK, and control for comparison. The surface soil samples were collected after 45, 90 and 135 days from the date of sowing of the cowpea. The entire biomass of cowpea was turned in the field at 60 days after picking the pods of cowpea. Data emanating from the experiment revealed that soil pH did not reveal any change owing to the treatments. At 45 days, the highest soil organic carbon (SOC) content was recorded in the sewage-sludge- treated soil; available N, NH_4-N and NO_3-N content were found in the NPK treatment. Conjoint application of sewage sludge along with 50% NPK was superior to sewage sludge + rice straw + 50% NPK. At 90 days (i.e., 30 days after incorporation of cowpea) appreciable increase in the available mineral N was found in all the treatments with the exception of untreated control and sewage sludge + rice straw (1:6). For studying the mineralization of C and N from decomposition of cowpea, the above ground portions of 30 and 60 days old cowpea plants were incubated with 200 g soil. Rice straw (2%) amended with cowpea was kept for comparison. At 30 days of incubation, higher values of organic C content were recorded in the treated soil. An appreciable increase in microbial biomass C (MBC) was observed in the cowpea-amended soil; this increase was higher than that obtained in the case of soil treated with cowpea plus rice straw.

After incorporation of cowpea during *kharif*, succeeding wheat crop (HD 2687) was grown with sewage sludge (1 t ha^{-1}) alone and mixed with rice straw in the ratio of 1:3, 1:6, and 1:9 supplemented with 50% NPK. Untreated and recommended dose of NPK were kept for comparison. The highest wheat grain yield (4.25 t ha^{-1}) was recorded in the treatment receiving sewage sludge + rice straw (1:6) along with 50% NPK which was statistically on a par with sewage sludge + rice straw (1:9) along with 50% NPK. All the treatments were superior to control, but within the rest of the treatments, sewage sludge alone produced the lowest grain

and straw yield. The highest content of organic C was observed in plot which had received sewage sludge and rice straw in a ratio of 1:6, while the highest available N was recorded in the treatment receiving sewage sludge + rice straw (1:6) in conjunction with 50% NPK.

3.2.7 Effect of Enriched Rice Straw Compost on Nutrition of Wheat and Cowpea and Soil Health

Five composts were prepared from rice straw alone and by mixing 2%N, 2%N+2%P, 2%N+2%K and 2%N+2%P+2%K with rice straw. A greenhouse experiment was carried out to evaluate the effect of these composts on the yield of and nutrient uptake by wheat and soil fertility. Cowpea was raised to evaluate the residual effect of these composts. Nitrogen @ 120 mg N kg^{-1} 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. The result showed that dry matter yield in all enriched treatments was significantly higher than that of control. Maximum dry matter yield (66.9 g pot^{-1}) was observed in treatment where N was applied at 50:50 through NPK-enriched compost and urea. Application of NPK-enriched compost in conjunction with urea-N was associated with significant increase in total N, P and K uptake by wheat over that of control. Application of NPK enriched compost in conjunction with urea (50% N) gave maximum uptake of N (416.4 mg pot^{-1}), P (235 mg pot^{-1}) and K (755 mg pot^{-1}), respectively. Higher apparent recovery of N (28.8-45.6%) was observed in those treatments where N was supplied through enriched-compost along with urea. The NPK- enriched compost in conjunction with 50% N through urea also recorded maximum uptake of Zn, Cu, Mn and Fe. Enriched-compost-treated soil also showed a significant increase in organic C, ammoniacal-N, nitrate-N, microbial biomass C (MBC) and dehydrogenase activity (DHA) over that in control. Maximum increase in organic C (0.61%), ammoniacal-N (40.1 mg kg^{-1}), nitrate-N (43.6 mg kg^{-1}), MBC (256.6 mg kg^{-1}) and DHA (49.6 µg g^{-1} h^{-1}) were recorded where N had been supplied in the ratio 50:50 by NPK enriched compost and urea. Availability of nutrients after wheat in soil enhanced the dry matter yield of cowpea to the tune of 32.3 - 71.6% over that of control.

3.2.8 Impact of Heavy Metal Contamination on Soil Biota and its Remediation

Surface samples (0-15 cm) from soils irrigated with sewage effluents emanated from Coronation Pillar sewage treatment plant as well as tube wells were collected from four villages of the National Capital Territory of Delhi, namely, Burari, Burari Extension, Ibrahimpur and Nathupura, and analyzed for various soil properties including available nutrients and heavy metals. The results showed that total organic carbon (TOC) content increased by 4% and 7% in soils irrigated with tube wells over those irrigated with sewage effluents in Ibrahimpur and Nathupura, respectively; however, in other villages, the difference in TOC content was non-significant. Soil pH and electrical conductivity were not influenced by sewage irrigation. Available phosphorus content increased significantly by 54% only in soils of Burari due to sewage irrigation. Available potassium and sulphur contents were increased significantly due to sewage irrigation in soils of Burari (84% K and 134% S) and Burari Extension (23% K and 25% S); however, available K and S exhibited an increase of 156% and 192%, respectively due to tube well irrigation in soils of Nathupura. Total iron, manganese, zinc, lead and nickel contents increased by 31%, 46%, 14%, 58% and 35%, respectively, in soils of Burari due to sewage irrigation, while total iron, manganese, cadmium and nickel increased by 34%, 137%, 60% and 52% in soils of Burari Extension**.** Total metal contents except zinc (22%) in Ibrahimpur, and iron and zinc (52% and 8%) in Nathupura did not increase significantly due to sewage irrigation. Available iron, manganese, zinc, copper, cadmium and lead contents increased by 56%, 62%, 246%, 224% and 107%, respectively, in soils of Burari due to sewage irrigation. Respective increases in available iron, manganese, zinc, copper contents were 32%, 135%, 124% and 57% in Burari Extension and 118%, 213%, 106% and 116% in Nathupura village. In Ibrahimpur soils, only available iron and zinc contents exhibited an increase of 34% and 63% due to sewage irrigation. The iron, manganese, and nickel contents in wheat biomass increased significantly due to sewage irrigation in Burari and Ibrahimpur villages.

Total and available iron, manganese, zinc, copper, cadmium, lead and nickel contents in sewage irrigated (SI) and tube well irrigated (TI) soils of various villages of Delhi

Soil	Metal contents (mg kg^{-1})						
	Fe	Mn	Zn	Cu	Cd	Pb	Ni
Burari							
SI	11023.0* (9.45*)	335.8* (4.93*)	42.27* (2.87*)	12.62 ns (1.41)	2.76 ns (0.42*)	10.3* (0.62*)	19.25*
TI	8415.0 (6.07)	230.6 (3.05)	(0.83)	10.97 (1.66)	2.20 (0.30)	6.5 (0.30)	14.29
% increase§	31 (56)	46 (62)	14 (246)	- (-)	- (-)	58 (107)	35 ()
Burari Extension							
SI	24783.0* (9.56*)	887.0* (7.50*)	74.11 n s(1.14*)	30.66 (3.14*)	4.51* (0.15 ns)	- (0.30 ns)	39.24* (-)
TI	18496.5 (7.22)	374.0 (3.19)	60.8 (0.51)	24.27 (2.00)	2.82 (0.15)	- (0.30)	25.87 (-)
% increase	34 (32)	137 (135)	- (124)	- (57)	60 (-)	- (-)	52 (-)
Ibrahimpur							
SI	14602.0 n s(8.47*)	248.9 ns (3.03 ns)	43.77* (0.98*)	13.54 ns (1.63 ns)	3.31 ns (0.089 ns)	- (-)	25.44 ns (-)
TI	19714.0 (6.34)	244.6 (3.54)	35.82 (0.60)	12.80 (1.88)	4.35 (0.086)	- (-)	19.69 (-)
% increase	- (34)	- (-)	22 (63)	- (-)	- (-)	- (-)	- (-)
Nathupura							
SI	17118.0* (8.07*)	207.4 (3.22*)	38.8* (2.05*)	11.87* (1.43*)	4.72 ns (0.15 ns)	- (-)	22.65 ns (-)
TI	11361.0 (3.70)	234.9 (1.03)	7.8 (0.99)	7.65 (0.66)	5.1 (0.16)	- (-)	20.3 (-)
% increase	51 (118)	- (213)	8 (106)	- (116)	- (-)	- (-)	- (-)

ns- not significant, *t test showing significant difference at 5% level of significance, § % increase over tube well irrigated soil, the data in parenthesis indicate available metal contents

3.3 WATER MANAGEMENT

3.3.1 Meteorological Studies

The long term rainfall data of WTC observatory of IARI farm were analysed by using modified Mann-Kendall non-parametric test to identify the existence of any trend in the data series. It was observed that there was a decreasing trend of annual rainfall depths for a period from 1972 to 2008 with Mann Kendall coefficient (-0.21) at 0.08 level of significance. This analysis corroborated that there was impact of climate change on the regional rainfall depths which resulted in reduced annual rainfall amount during the preceding 37 years. It was also observed that the CLIMGEN generated future data for a period from 2009 to 2050 exhibited a non-significant increasing trend of annual rainfall depths. However, the rainfall depths during the monsoon season did not exhibit any significant trend for these observed and estimated periods. Further, monthly runoff-rainfall indices of IARI watershed were estimated by employing the Natural Resources Conservation Service Curve Number method (NRCS-CN). It was revealed that at 90% probability level with 500 mm of rainfall occurring over the IARI farm, a harvestable runoff of 130 mm is plausible under the existing land use and soil type and the antecedent moisture conditions prevailing over the region. The developed monthly runoff-rainfall indices can be used to estimate the monthly, seasonal and annual surface runoff over the IARI farm for subsequent planning and management of water resources.

3.3.2 Watershed Based Studies

3.3.2.1 Surface runoff estimation and groundwater monitoring in IARI campus

Surface runoff from IARI campus was estimated by using USDA NRCS Curve Number method for the year 2008 on a daily basis to examine the possibility of rain water harvesting and groundwater recharge. The whole campus was divided into 5 sub areas depending on the road net work and land use pattern. Surface runoff was estimated from each sub areas. Total surface runoff was estimated to

Estimated rainfall precipitation ratio (RPR) for different months by the use of NRCS CN and long term rainfall data of IARI farm

Month	RPR	Year 2008		Year 2007		Year 2006	
		Rain (mm)	Runoff (mm)	Rain (mm)	Runoff (mm)	Rain (mm)	Runoff (mm)
January	0.03	1.8	0.054	1.6	0.05	2	0.06
February	0.07	0	0	70	4.9	0	0
March	0.1	0	0	34.4	3.44	23.2	2.32
April	0.18	24.87	4.5	0	0	3	0.54
May	0.23	135.3	31.1	55.1	12.67	94	21.62
June	0.24	76.2	18.3	86.8	20.83	90.6	21.74
July	0.28	159	44.52	91	25.48	305.2	85.46
August	0.36	264	95.04	234.8	84.53	113.6	40.89
September	0.15	106.8	16.02	43	6.45	86	12.9
October	0	0	0	0	0	1.4	0
November	0	0	0	0	0	2.6	0
December	0	0	0	0	0	0	0
Total (depth)		767.97	209.52	616.7	158.35	721.6	185.54
Volume (MCM)			1.05		0.8		0.93
Yearly RPR			0.27		0.26		0.26

be 0.5 million cubic meter (MCM). This shows that there is enough potential for rainwater harvesting in the campus.

3.3.2.2 Estimation of surface runoff by the use of SCS curve number (CN) method, remote sensing and GIS from Manesar Nala Watershed in Gurgaon (Haryana)

Surface runoff of the Manesar Nala Watershed (MNW) located in Gurgaon district of Haryana, lying between 28°15/ N and 28° 26/ N latitudes and 76°52/ E and 76° 60/ E longitudes was studied by the use of remote sensing and geographical information systems and SCS curve number method. The total area of the watershed is approximately 73.945306 sqkm (7394.5306 hectares). The data used for the present analysis consisted of NOAA satellite derived daily rainfall data for 2006; soil map generated from extensive field surveys and laboratory analysis, IRS-1D (LISS-III) sensor data classified by using standard digital image processing tools and techniques and survey of India, topographical sheet No. H43W15 of 1: 50,000. ILWIS Ver. 3.4 that has a good RS and GIS operation capability, and has been specially built for spatial analysis for land -and water resources was the main software used for compiling, collating and analyzing the various data layers. The daily precipitation maps for the study period 2006 for MNW were derived from the downloaded data form NOAA climate prediction center. The daily weighted rainfall for the study region was computed and converted into antecedent moisture condition (AMC) values. The soil map was digitized to extract different soil types and finally converted into hydrological soil group maps (HSG) based on their infiltration property. Land use map was prepared from IRS 1D (LISS-III) data by supervised classification method (SC). The SCS Curve Numbers were computed by using the SCS-CN formula for the MNW and by using the different thematic layers after combining them in GIS environment (ARC View 9.1, ESRI).

The SCS-CN model (NRC-SCS CN, 1972) was applied to estimate the event wise runoff from the daily rainfall finally cumulated for the whole year to get the annual runoff. The maximum rainfall was derived for the month of October (380.61 mm) whereas the minimum was recorded for the month of September (12.7 mm). The annual rainfall for the watershed was estimated to be 1117.3 mm. The maximum runoff was observed for the month of March (14.4 mm) whereas the minimum was seen for the month of September (0.0 mm). Significant runoff discharge was seen only for the months March, May, October and November while negligible or no runoff discharge was seen in other months. Rainfall-runoff curves were plotted for the different months and their relationship was developed.

3.3.3 Irrigation Agronomy

3.3.3.1 Effect of planting method and inter-cropping on the yield of maize and peanut under maize-based cropping system

A field experiment was conducted on sandy loam soil of the research farm of IARI, New Delhi during *kharif* season, 2008. The treatments comprised 2 planting methods, i.e., flat bed and ridge and furrow, and 3 cropping systems, i.e., sole maize, sole peanut, and maize + peanut. These treatments

Intercropping of peanut with maize

were tested under both rainfed and limited irrigation conditions. The experiment was laid out in randomized block design with 3 replications. The crop varieties for maize and peanut were HPQPM 1 and GG20, respectively. Two irrigations gave significantly higher yields of maize and peanut irrespective of the cropping system and planting method compared to that of rainfed. Similarly, planting on ridge produced higher yield compared to flat bed planting under both rainfed and limited irrigation. Intercropping of peanut did not show adverse effect on the yield of main crop of maize either grown in flat bed or in ridge under both rainfed and limited irrigation. Maize equivalent yields were higher under limited irrigation compared to rainfed crop. Similarly, planting on ridge gave higher equivalent yields compared to those on normal planting.

Effect of planting method and intercropping on yields of maize and peanut under maize-based cropping system

Treatment	Sole maize (kg/ha)	Sole peanut (kg/ha)	Maize+ peanut (kg/ha)	Maize equi.yield (kg/ha)
Rainfed				
Flat bed	2964	1922	3010 +625	4260
Ridge	3280	2315	3395+815	5025
Mean	3122	2148	-	4642
Irrigated				
Flat bed	3780	2630	3712+902	5516
Ridge	4216	3085	4175+1065	6305
Mean	2998	2857	-	5910

CD(P=0.05): Irrigation schedule - 314; cropping system - 307; and planting method - 298

3.3.4 Pressurized Irrigation Studies

3.3.4.1 Effect of poor quality water on dripper clogging

Operational difficulties in drip irrigation system sometimes arise from the clogging of drippers. Clogging is one of the factors, which affects the irrigation system efficiency because it influences the uniformity of distribution affecting the crop yield. Clogging usually develops slowly until it reaches the stage of "partial or full "clogging. Five types of micro irrigations (I1, I2, I3, I4 and I5) were installed and water of four salinity levels (S1, S2, S3 and S4) was used to study the effect of salinity on clogging of the system as described below:

I1 = Drip tape (Dripper discharge = 1.38 Lph)

I2 = Online drip system having PC drippers (Dripper discharge = 4.2 Lph)

I3 = Online drip system having NPC drippers (Dripper discharge = 3.16 Lph)

I4 = Inline drip system having (Dripper discharge = 1.41 Lph)

I5 = Inline drip system having (Dripper discharge = 2.71 Lph)

S1 = < 1.5 dS/m (plain water)

S2 = 3.0 - 4.5 dS/m

S3 = 7.5 dS/m

S4 = 10 dS/m

After a crop season of 6 months, the system I2 showed maximum clogging of 35%. Salinity increased the clogging, and one third of drippers got clogged needing de-clogging treatment. Minimum clogging was observed in system I4 (0.7 %) which was operated by using plain water.

3.3.4.2 Sub-surface drip system for summer tomato

An experiment was conducted on sandy-loam soils during 2007 to evaluate the economic viability of subsurface

drip irrigation system during summer. Laterals of subsurface drip irrigation system were placed at surface, 5 cm, 10 cm, 15 cm, 20 cm, 30 cm and 45 cm soil depths with drippers spaced at 40 cm each with an application rate of 2.0 Lph. Tomato (var. Indam 2103) was transplanted on February 17 with a row to row and plant to plant spacing of 100 cm and 40 cm, respectively. Daily water requirement was estimated by multiplying the reference crop evapo-transpiration with crop coefficient. The average seasonal requirement of crop was estimated to be 79.3 cm. The highest yield of tomato of 72.1 t ha^{-1} was recorded at 20 cm depth of placement of drip lateral. It was also found that through subsurface placement of laterals, the yield increased by about 35%.

3.3.4.3 Effect of micro irrigation systems on okra production

A field experiment was conducted to study the feasibility of different micro irrigation systems in okra. Okra (var. Versa Improved) was transplanted in a row to row and plant to plant spacing of 60 cm and 30 cm, respectively. Laterals with in-line drippers built at a spacing of 30 cm were used in surface and subsurface drip system, and micro sprinkler nozzles having 250 Lph at a spacing of 5 m were used to apply water in micro sprinkler system. Total water requirement of okra based on crop consumptive use requirements was estimated to be 47.0 cm. In a total crop period of 96 days, keeping the irrigation interval as 2 days, 48 irrigations through surface drip, subsurface drip and micro sprinkler were planned. The fertilizers were dissolved in water and the solution was applied along with the irrigation water through micro irrigation systems. Maximum yield was observed with micro sprinkler (36.6 t/ha) followed by that with subsurface drip system (34.5 t/ha).

3.3.4.4 Performance of groundnut (*Arachis hypogaea* L.) under drip irrigation and rainfed conditions

A field experiment was carried out to study the crop growth and yield of groundnut under drip irrigated and rainfed conditions. The parameters such as variations in soil profile moisture, leaf area index, canopy temperature difference and other yield attributes were recorded during the *kharif* season. There were four treatments of water regime that included 3 drip irrigated experimental plots with an amount of water as per the actual ET of the crop with daily, 4 days' and 7 days' intervals and the fourth one was rainfed. A severe biotic stress due to groundnut bud necrosis virus (GBNV) was observed after 65 days of planting of the crop leading to damage of the healthy crop. The results are reported in the following table:

Yield data of groundnut crop under four different treatments

Parameters	Daily	4-days	7-days	Rainfed
Fresh pod yield (t/ha)	1.87	1.75	1.40	0.76
Dry pod yield (t/ha)	1.07	1.12	0.96	0.53
Marketable pod yield (t/ha)	0.76	0.80	0.80	0.41
CATD(^{0}C)	2.73	1.59	1.3	1.0

CATD- Canopy air temperature difference

3.3.5 On-farm Studies

3.3.5.1 Modeling evapotranspiration and root-zone soil water balance for cropping system analysis in the trans-Gangetic plains (TGP) region of India through remote sensing and GIS techniques

A regional water balance model, namely, the Modified Thorntwaite-Mather Model (T-M model) was validated and tested for Haryana state in the trans-Gangetic plains region. The T-M root-zone water balance model was used to generate the daily soil moistures in the root-zones, based on the monthly rainfall and monthly potential evapotranspiration for 19 districts of Haryana state. The required model input data were rainfall (P), available water capacity (AWC), rooting depth and linear reservoir coefficient 'f'. Available water capacity (AWC), rooting depth, linear reservoir coefficient 'f' and other relevant data used in this analysis were taken from the public domain information of India Water Portal, standard literature and published sources. Monthly water balance was cumulated and the estimates of deficit and surplus were made on seasonal and annual basis. It was concluded that almost all the districts of Haryana state faced negative water balance which meant a severe water resources crunch in the area, and inadequate water availability to meet the irrigation requirements of the crops. Spatial maps were also generated by using a geostatistical software. Spatial variations of some of these parameters

Annual estimated water deficit in various districts of Haryana state (mm)

District	Latitude	Longitude	P	PET	P-PET	APWL	S W	dSW	AET	Deficit
Ambala	30.3	76.8	633.4	4436.4	-3802.9	-20179.3	1797.4	-400.0	1033.38	3403.0
Bhiwani	28.8	76.1	437.0	2384.6	-1947.6	-11400.4	1122.7	-395.7	832.70	1551.8
Faridabad	28.4	77.3	653.3	2344.9	-1691.6	-8505.8	1299.4	-381.8	1035.09	1309.8
Fatehabad	29.5	75.5	375.3	2405.8	-2030.5	-11842.9	1118.4	-396.5	771.87	1633.9
Gurgaon	28.4	77.0	625.5	2348.0	-1722.5	-9011.8	1249.4	-385.9	1011.45	1336.6
Hisar	29.2	75.7	402.2	2395.3	-1993.2	-11644.2	1120.8	-396.2	798.34	1597.0
Jhajjar	28.6	76.7	528.5	2345.1	-1816.7	-10747.0	1152.5	-394.1	922.59	1422.6
Jind	29.3	76.3	469.3	2363.6	-1894.3	-11133.1	1147.1	-395.2	864.52	1499.1
Kaithal	29.8	76.4	498.9	2353.4	-1854.4	-10902.3	1166.0	-394.7	893.67	1459.7
Karnal	29.7	77.0	583.3	2324.7	-1741.5	-10303.6	1197.0	-393.1	976.34	1348.4
Kurukhetra	30.0	76.8	589.8	2328.2	-1738.3	-10255.3	1209.2	-393.0	982.89	1345.3
Mahendragarh	28.3	76.2	524.7	2367.9	-1843.2	-10835.4	1142.0	-394.4	919.13	1448.8
Panchkula	30.7	76.9	678.3	2328.4	-1650.0	-9729.0	1261.7	-391.5	1069.84	1258.5
Panipat	29.4	77.0	561.9	2328.9	-1767.0	-10458.1	1179.3	-393.4	955.27	1373.6
Rewari	28.2	76.6	546.2	2352.7	-1806.5	-10676.6	1151.6	-393.9	940.13	1412.6
Rohtak	28.9	76.6	494.9	2355.9	-1861.0	-10972.9	1144.0	-394.7	889.65	1466.2
Sirsa	29.5	75.0	313.6	2445.6	-2132.0	-12373.1	1098.2	-397.3	710.91	1734.7
Sonepat	29.0	77.0	562.9	2332.1	-1769.2	-10208.9	1184.3	-392.4	955.35	1376.792
Yamunanagr	30.1	77.3	677.2	2311.8	-1634.6	-9172.5	1282.8	-388.6	1065.79	1246.01

P = precipitation, ET = evapotranspiration, APWL = accumulated potential water loss (negative), SW = available soil water (i.e., above wilting point), dSW = change in available soil water (i.e., above wilting point), AET = actual evapotranspiration

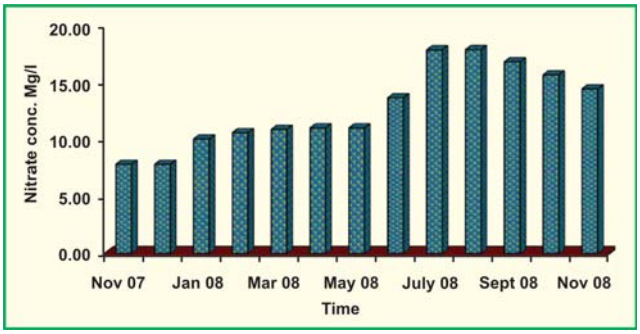
established that largely there was high uniformity except in some localized pockets. Generation of spatial data base of the existing cropping systems and land uses in the TGP of India by using RS and GIS was undertaken. The results were corroborated with spatial variability maps of the region generated by IMD.

3.3.6 Groundwater Studies

Groundwater monitoring carried out in the years 2007 and 2008 revealed that pre-monsoon and post-monsoon water table varied from 9.7 m to 15.1 m and 8.6 m to 14.2 m, respectively. When compared to the water table in the late sixties, the water table was seen to have gone down by approximately 6-10 m due to ground water pumping. Groundwater monitoring results also revealed that the rise in water table due to the natural groundwater recharge was marginal in the late July and early August even though there was good rain in 2008. This indicates excessive groundwater pumping even in the monsoon season.

3.3.7 Water Quality Studies

Groundwater samples of 17 operational tube wells on IARI farm were collected from November 2007 onwards on a monthly frequency basis. The samples were analysed for estimation of NO_3^--N by using *Kjeldahl* apparatus. It was observed that the NO_3-N concentration varied from a minimum of 9.2 mgl^{-1} in January 2008 to a maximum of 23.5 mgl^{-1} in August 2008. This may be attributed to the deep percolation of recharged water after cessation of monsoon rainfall and carrying of the nitrate load to the ground water. The sample collection and analysis will be used for development and validation of ground water pollution model.



Mean nitrate-N concentration in the tubewells of IARI farm

3.3.8 Socio-economic Studies

3.3.8.1 Evaluation of institutional role and organizational set-up in irrigation water management

A field study was initiated a in Mewat district, Haryana, in order to ascertain the procedural problems in the implementation of watershed programmes in partnership mode. Watershed projects of Haryana government at the villages, namely, Hasanpur, Bilonda and Bai were selected for the study. Information was collected on inter-relationships between traditional user groups, panchayat and the state department in relation to the implementation of these projects. This was carried out in relation to activities like generation of proposal, entry point activities, site selection, formation of watershed development team, formation of watershed development association, execution of works and the difficulties and problems faced by the staff. The study revealed insignificant role of village level associations (i.e., panchayats) in the management of natural resource base independent of state departments activities. Project proposals were generated depending upon the objectives of the state departments. Little attention was paid to the multi-disciplinary activities in watershed management.

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

A long-term field experiment established at IARI farm in 1971-72 under the aegis of AICRP-LTFE continued for the 37th consecutive year with maize-wheat cropping system.

The experiment consists of 10 treatments that include sub-optimal to super-optimal (50 - 100% of recommended NPK), unbalanced fertilizer input (NP or N alone), NPK supplemented with Zn, S or FYM, NPK + hand-weeding and an unfertilized control.

Annual crop productivity and nutrient uptake. Application of 100% recommended NPK increased the maize grain yield by 1.35 t ha^{-1} over the unfertilized control, and by 0.58 t ha^{-1} over 50% of recommended NPK. The corresponding yield responses in wheat were relatively greater, i.e., 2.20t and 1.17 t ha^{-1}, respectively. An increase in nutrient input either by raising fertilizer NPK to 150% of recommended rate or by supplementing 100% NPK with 15 t FYM ha^{-1} out-yielded the treatment with 100% NPK significantly, producing 1.1 - 1.2 t ha^{-1} additional grain (maize+wheat) annually. Both the crops responded tremendously to fertilizer P, but the yield increases due to K, S or Zn were statistically significant in maize only. Straw/stover yields also exhibited similar treatment effect. Yield trend analysis revealed temporal increase in crop response to P, K, S and Zn as also to the enhanced NPK

Effect of long-term use of fertilisers and manure on yield (t ha^{-1}) of maize and wheat

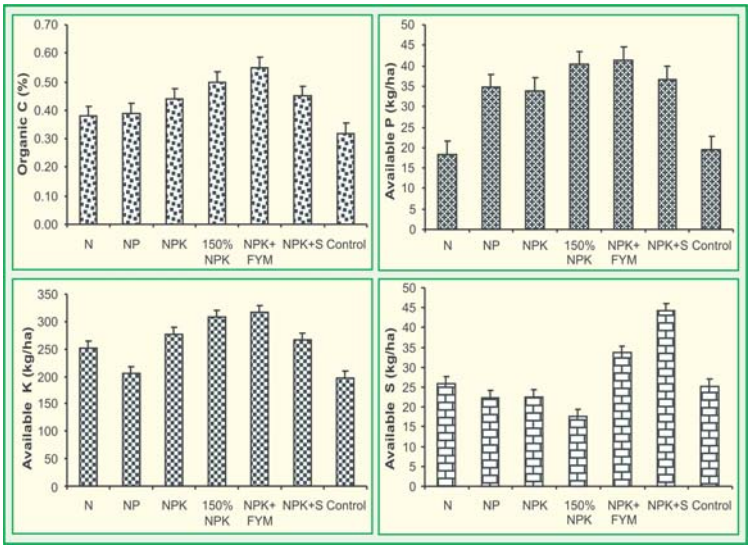
Treatment details#	Maize (2008)		Wheat (2007-08)	
	Grain	Stover	Grain	Straw
50% NPK	2.00	2.39	3.54	3.91
100% NPK	2.58	3.18	4.71	5.13
150% NPK	3.06	3.54	5.38	5.94
100% NPK+ hand weeding	2.74	3.22	4.85	5.38
100% NPK+ Zn	2.91	3.22	4.82	5.25
100% NP	2.35	2.79	4.34	4.81
100% N	1.66	2.13	3.57	4.25
100% NPK+ FYM	3.17	3.50	5.22	5.53
100% NPK+ S	2.89	3.18	4.97	5.21
Unfertilized (Control)	1.23	1.54	2.51	3.13
LSD (P=0.05)	1.81	2.26	0.51	0.53

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

input, which further proved the inadequacy of current fertilizer recommendations. The results thus underline not only the significance of balanced use of NPK, but also suggest an upward revision of fertilizer recommendations for achieving sustained high productivity under this intensive cereal-cereal system.

Annual nutrient uptake (maize+wheat) showed a large variation amongst the treatments, and followed the trends similar to grain and straw/stover yields. The N, P and K uptake by the two crops under control was 91.7 kg, 10.1 kg and 71.3 kg ha^{-1}, respectively, which was increased to 245.7 kg, 30.3 kg and 198.2 kg ha^{-1}, respectively, with 150% NPK application. Mining of soil K was apparent not only in N or NP treatments, but also under 100% or 150% NPK.

Changes in soil fertility. After completion of 37 annual crop cycles, soil organic carbon (SOC) content of surface soil (0-15 cm depth) under 100% NPK, NPK+Zn, NPK+S, and NPK+hand weeding remained statistically similar to the initial content of 0.44% indicating that these treatments did not deplete soil OC levels even under continuous intensive cropping. On the other hand, a significant decline in SOC was recorded under NP, N alone or control, with the highest magnitude of such decline under control. Treatments like 150% NPK or NPK+FYM resulted in a build-up of SOC in surface soil, possibly due to relatively higher yield of crops under these treatments and thereby a greater recycling of root mass and stubbles. The SOC content was the highest (0.55%) under NPK+FYM treatments. Available P and K contents under super-optimal NPK and NPK+FYM were comparable and significantly greater than those of other treatments. Among the fertilizer treatments, available P was the lowest in the plots receiving N alone, whereas the lowest content of available K was recorded in the NP plots. In the case of available S, the values under 100% or 150% NPK (17.6 - 22.6 kg ha^{-1}) were significantly lower than those in control (25.3 kg ha^{-1}).



Soil fertility status under long-term cropping and manuring after completion of 37 crop cycles

3.4.2 Integrated Nutrient Supply and Management in Pigeonpea-Wheat System

A field experiment on pigeonpea-wheat system commenced in 2004-05 at IARI farm was continued. The soil of experimental site is a sandy loam Typic Haplustept and had at the onset of the experiment 0.36% organic C, 194 kg ha^{-1} available N, 13.7 kg ha^{-1} available P, 232 kg ha^{-1} available K and 7.2 mg kg^{-1} available S. Fifteen treatments comprising fertilizer NPK alone or in combination with organic manures, i.e., FYM or sulphitation pressmud (SPM), induced defoliation (ID) in pigeonpea through foliar spray of 10% urea solution at physiological maturity, and an unfertilized-control, were compared in terms of yield and soil health parameters. Data for the prominent treatments are presented below:

3.4.2.1 Crop productivity

In pigeonpea, the application of soil test-based NPK produced 1.88 t ha^{-1} grain yield that was significantly greater than that of FYM or SPM alone (0.90 to 1.16 t ha^{-1}). Conjoint use of NPK and organics, however, gave an additional yield of 0.24 - 0.42 t ha^{-1} over that of sole NPK; the yield advantage due to integration of organics was relatively higher in wheat (0.76 - 1.35 t ha^{-1}). An increase in the rate of NPK application also increased wheat grain yield significantly. Results further revealed that (i) the performance of SPM was constantly superior in terms of yield response, and (ii) the use of manure (FYM or SPM) at 2.5 t ha^{-1} in pigeonpea and 7.5 t ha^{-1} in subsequent wheat was a better management strategy than the application of the entire quantity

to wheat. Induced defoliation (ID) in pigeonpea did not influence pigeonpea yield but enhanced wheat yield by about 0.5 t ha^{-1} over that of fertilizer NPK.

3.4.2.2 Pigeonpea leaf-litter recycling through induced defoliation

Foliar spray of urea solution (10% w/v) at physiological maturity in pigeonpea resulted in nearly complete defoliation within 5-7 days, this adding to the soil 1.77 - 2.04 t leaf litter ha^{-1} (average 1.88 t ha^{-1}). In other treatments, litter-fall due to natural senescence ranged between 0.53t and 0.99 t ha^{-1} (average 0.72 t ha^{-1}). This addition of leaf-litter recycled into the soil due to ID added over 50 kg N ha^{-1} besides substantial amounts of P, K and S.

3.4.2.3 Effect on soil health parameters

Soil analysis after completion of 4 crop cycles revealed a significant increase in OC and available N, P, K and S contents consequent to the integration of manures and/or ID with fertilizer NPK, in comparison to those under sole fertilizer treatments. The highest OC content of 0.52% was recorded under NPK+FYM+ID, whereas it was the lowest (0.31%) under unfertilized control. On the other hand, the treatments receiving SPM showed significantly higher available S content *vis-à-vis* other treatments. Available S tended to decline with continuous cropping using NPK alone. Soil biological parameters, viz., microbial biomass carbon (MBC) and dehydrogenase activity (DHA) measured at panicle emergence in wheat also established the superiority of integrated nutrient supply.

Effect of integrated nutrient supply on soil health parameters

Treatment	SOC (%)	Available nutrients (kg ha^{-1})				MBC (mg kg^{-1})	DHA (µg TPF 24 h^{-1} g^{-1})
		N	P	K	S		
Control	0.31	200	13.5	200	16.2	185	41.0
NPK	0.38	213	20.4	236	15.0	242	44.5
NPK+FYM	0.45	213	24.3	255	18.7	370	56.3
FYM alone	0.40	224	18.3	247	18.0	268	52.2
NPK+SPM	0.42	223	23.1	262	29.6	315	51.0
SPM alone	0.39	216	24.3	248	28.6	265	48.1
NPK+ID	0.42	248	24.3	267	18.1	295	49.5
NPK+FYM+ID	0.51	261	26.4	280	19.3	388	59.4
NPK+SPM+ID	0.47	268	28.5	283	31.0	335	53.8
LSD (P=0.05)	0.04	15.4	4.12	29.8	2.17	30.5	4.62

3.4.3 Integrated Nutrient Supply and Management in Pearl Millet-Mustard Cropping System

Results from the on-going experiment revealed that the application of sulphitation pressmud (SPM) @ 5 t ha^{-1} along with sub-optimal level of nutrients (75 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}) to pearl millet as well as mustard was as effective as the application of the recommended level of nutrients through fertilizer alone (N, P_2O_5 and K_2O - 100, 50 and 50 kg ha^{-1}) in relation to grain yield and nutrient uptake (N, P and K) in crops, but the former was better than the latter with respect to N and P use efficiency in pearl millet and mustard. Sulphitation pressmud, applied once in the cropping sequence only to the preceding pearl millet @ 10 t ha^{-1} had significant residual effect on the succeeding mustard comparable to the effect of its half dose (5 t ha^{-1}) applied each to pearl millet and mustard in relation to grain yield and nutrients uptake in mustard. There was a significant build up in available P content in soil after mustard where FYM had been applied @ 10 t ha^{-1} along with the recommended level of nutrients (N, P_2O_5 and K_2O - 100, 50 and 50 kg ha^{-1}).

3.4.4 Biofertilizers in Integrated Nutrient Management (INM) in Rice-Wheat Cropping System

A field experiment on INM for rice (var. Pusa Sugandh 4) and wheat (var. HD2851) was conducted with 17 treatment combinations having two doses of chemical fertilizer (40 kg and 80 kg N/ha), two biofertilizers (*Azolla* and BGA) and one organic matter (FYM) treatment. A significant increase in grain yield of rice and wheat was recorded due to the application of BGA, *Azolla* or FYM alone or in combination with chemical fertilizer. An increase of 49% in rice grain yield was found due to N_{40}, whereas the increase ranged between 62% and 86% when BGA, *Azolla* or FYM were applied in combination with N_{40}. At N_{80}, rice grain yield increased by 98% over control whereas

the increase was between 122% and 147% when these bio-inoculants were applied with N_{80}. In wheat also, similar trends were observed.

3.4.5 Evaluation of Value-added Composts on Sustainable Crop Production and their Impact on Soil Quality under Wheat-Maize Cropping System

Field evaluation of value added products in sustainable crop production and their impacts on soil quality under wheat-maize cropping system was initiated at the experimental farm of IARI. Value added organic products, namely, vermicompost, NADEP compost and FYM obtained from IVRI were included in this study as per the treatments: T_1: Control; T_2: Recommended dose of fertilizers (100% RDF); T_3: Vermicompost @ 5 t ha^{-1}; T_4: NADEP compost @ 5 t ha^{-1}, T_5: FYM @ 5 t ha^{-1}, T_6: 50% RDF + Vermicompost @ 5 t ha^{-1}, T_7: 50% RDF + NADEP compost @ 5 t ha^{-1} and T_8: 50% RDF + FYM @ 5 t ha^{1}. Whole quantities of value added composts and inorganic fertilizers were applied directly to soil before sowing of wheat. Results revealed that the addition of value added products and inorganic fertilizers applied either alone or in combination recorded significantly higher yield of and nutrient uptake by wheat than by control. The highest grain yield (3.53 t ha^{-1}) was observed in treatment T_6 where 50% RDF was applied through inorganic fertilizers along with 5 t ha^{-1} of vermicompost, which was 52.0% higher than that of control (2.37 t ha^{-1}). The relative efficiencies of the products on grain yield of wheat ranged from 18.4% (T_4) to 137.9% (T_6), as with 100% RDF. The maximum N uptake by wheat grain (76.8 kg ha^{-1}) and straw (99.6 kg ha^{-1}) was obtained in the treatment receiving 5 t ha^{-1} of vermicompost along with 50% RDF, which was 125.7% and 108% and as effective as 100% RDF. Similarly, the application of 5 t ha^{-1} of vermicompost along with 50% RDF recorded significantly higher P and K uptake by wheat grain and straw as compared to the other treatments. Significant build-up in soil organic C, mineralizable N (NH_4-N and NO_3-N), available P and K were observed due to the addition of value added composts and 50% RDF over other treatments. The results indicated that value added products, namely, vermicompost, NADEP compost and FYM besides sustaining the crop productivity and soil fertility could substitute 50% of the inorganic fertilizers.

3.4.6 Development of Basic Data and Soil Test Based Fertilizer Recommendations for Pigeonpea and Wheat

Under the All India Coordinated Research Project on Soil Test Crop Response Correlation, field experiments were conducted on pigeonpea (Manak) and wheat (PBW 373) crops on the Inceptisols of IARI farm. By the use of basic data generated on the nutrient requirement and per cent utilization efficiency of nutrients from soil, fertilizers and manure by these crops, the soil test based fertilizer recommendations for targeted levels of yield production were developed.

These fertilizer adjustment equations developed for wheat and pigeonpea were utilized for adjusting the fertilizer doses of NPK according to soil fertility status of NPK for

Basic data and soil test based fertilizer adjustment equations for pigeonpea and wheat

Parameter	Wheat (PBW 373)			Pigeonpea (Manak)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
NR	2.48	0.96	3.00	5.31	1.47	3.22
%CS	22.45	28.34	20.64	39.22	27.65	16.10
CF	58.14	28.23	116.31	96.89	21.99	41.76
%CFYM	16.50	4.90	27.70	24.58	8.21	9.59

Soil test based fertilizer adjustment equations for wheat and pigeonpea

Wheat (PBW 373)	Pigeonpea (Manak)
Without FYM	
FN = 42.7 T – 0.39 SN	FN = 54.8 T – 0.40 SN
FP_2O_5 = 34.0 T – 2.29	SP FP_2O_5 = 66.8 T – 2.88 SP
F K_2O = 25.8 T – 0.22	SK FK_2O = 77.0 T – 0.40 SK
With FYM	
FN = 42.7 T – 0.39 SN – 2.80 FYM	FN = 54.8 T – 0.40 SN – 2.50 FYM
FP_2O_5 = 34.0 T – 2.29 SP – 3.90 FYM	FP_2O_5 = 66.8 T – 2.88 SP – 3.70 FYM
F K_2O = 25.8 T – 0.22 SK – 2.90 FYM	F K_2O = 77.0 T – 0.40 SK – 2.30 FYM

Note: NR is nutrient requirement in kg t^{-1} of grain production, %CS, %CF and %CFYM is per cent contribution of nutrients from soil, fertilizer and FYM, respectively. S and F represent soil and fertilizer nutrients (kg ha^{-1}), and FYM represents farmyard manure (t ha^{-1}) and T denotes yield target (t ha^{-1})

specific levels of grain yield production. For each one tonne of the applied farmyard manure, the rates of N, P_2O_5 and K_2O application to wheat and pigeonpea could be reduced by 2.8 kg and 2.5 kg, 3.9 kg and 3.7 kg, and 2.9 kg and 2.3 kg ha^{-1}, respectively.

3.5 NUTRIENT MANAGEMENT

3.5.1 Appraisal of Multi-nutrient Deficiencies in Soils and their Redress through Site-specific Nutrient Management

In the ongoing IARI-IPNI India Programme collaborative research project, Lohtaki village (District Gurgaon) representing north Punjab plain and Ganga-Yamuna Doab agro-ecological sub-region (AESR 4.1) was intensively sampled for soil fertility appraisal. Soils were grouped into fertilizer-responsive (low+medium fertility) and non-responsive (high fertility) categories with respect to different nutrients, and the extent of simultaneous inadequacy of two or more nutrients referred to as multi-nutrient deficiency was also assessed. Besides, site-specific nutrient management (SSNM) prescriptions for pearl millet-wheat and pearl millet-mustard cropping systems were formulated and evaluated *vis-à-vis* other nutrient management practices in on-farm experiments. Salient findings emanating from the study are reported hereunder:

3.5.1.1 Soil fertility appraisal

Soil samples were neutral to mildly alkaline in reaction (soil pH 7.25 to 8.74, mean 7.66). None of the samples exhibited salinity. Widespread deficiencies of N (assessed in terms of organic C), K, S and B were recorded in these loamy sand to sandy soils. Whereas nearly all the samples contained organic C in the fertilizer-responsive range, 52%, 83%, and 34% samples were placed in K, S and B responsive categories, respectively. Deficiency of P was of relatively lesser magnitude, and the soils had adequate exchangeable Ca and Mg contents. Of the DTPA extractable micronutrients, Zn and Cu deficiencies were noted in 38% and 20% samples, respectively. The soils were so depleted of plant nutrients that simultaneous deficiencies of 2 to 5 nutrients were frequently observed. More than twenty multi-nutrient deficiency combinations were noticed, of which NKS (16%), NS (12%), NSB (11%) and NKSZnB (7%) were the prominent ones.

3.5.1.2 On-farm SSNM experiments– A case study at village Lohtaki

Lohtaki village was chosen as on-farm experimentation site in view of the large variability in multi-nutrient deficiencies, inappropriate fertilizer use by the farmers and very poor annual productivity. Detailed interactions with the farmers revealed that pearl millet-mustard and pearl millet-wheat were the predominant cropping systems of the area. Farmers grew high yielding cultivars of these crops with very low and unbalanced fertilizer input. For instance, hybrid pearl millet with an achievable yield potential of 4 t/ha or above was usually grown with 60 kg N ha^{-1} only. Winter crops received NP fertilizers, but the use of K, S and micronutrients was largely ignored. As a result, the crop productivity of not only Lohtaki, but also that of neighbouring villages, namely, Siriska, Khaika, Daula, Abhaypur, and Lakhuvas was extremely low. The average productivity of pearl millet, mustard and wheat in these villages, as assessed on the basis of the farmers' response during the survey, was 1.5-2.0 t ha^{-1}, 1.0-1.6 t ha^{-1} and 3.0 t ha^{-1}, respectively. In order to evaluate SSNM options and increase farmers' awareness on soil test-based balanced fertilization, 14 on-farm experiments (8 with pearl millet-wheat and 6 with pearl millet-mustard cropping system) were conducted.

For each experiment, half-acre (2000 m^2) farm area was divided into seven strips to impose seven fertilizer treatments, i.e., T_1: SSNM; T_2: Fertilizer NPK recommended for a pre-set yield target as per AICRP-STCR's yield adjustment equations (TY); T_3: TY+secondary and micronutrients (TY+Micro); T_4: State *ad-hoc* recommendation (SR); T_5: SR+K; T_6: Farmer's fertilizer practice (FFP)+K; and T_7: FFP. Fertilizer rates in SSNM and TY varied for different experiments in accordance with the soil test values. All the experiments were managed by the farmers themselves under the technical guidance of the researchers.

Yield response to fertilizer options in pearl millet-wheat system. Pearl millet grain yield, averaged across 8 on-farm experiments, varied from 2.21 t ha^{-1} under farmers' fertilizer practice (FFP) to as high as 4.12 t ha^{-1} under SSNM**.** The SSNM treatment, wherein nutrients were applied not only to meet the crop demands but also to avoid any mining from soil reserve, out-yielded the targeted yield (TY) treatment that received NPK as per AICRP-STCR's yield adjustment

equations. Inclusion of 45 kg K_2O ha^{-1} alone in FFP produced an additional grain yield of 0.39 t ha^{-1}; the benefit of K fertilization was, however, greater (0.58 t ha^{-1}) when SR was supplemented with fertilizer K. Surprisingly, the SR for a K-exhaustive crop like pearl millet was devoid of K, causing not only a substantial yield loss year after year but also an excessive mining of already depleted native K reserves. In subsequent wheat also, SSNM out-yielded FFP and SR by, on average, 2.21 t and 1.58 t ha^{-1}, respectively, establishing again the inadequacy of SR in exploiting the high yield potential of modern cultivars under otherwise congenial environments. Results suggested that (i) on the coarse-textured and K-exhausted soils, as those under the present study, a lower fertilizer K rate would not suffice, and (ii) high productivity systems have to be necessarily supplemented with relatively higher K rates. The carryover effect of S and micronutrients accounted for 0.39 t ha^{-1} wheat grain yield, which was greater compared with the direct effect (0.28 t ha^{-1}) recorded in pearl millet. Annual productivity of pearl millet-wheat system computed as PMEY revealed a yield increase (over FFP) ranging from 1.05 t ha^{-1} in FFP +K to 5.69 t ha^{-1} in SSNM, which corresponded to a response range of 13.1% to 71.1% over FFP.

Yield response to fertilizer options in pearl millet-mustard system. The treatment effects in pearl millet were similar to those noticed in pearl millet-wheat system, although the grain yield ranged between 2.36t and 4.05 t ha^{-1}, with the lowest in FFP and the highest in SSNM**.** Mustard grain yield under SSNM (that included on average 120 kg N + 60 kg P_2O_5 + 100 kg K_2O + 40 kg S ha^{-1} along with carryover effect of S, Zn and B applied to preceding crop) ranged between 2.76 t and 3.11 t ha^{-1} in different experiments with a mean of 2.88 t ha^{-1}, which was 83% to 92% (mean 85%) greater than that recorded in FFP**.** Although mustard is not known to be as responsive to fertilizer K as wheat, yet the inclusion of K in FFP or SR increased its yield by an average of 0.15 t to 0.25 t ha^{-1} in the present studies, possibly due to extremely low K content of soils. In PMEY also, the yield differences between SR+K and SR were greater compared with those between FFP+K and FFP, indicating that a crop well-fertilized with NP (and preferably other deficient nutrients) would respond better to fertilizer K compared with a crop receiving N alone or N and P at a lower rate as in the case of FFP.

Effect of fertilizer options on the grain yield (t ha^{-1}) of cropping systems

Treatment	Pearl millet-wheat system (8 experiments averaged)			Pearl millet-mustard system (6 experiments averaged)		
	Pearl millet	Wheat	System (PMEY*)	Pearl millet	Mustard	System (PMEY*)
SSNM	4.12	5.61	13.69	4.05	2.88	12.83
TY	3.65	4.88	11.97	3.50	2.45	10.96
TY+micro	3.93	5.27	12.91	3.83	2.76	12.23
SR	3.10	4.03	9.97	3.08	1.93	8.96
SR+K	3.68	4.83	11.92	3.52	2.18	10.17
FFP+K	2.60	3.78	9.05	2.73	1.71	7.94
FFP	2.21	3.40	8.00	2.36	1.56	7.12

*Pearl millet equivalent yield

Economics of SSNM vis-à-vis other fertilizer options. In pearl millet-wheat system, the annual net returns were higher (Rs. 35856 ha^{-1}) under SSNM, followed by TY+Micro (Rs. 31556 ha^{-1}) and TY (Rs. 26558 ha^{-1}). Supplementing K to the state recommendations (SR) almost doubled the net-returns over the SR (Rs. 12586 ha^{-1}). In pearl millet-mustard system also, the profits increased substantially consequent to the adoption of improved fertilizer practices. Net returns under different fertilizer options followed a trend similar to that of pearl millet-wheat system with the highest values (Rs. 32346 ha^{-1}) under SSNM. The inclusion of K in state recommendation (SR) brought, on an average, an additional net return of Rs. 7500 ha^{-1}.

Results of these experiments thus, clearly established the significance of SSNM and other improved fertilizer practices such as AICRP-STCR recommendations supplemented with secondary and micronutrients in augmenting crops yield and economic returns without any further depletion of soil nutrient reserves.

3.5.2 Soil Organic Carbon and Available Nutrient Content in Rice-Wheat System under Conservation Tillage

Soil organic carbon content was measured in the experiment conducted in 2008 *kharif* season with rice variety

Pusa Sugandh 3 under transplanted unpuddled raised bed condition and puddled flat bed continuously flooded condition. In the surface 0-15 cm layer, about 11.7-16.9% higher carbon content was observed under un-puddled raised bed condition compared to that under puddled flat bed treatment. The results are consistent with the previous season/crops (12-16%). The labile carbon fractions, soil aggregates and polysaccharide contents also followed the same trend. Further monitoring of available phosphorus, potassium, micronutrients (Zn, Fe, Mn and Cu), calcium and magnesium contents after each crop season clearly showed the beneficial effect of conservation tillage practices.

3.6 ORCHARD MANAGEMENT

3.6.1 Epidemiological Studies on Mango Malformation

The Prediction model in relation to mango malformation and *Fusarium mangiferae* using multiple linear regression analysis, critical criteria analysis, logistic regression analysis and GIS tools showed that temperatures ranging between 25 ºC and 28 ºC, and relative humidity more than 60% are congenial for the optimum growth of *Fusarium mangiferae* and malformation with 98% accuracy. Confirmation studies made under phytotron and *in-vitro* conditions proved the above conclusions.

3.6.2 Response of AMF on Kinnow

In citrus, *jatti khatti* and *Troyer citrange* rootstock seedlings and kinnow budded on these seedling rootstocks were screened for AMF. On the basis of root colonization and improved growth, physiological, biochemical and nutritional constituents, the AMF strain *Glomus intraradices* followed by mixed AMF strains were screened for the *Troyer citrange* seedlings as well as kinnow budded on *Troyer citrange*. The AMF strain *G. fasciculatum* was found superior for improving plant performance of *jatti khatti* seedlings and kinnow budded on *jatti khatti* rootstock. Further, *jatti khatti* seedlings and kinnow budded on *jatti khatti* seedlings were inoculated with above two strains of AMF along with non-inoculated control and were subjected to water stress treatments. Among two strains, *G. fasciculatum* inoculated plants showed maximum root colonization in both plant types, viz., *jatti khatti* seedlings and kinnow/ *jatti khatti* under both WW (49.38%, 53.17%) and WS (49.10% and 51.87%) conditions. The AMF colonization in these plants changed the plant growth, physiological and biochemical characters and osmotic adjustment of both the plant types. Antioxidant enzymes such as superoxide dismutase (15.43 and 16.23 µ mg^{-1} protein), ascorbate peroxidase (13.46 and 13.51 µ mg^{-1} protein), and catalases (10.75 and 10.18 µ mg^{-1} protein) were produced more in AMF inoculated plant under water stress conditions. The AMF treatments had a positive effect on water stress mitigation of kinnow plants budded on *jatti khatti* seedlings.

3.6.3 Micronutrient Management in Kinnow

To improve the fruit quality of kinnow, foliar spray of micronutrients, i.e., iron, copper, boron and zinc, each at 0.4% alone and in combined doses, were tested. The plants were also supplied recommended dose of N,P, K and *Azotobacter* (10 g/plant) + PSB (10 g/plant). Growth, yield (98 fruits/plant) and physico-chemical quality of kinnow were found better in treatment comprising combined spray of micronutrients (Fe, Cu, B and Zn at 0.4% each) as compared to control and other treatments.

3.6.4 Effect of Paclobutrazol on NaCl Stress in Mango

Effects of paclobutrazol (PBZ) was investigated on one year-old plants of mango 'Olour' subjected to NaCl stress under polythene tunnel conditions. Plants were treated with two levels of salt, i.e., 0.0 g NaCl (control) and 25 g NaCl 25 kg^{-1} soil (equivalent to 1 g NaCl kg^{-1} soil) and three levels of PBZ solution, i.e., 0.0 mg l^{-1} (control), 750 mg l^{-1} and 1,500 mg l^{-1}. Mortality in saline-treated mango plants was significantly reduced following the application of PBZ. NaCl stress reduced the survival of plants without PBZ treatment by 89%, but only by 28.4% in 1,500 g l^{-1} PBZ-treated plants. PBZ-treated plants also showed less defoliation, and fewer leaves/plant showed salt stress symptoms. It was also evident that the treatment with PBZ increased the relative water and chlorophyll contents of mango seedlings and reduced membrane injury under salt stress. Furthermore, saline treatment without PBZ increased the contents of Na^+ and Cl^- ions in leaves and roots. However, application of PBZ consistently lowered these ion contents significantly. The

Na^+ content of leaves of saline plants was reduced by 17-37%; whereas, Cl^- contents were reduced by 22% - 39% by PBZ treatment compared to salt-treated seedlings without PBZ. These results suggest the role of PBZ in promoting the avoidance of salt stress in mango by increasing the levels of photosynthetic pigments, water content and K^+ uptake and accumulation, and by reducing defoliation, the membrane injury index and the uptake and accumulation of harmful Na^+ and Cl^- ions.

3.6.5 Effect of Paclobutrazol and Putrescine on Citrus Rootstock under Salt Stress

The application of PBZ in combination with putrescine improves the salt tolerance in both rootstocks at varying degrees. Plant height, number of leaves and dry mass of plants were increased with the application of paclobutrazol (PBZ) in combination with putrescine under NaCl stress. However, growth was reduced in both rootstocks with the application of PBZ alone under normal soil condition. Stomatal conductance and relative water content (RWC) were reduced under NaCl stress in both rootstocks. However, the application of PBZ in combination with putrescine increased both stomatal conductance and RWC in both rootstocks. Significant effect of PBZ and putrescine was also found in membrane injury index (MII). The minimum MII was recorded with the application of 500 ppm PBZ and 50 ppm putrescine in salt tolerant rootstock, while in salt susceptible rootstock, the lowest MII was recorded with the application of lower dose of PBZ (250 ppm) under salt stress.

3.6.6 Effect of Biofertilizers on Growth, Yield and Quality of Papaya

To standardize the biofertilizers and to know their effect on growth, yield and quality of papaya, an experiment was conducted with 100%, 75% and 50% recommended dose of fertilizers along with biofertilizers, viz., VAM, PSB, *Azospirillum* and *Azotobactor*. Application of 100% recommended dose of fertilizers alongwith VAM (50g/plant) + PSB (25g/plant) + *Azospirillum* (50g/plant) + *Azotobactor* (50g/plant) significantly influenced the growth attributes and yield of papaya.

3.6.7 Effect of Micronutrients on Growth, Yield and Quality of Papaya

To know the effect of micronutrients on growth, yield and quality of papaya, an experiment was conducted with zinc sulphate (0.5%) and borax (0.1%) in one spray at four months after transplanting and two sprays at four and eight months after transplanting separately and in combination. Zinc sulphate 10 g and borax 5 g in combination were used as soil application. Foliar application of zinc sulphate (0.5%) and borax (0.1%) during the 4th and 8th months significantly influenced growth, yield and yield attributes of papaya.

3.7 PROTECTED CULTIVATION TECHNOLOGY

3.7.1 Evaluation of Semi-climate Controlled Greenhouse for Parthenocarpic Cucumber Cultivation during Peak Summer Period

Semi-climate controlled greenhouse equipped with cooling pad and fan system is technically suitable for growing parthenocarpic cucumber crop during peak summer period (i.e., from May to July). Twenty-two days old seedlings of cucumber (var. Kian) were transplanted on 28th of April 2008

Parthenocarpic cucumber grown inside naturally ventilated greenhouse

Techno-economic evaluation of semi-climate controlled greenhouse for parthenocarpic cucumber cultivation during peak summer period

Crop	Date of transplant	Date of first harvesting	Date of last harvest	Total fruit yield (t/1000 m²)	Average fruit yield (t/ha)	Cost benefit ratio
Cucumber (var. Kian)	28-4-2008	25-5-08	16-7-08	1.62	16.20	1:1.60

at a spacing of 40 cm x 30 cm. First harvesting was done on 25th of May and continued up to 16th July 2008. The total fruit yield was 1.62 t/1000 m^2.

3.7.2 Techno-economic Suitability of Low Cost Insect Proof Net House for Virus Free and Off-season Nursery Raising in Vegetables

An insect proof net house fabricated by using 40 mesh insect proof nylon net and ½ inch GI pipes with double doors with a provision of a hanging yellow sticky card inside the net house is technically suitable for virus free nursery raising of vegetables, viz, tomato, chilli and sweet pepper, during rainy and post rainy seasons. The same net house after covering with a transparent plastic of 100-150 micron thickness during peak winter season is suitable for off-season nursery raising of different vegetables during December and January months. Additionally, the same insect proof net house is suitable for nursery raising of early season cauliflower or cabbage during peak summer months (May- August) if covered with 40-50% black colored shade net. The total cost of fabrication of such 50 m^2 net house is only Rs. 5500, and it can be fabricated by rural artisans at village level.

Insect proof net house for virus free and off-season nursery raising

3.7.3 Evaluation of Seed Spices (Cumin and Coriander) under Different Protected Conditions

Two seed spice crops, viz., cumin and coriander, were grown under plastic covered walk-in tunnels, insect proof net covered walk-in tunnels and plastic low tunnels. First, both the crops were sown by seeds on raised beds under drip irrigation system on 15th October. In the first week of December, all the tunnels were erected over the crops except the crops under controlled plots. Both the seed spice crops had very good growth and flowering under plastic covered tunnels, net covered tunnels and open field, whereas under plastic low tunnel, the cumin crop was severely damaged due to increase in temperature during February month. Therefore, technically, plastic low tunnels are not suitable for cumin cultivation.

3.7.4 Techno-Economic Evaluation of Lemon Grown with Drip Fertigation Technology

Drip fertigation scheduling and production economics of lemon cv. Kagzi Kalan (root stock: *Jatti Khatti*) were standardized for Delhi conditions. The total irrigation amount and the number of irrigations were standardized as 575 liters and 53, respectively, for a fully mature 8 - year old lemon tree

Techno-economic analysis of low cost insect proof net house for virus free and off- season nursery raising in vegetables

Kind of structure	Size	Fabrication cost (Rs.)	Objective/suitability of the structure	Most appropriate season of use	Regional suitability
Insect proof net house	Minimum 50 m^2 area; can be increased as per requirement	5500/-	Virus free nursery raising of vegetables, viz., tomato, chilli, sweet pepper for 2.0 acres area	Rainy and post rainy seasons	All over India
Insect proof net house covered with transparent plastic of 100-150 micron thickness	Minimum 50m^2 area; and can be increased as per requirement	7500/-	Off-season nursery raising of vegetables viz., tomato, chilli, sweet pepper, cucurbits, etc., for 2.0 acre area	Peak winter month (December and January)	Plains and hills of northern India
Insect proof net house covered with 40-50% black shade net	Minimum 50 m^2 and can be increased as per requirement	7500/-	Nursery raising of early cauliflower and cabbage during peak summer months for 2.5-3.0 acre area	May, June, July, August	All over India in plains

Month-wise fertigation scheduling and production data (per tree) for lemon grown with drip fertigation technology

Month	Irrigation scheduling		Fertigation dosage (g)			Av. fruit production (kg/tree)	Av. wt. of fruit (g)
	Irrigation water (liter)	No. of irrigation	N	P_2O_5	K_2O		
Jan.	40	3	-	-	-	-	-
Feb.	45	4	125	75	150	-	-
Mar.	50	5	125	75	150	-	-
April	60	7	-	-	-	-	-
May	75	8	-	-	-	8	75
June	80	8	-	-	-	10	80
July	75	5	-	-	-	7	80
Aug.	-	-	-	-	-	-	-
Sept.	-	-	125	75	150	-	-
Oct.	55	6	125	75	150	9	90
Nov.	50	4	-	-	-	15	100
Dec.	45	3	-	-	-	11	100
Total	575	53	500	300	600	10	87.5

in drip fertigated orchard. The total fertilizer dosages applied and standardized were 500 g nitrogen, 300 g phosphorus and 600 g potassium per tree per year. The total average fruit yield per tree was found to be 60 kg (summer yield: 25 kg and winter yield: 35 kg). The average fruit weight was 80 g and 100 g, respectively, for summer and winter crops. The total income and net income generated from 1 acre drip fertigated lemon orchard was 1.44 lakhs and 1.03 lakhs, respectively.

3.7.5 Standardization of Crop Water Productivity and Fertigation Scheduling of Cucumber Grown in Naturally Ventilated Greenhouse

The total water use, yield and crop water productivity were calculated for cucumber grown in different growing periods inside a naturally ventilated greenhouse. The total water use was found to be minimum (750 m^3) for winter crop grown during Nov.-Feb. and maximum (1470 m^3) for summer crop grown during March-May. The total yield was found to be maximum (40 tonnes/ha) for winter crop, and minimum (30 tonnes/ha) for summer and rainy season crops. The crop water productivity was the highest (53.3 kg/m^3) for winter crop, and the lowest (20.4 kg/m^3) for summer crop.

Crop water productivity for cucumber grown in different growing periods inside a naturally ventilated greenhouse

Growing period	Total water use (m^3/ha)	Total yield (kg/ha)	Crop water productivity (kg/m^3)
Aug.-Oct.	1000	30,000	30
Nov.-Feb.	750	40,000	53.3
Mar.-May	1470	30,000	20.4

3.7.6 Studies on Mother Stock Stage for Raising Plugs in Chrysanthemum

An experiment carried out to study the response of mother stocks raised under long days by self rooted terminal cuttings (at 30,35,40 and 45 days maturity) showed that 40-day old mother stocks are best suited to produce long day plants for new crop and most suitable for raising soilless plugs for new crop in chrysanthemum under long day conditions.

3.7.7 Study on Bending Frequency in Rose Grown with Drip Fertigation

An experiment was conducted on newly planted rose crop in greenhouse to study the response on plants due to bending of new shoots in three cycles of 21 days each with 2,3 and 4 shoots at one time in the varieties, Grand Gala and Golden Streak. It was observed that the final number of new shoots produced per bush were the highest in Grand Gala (12.5) followed by Golden Streak (9.8)in the plants bended with two shoots every bending cycle, which could sprout faster in Grand Gala (16.2 days) compared to those in Golden Streak (19.6 days) after bending.

3.7.8 Photoperiodic Regulation of Flowering in Chrysanthemum Grown with Drip Fertigation

Day length extension experiment. A cyclic lighting (30 minutes with 10 minutes on and 20 minutes off) for 6,9,12 and 15 days @ 100 µmole m^{-2} s^{-1}, illuminating 13 hours a day (long day) with high pressure sodium lamp was compared with short day (no additional lighting) and it was found that the

plants treated with day length extension for 9 days were the best to produce quality flowers followed by 12 days' extended light in chrysanthemum varieties, Zembla (standard) and LeMans (spray).

Effect of spectra (LEDs) lighting. LED lighting experiment was conducted with short day (80% red + 20% blue), long day (80% red + 20% blue) and long day with additional 80% red + 20% blue (4 h) for 11 h and 15 h, respectively. Long day (with 80% red + 20% blue lighting) was able to induce flowering under enriched spectra using PAR (photosynthetically active radiation). However, the plants under continuous long days (15 h of 80 % red + 20% blue) delayed the induction of flowering by 12 days as compared to the plants under short day treatments.

3.8 AGRICULTURAL ENGINEERING

3.8.1 Tractor Drawn Onion Digger

An onion digger operated by a 45 horse power (hp) tractor, was designed and developed. The digger has a digging unit with inverted V shaped blade (1000 mm x 264 m x10 mm) and a separating unit consisting of an elevator (1200 mm x 988 mm) and a windrower. The overall dimension of the machine is 1975 mm x 1500 mm x 1000 mm.

A tractor drawn onion digger

The digging blade was selected out of six different shapes with minimum draft of 625 N for inverted V type. A prototype scale experimental set up of the tractor drawn onion digger was fabricated with the provision of changing the length from 1.0 m to 1.5m, slope from 15° to 25° and speed ratio from 1.0 to 1.5 of the elevator for performance evaluation on digging efficiency, separation index and damage percentage. The maximum digging efficiency was 94% at 15o slope and 1.25 of speed ratio of the elevator. The highest separating index was 79% at 1.5 m length, 20o slope and 1.5-speed ratio of the elevator. The minimum damage of bulbs was 2.94% for 1.0 m length of the elevator. Based on the performances, the final design values of the onion digger were inverted V shape blade, elevator length of 1.2 m, slope of elevator 15o and speed ratio of 1.25. The field capacity of the machine was 0.32 ha/h at a forward speed of 3.0 kmh-1. The average fuel consumption was 4.10 l/h. The draft of the machine was 1078 kgf with an energy consumption of 12.08 kWh/ha. The estimated cost of the onion digger is Rs.12,500 with an operation cost of Rs 992/ha. The saving was 45.87% over manual digging. The break even point for operation was 122 hours with a payback period 3.9 years.

3.8.2 Pressurized Aqua-fertilizer Metering Seeder

A gravity feed aqua-ferti seed drill developed earlier was extensively evaluated on research farms and farmers' fields. During the year 2008, two prototypes were fabricated and demonstrated in 10 ha of dryland area in Churu and Jhunjhunu districts of Rajasthan for sowing of wheat crop. The feedbacks indicated the necessity of suitable arrangement to regulate supply of aqueous fertilizer by the machine in a wider range. A pressurized metering system was accordingly designed and developed for precision seeding by controlled application of aqua-fertilizer as per soil moisture availability. The pressurized aqua ferti metering system consisted of a positive displacement gear pump with a provision of varying pump rotational speed and relative pressure between pump and pressure, and a volume control valve to control the required rate of aqueous fertilizer. The pressurized pumping system operates at pump rotational speed of 864, 1080, 1152 or 1440 rpm, line pressure of 0, 2 or 4 kg/cm^2 and nozzle size of 10 mm. The fertilizer metering mechanism was mounted on the existing seeder after suitable modifications. The developed machine is capable of delivering a variable rate of aqueous fertilizer with uniformity.

3. 8.3 Modified Onion Detopper

An onion detopper developed earlier was modified for simplicity of design. The power transmission system was redesigned for operation of the machine by a single electric motor in lieu of two motors provided earlier. For better material flow, the slope of the oscillating conveyor was optimized to 1 degree with a provision of adjustment up to 2 degree by screw jack method. The cutting blade speed was also optimized to 10m/s for clean cut of the leaves from the bulb. The oscillating speed of the conveyor unit was adjusted to 6 strokes per second. Transport wheels have been provided for the unit for ease of movement.

A modified onion detopper

3.8.4 Performance Evaluation of Ridger Planter for Cowpea Planting

A tractor operated ridger planter developed by the Institute was tested for planting cowpea seed on ridges. The crop was sown with a row spacing of 45 cm and a seed spacing of 30 cm. The depth of planting was in the range of 3-5 cm and the ridge height was 15 cm in a single pass. The average plant spacing was observed to be 27.6 cm with 8 plants per sq. m. The feed index, multiple index and miss index were 79%, 16% and 5%, respectively. The degree of variation was observed to be 22.61. The field capacity of the planter was 0.22 ha/h with a field efficiency of 68.5 per cent. The machine can thus operate for different crops.

3.8.5 Densification of Biomass in Briquetting Plant for Fuel

Agricultural residues form a major component of renewable energy sources, and can be conveniently used as an efficient energy source after briquetting. Mustard stalk, mixed waste and wood waste with three organic binding materials (molasses, pressmud and distiller's dry grain) with varying concentrations of 5%, 10%, 15% and 20% were used for the preparation of briquettes with different die diameters of 41.5 mm (123.42 MPa), 42.5 mm (117.68 MPa) and 43.5 mm (112.34 MPa). The influences of die pressure, biomass materials, binder and their concentrations as well as storage time on physical and burning characteristics and transportability of briquettes were investigated. The moisture content, size, shape, and distribution of particle sizes in the biomass materials in the sample affected the density, heating value and stability of biomass briquettes. Pressmud was found to be the best binding agent followed by distiller's dry grain, and molasses. Among biomass materials, mustard stalk briquettes performed best, followed by mixed waste and wood waste briquettes, in terms of their physical and transportation properties. The briquettes prepared from the wood waste blended with pressmud (20% concentration) at a die pressure of 123.42 MPa had the highest calorific value and energy gain. The physical properties (bulk density, compression ratio, compressive strength, shattering resistance and tumbling resistance) of briquettes prepared from the three raw materials using either pressmud or distiller's dry grain as

Briquettes made of mustard stalk, mixed waste and wood waste with pressmud

binder increased with the increase in the concentration as well as increase in the pressure with all three dies. However, in the case of the briquettes prepared with molasses as binders, a reverse trend was obtained. The profit obtained from the briquettes made of mixed waste/mustard stalk blended with 20% concentration of pressmud and at 123.42 MPa die pressure was 117% and 115% more than the briquettes made from the wood waste blended with 20% concentration of pressmud.

3.8.6 Powered Vegetable Seed Extractor

A 2-hp motor driven vegetable seed extractor was designed and fabricated. The seed extraction mechanism includes a GI expanded metal wiremesh concave and a GI cylinder (910 mm in length) having blades on its periphery for cutting and conveying vegetable. The clearance at feeding end is 139 mm and that at the other end is 79 mm. A positive drive mechanism (chain and sprocket system) was incorporated for power transmission from the motor to the drum at a reduced speed of 180 rpm. Vegetables are fed through hopper and are cut and crushed to separate seeds from the pulp. The seeds are collected in the tray at the side of the machine while the pulp is simultaneously conveyed to the tray at the other end of the machine. The machine was tested for seed extraction from brinjal (round), bottlegourd and ash gourd. The throughput capacity ranged between 200 kg/h (ash gourd) and 500 kg/h (round brinjal).

A vegetable seed extractor

3.8.7 Production Die Sets for Okra Planter Ridger Bottom

The quality of agricultural machinery manufactured by small scale industries mostly depends on the skill of artisans. The wings of ridger bottom of okra planter produced similarly by black smiths did not have the required accuracy and repeatability resulting in the formation of non-uniform ridges in the field. A set of die was, therefore, developed for the fabrication of the wings with specified shape and curvature. The die sets for left and right wings were made of cast steel. POP templates were prepared and used for casting of the upper and lower parts of the die sets. The lower part of each die set is fixed to the bench of a hydraulic press and the upper part anchored to the piston. The M.S plate sample, developed through profile cutting, is hydraulically pressed to obtain the desired curvature of the wings. The time taken for the whole operation is approximately 5 minutes.

3.8.8 Drying Studies in Modified Solar Cabinet and Greenhouse Type Dryer

A solar cabinet dryer (0.725 m^3) with two perforated trays (0.93 m^2 and 1.15 m^2) for material to be dried was tested for drying of garlic. Open sun drying of the material was done as control. The garlic was blanched with 10% potassium meta-bisulphite (KMS) and heated for 10 minutes. The average temperature of open sun was 29.5^{0}C while for solar cabinet dryer it was 43.03^{0}C. A maximum increase in temperature of about 18^{0}C was observed in solar cabinet dryer over that of the ambient temperature. The moisture content of garlic in the solar cabinet dryer (SCD) was reduced from 63.90 % to 6.04 % in 28 h while in open sun drying (OSD), it took about 38 h to reduce the moisture to the same level. The drying rate was also higher at different moisture contents in SCD compared to that in OSD. The quality of dried product in solar cabinet dryer was better than that of the product dried in the open sun.

In another study, drying was conducted for green coriander leaves in a natural convection greenhouse dryer (6 m x 4 m x 2.4 m with 36 m^3 volume), solar cabinet dryer and open sun. The sample was blanched with 10% sodium meta-bisulphate and heated for 10 minutes. The average temperature of open sun was 30^{0}C while that of solar cabinet

dryer and greenhouse type dryer was 40^{0}C and 35^{0}C, respectively. The moisture content of coriander in greenhouse type dryer (GTD) could be reduced from 90.66% to 8.03% in 18 hours while it took 14 hours in solar cabinet dryer (SCD) and 22 hours in open sun drying for the same moisture reduction. The drying rate was higher at different times and moisture contents in SCD compared to that in GTD and OSD. The quality of produce dried in solar cabinet dryer and greenhouse type dryer was better than that of the produce dried in open sun.

3.8.9 Ergonomic Evaluation of Foot Operated Rotary Power Generation

Ergonomic evaluation of foot operated rotational power generation by agricultural workers in different modes (pedal, stepper and bicycle) at five mechanical output conditions was carried out. During the experiments, physiological and postural parameters were evaluated. The bicycle mode of operation was found to be the best up to 55.9W of mechanical power output while the stepper mode was better for higher loads up to 74.6W of mechanical power output. The overall discomfort score was the lowest in bicycle mode up to 18.6W of mechanical output, and in stepper mode between 37.3W and 74.6W mechanical output. The human efficiency was the highest in bicycle mode up to 55.9W of mechanical output conditions but at 74.6W mechanical output condition, the highest human efficiency was obtained in stepper mode.

3.8.10 Ergonomic Evaluation of Chaff Cutter

Chaff cutter is one of the most common farm equipment owned by farming families. A survey undertaken in five villages of Ghaziabad district (block Razapur) indicated 36 cases of chaff cutter injuries (29 male and 7 female), of which 40% were in children below the age of 15 years. The survey establishes that injuries caused by chaff cutter are prevalent in all age groups and gender.

The causal factors responsible for the injuries are: children playing with the machine, diverted attention while feeding, loose clothes, unstable platforms, no formal training, sickness/tiredness of the person, and fluctuation in the speed of prime mover. Ergonomic assessment of chaff cutter operation was done on the basis of oxygen consumption. It was found that the oxygen consumption varied from 27% to 70% of VO_2max for cutting fodder where as the limit for sustainable activity was 35%. Over fatigue also results in injuries or near injury situation. The energy requirement varies with the blade length coming in contact with the fodder. Experimentally, it was observed that the length of cutting front of the blade increased almost linearly from 0 mm at 0^o to 79 mm at 35^o angle of rotation of the flywheel and followed a typical pattern. The cutting of fodder thus occurs for 200^o of rotation of the flywheel, and for the rest of the time the flywheel rotates idle gaining momentum. The area of cutting was also calculated by using pictorial simulation of cutting front and trough area at different angles.

Force exerted at different angles of rotation of the flywheel initially decreased from 13.5 kg to 8.1 kg for angle of rotation between 10^o and 90^o. The force executed from 280^o to 360^o was higher because the posture was above handle height and a person took advantage of his body weight to exert force.

3.8.11 Grain Polisher

A grain polisher developed earlier was modified for polishing grains by removing sticky dust from the grain surface. The polisher consists of wooden roller covered with 3 mm thick leather, a perforated concave partially covered with rubber, a feed hopper and frame. The roller and concave is assembled on slope for free movement of grains between the roller and concave. The feed hopper with feed control mechanism is assembled at the upper end of the roller. At lower end of the roller, a pressure-control outlet adjusts the pressure on the grains inside the machine. The polished grains exit from the outlet and dust passes through the perforation of the concave. The machine is operated with a 3-hp electric motor. The machine was tested with black gram at different speeds and feed rates. The maximum output of 52 kg/h was obtained at a peripheral speed of 8-9 m/s with acceptable appearance and minimum loss of 0.5 per cent.

3.8.12 Mechanization Studies in Sugarcane Growing Areas of Western Uttar Pradesh

A study was conducted in selected areas of western U. P. on the use pattern of farm tractors operated (i) on owned farms, and (ii) mainly on custom hiring. The average annual

use of tractor on owned farm and on custom hiring were 253 h and 990 h, respectively. The tractor use was mainly in land preparation, transport of produce and wheat threshing. Tractors mainly used on custom hiring were engaged in agricultural operations for 85% of time and in non-agricultural operations for the rest. It is necessary to develop farmers' entrepreneurial and adaptive management capacity to use farm machines on custom hiring, including opportunities to use agricultural machinery in off- farm and non-agricultural activities such as in transportation and in rural infrastructure maintenance to create business as well as to increase annual use of machines for economic benefits.

Mechanization should also be strategically viewed with a long-term perspective as part of a broad-based economic development strategy aimed at economic growth and agro-industrialization.

3.8.13 Farm Operation Services

3.8.13.1 Field operations

The Farm Operation Service Unit (FOSU) is catering to the needs of the divisions/project directorates/ establishments of the Indian Agricultural Research Institute for conducting field experiments. The entire farm of about 750 acres is under the management control of FOSU. About 35 acres are rainfed and the rest of the area is irrigated.

During summer, after harvesting of *rabi* crops such as wheat, mustard, gram, soybean, peas, etc., deep ploughing was done.

The fields were prepared after the first rainfall. Around 115 acres of land were put under green manuring by broadcasting *dhaincha* seed and incorporating crop into soil by using cultivator and planker. The green manuring crop buried into soil in the months of August and September resulted in an increase in fertility of the soil.

During the year, a massive programme of cleanliness was undertaken on roads drainage channel, sewage *nala*, *mela* ground and top block of the farm.

Inspite of man power limitation and more micro-experiments, the Unit made efforts to satisfy the needs of each experiment.

All imported and indigenous machines available with the Unit were repaired well in advance to meet the requirement of experiments.

3.8.13.2 Irrigation distribution management

The farm area is divided into (i) rainfed, (ii) canal irrigated, and (iii) tube well irrigated areas. Major demands of water are met by tube well irrigation system. The institute has 19 tube wells to pump ground water for 24 hours. These tube wells were used for 54705.5 hours and consumed 505053 electrical units.

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 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.

3.9 POST HARVEST TECHNOLOGY AND MANAGEMENT

3.9.1 Quality Retention of Sapota Fruits through Standardization of Harvest Maturity and Packaging

Sapota fruit harvested at mature green and half ripe stage and packed with ethylene absorbents provides positive results for post harvest quality during ambient storage by reducing ethylene production and delaying softening, decay development and colour changes without altering the chemical content of fruit.

3.9.2 Varietal Evaluation of *Aonla* Fruits during Ambient and Low Temperature Storage

Freshly harvested *aonla* fruits exhibited the symptoms of chilling injury on the 10th day of storage at 8.5 °C. However, fruits were free from chilling injury at 12.5 °C with 90% RH even after three weeks of storage.

3.9.3 Evaluation of a Novel RTS Beverage without Sugar from *Jamun* Fruits

A new formulation of *jamun* drink without sugar was developed and evaluated for its storage stability and sensory quality for six months. Though a slight degradation of colour was observed during the storage for six months, the drinks were found to be acceptable on sensory evaluation. After six months of storage the drinks were evaluated for their microbiological quality attributes. No trace of any microbial count could be observed even after 6 months of storage. This drink could be a boon to the patients suffering from insulin independent diabetes.

3.9.4 PA Biosynthesis Gene Expression Studies with respect to Post Harvest Quality Attributes of Transgenic Tomatoes

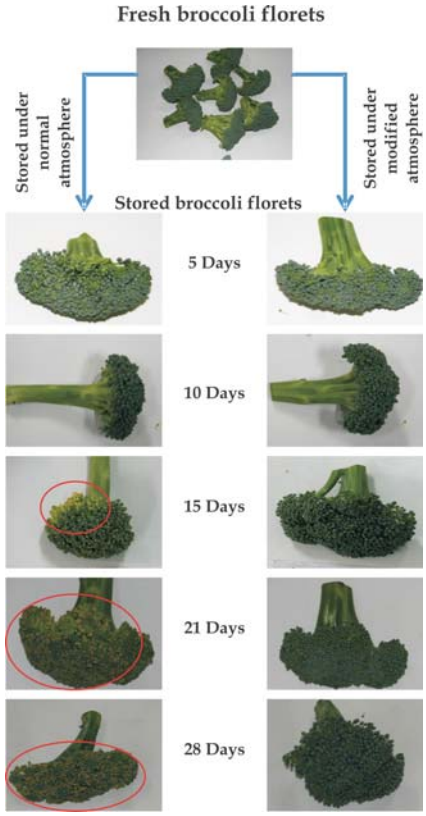
A study revealed the expression of high lycopene levels (approximately double) in some of the transgenic lines of tomato. Hence, there is a tremendous potentiality for the use of these lines in the breeding programme for improvement of nutraceutical properties with high lycopene contents commercial cultivars.

3.9.5 Modified Atmosphere Packaging of Broccoli Florets

Broccoli florets were stored under modified atmospheres by the use of four micro-perforated films and one macro-perforated film. The microperforated film with antifogging property was found to be the best material for the storage of the florets. The storage life of broccoli florets was of 28 days in micro-perforated film in comparison to only about 14 days under macro-perforated film, which maintained near environmental conditions. The broccoli florets stored under modified atmosphere not only retained the colour but also retained its texture, antioxidants and other nutritional components.

3.9.6 Standardization of Shrink-wrapping Technique for Apples

Shrink-wrap packaging technology was standardized for apples. It involves the wrapping of apples in heat shrinkable films (9 mm) and then passing them in heat shrinkable machine



Broccoli florets stored under normal and modified atmospheres

for a short time (10-15 seconds). Shrink-wrapped apples can be kept for a longer time (35 days) at room temperature compared to un-wrapped ones (control) without any adverse effect on quality attributes. In addition, the apples remain dirt free and look attractive to the consumers. Both individual and tray wrapping techniques of shrink wrapping are useful for apples. However, tray wrapping appeared to be better from economic and consumer point of view.

3.9.7 Microbial Antagonists for the Control of Post Harvest Diseases of Apple

Microbial antagonists such as *Pseudomonas syringae*, *Trichoderma viride*, *Trichoderma harzianum, Debaryomyces hansenii,* etc., with different concentrations were tried to control the post harvest diseases of apple. Of the several treatment combinations, *Pseudomonas syringae* (10^7 CFU/ml) was the best treatment to control blue mold caused by *Penicillium expansum* and gray mold caused by *Botrytis cinerea*.

3.9.8 Quality Evaluation of Citrus Juice with Added Hydrocolloids

Hydrocolloids, namely, CMC (0.6%), pectin (0.1% and 0.2%) and gum acacia (0.6%) were used to attain cloud stability in citrus juice. The samples were stored at ambient temperature in transparent bottles. During 3 months of storage, acidity, total sugars, reducing sugars, TSS and viscosity of all the samples increased. Ascorbic acid decreased significantly (The decrease being minimum in samples containing CMC and maximum in samples having 0.2 per cent pectin). Maximum cloud stability (separation of serum prevented) was observed in samples containing CMC. Non-enzymatic browning increased in the case of all the samples.

3.9.9 Changes in Cooking Quality Attributes of *Basmati* Rice Varieties during Storage

The effect of storage period on the cooking quality attributes (cooking time, volume expansion ratio, water uptake ratio, per cent solids lost in gruel) of six *basmati* rice varieties (P1121, P2511, PS1, PS2, PS3 and PRH 10) was observed. During a storage of four months at ambient temperature, cooking time, volume expansion ratio, elongation ratio and water uptake ratio showed a slight increase whereas the per cent solids lost in gruel decreased.

Changes in cooking quality attributes of *basmati* rice varieties during storage

Variety	Cooking time(min)		Volume expansion ratio		Elongation ratio		Water uptake ratio		Per cent solids lost in gruel	
	F	A	F	A	F	A	F	A	F	A
P 1121	21	22	1.03	1.04	1.18	1.22	2.59	2.68	3.13	3.09
PRH 10	19	20	1.03	1.03	1.23	1.24	2.52	2.59	3.29	3.19
P 2511	23	24	1.02	1.03	1.45	1.50	2.64	2.72	2.76	2.61
PS 1	21	22	1.05	1.06	1.38	1.41	2.49	2.67	2.91	2.83
PS 2	21	21	1.02	1.04	1.33	1.36	2.51	2.62	2.85	2.80
PS 3	21	22	1.03	1.04	1.34	1.36	2.49	2.65	3.01	2.81

Note: F refers to fresh sample; A represents 4-month aged sample

3.9.10 Standardization of Method of Flaking for Pigeonpea *Dal*

A method for flaking of pigeonpea *dal* for quick cooking was standardized. The process involved the soaking of *dal* in sodium chloride solution (1%) for 2 h followed by drying to a moisture content of 7-8%. The dried *dal* was then passed through a hand operated flaker to obtain flakes of 1mm thickness followed by drying of the flakes. The flaked *dal* reduced its cooking time to about 6 min.

3.9.11 Nutritional Evaluation of Corn Varieties

Six varieties of field corn, namely, PC 1, PC 2, PC 3, PC 4, NEP and Arun, were evaluated for their nutritional quality for use in value added products. The field corn PC 3 showed maximum protein (10.56%) and fat (4.91%) contents whereas PC 1 had minimum protein (9.30%) and fat (4.19%) content.

Nutritional evaluation of field corn varieties

Variety	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Ca (ppm)	Mg (ppm)
PC 1	11.80	9.30	4.19	4.96	56.12	16.85
PC 2	11.62	9.54	4.38	4.95	62.14	12.22
PC 3	11.76	10.56	4.91	4.95	63.23	11.21
PC 4	12.34	10.43	4.67	4.96	63.42	11.21
NEP	12.38	10.48	4.81	4.93	55.11	15.66
Arun	11.78	9.57	4.61	4.92	58.24	16.03

3.9.12 Standardization of Growth Regulator Treatments to Delay Flower Senescence in *Alstroemeria*

In *Alstroemeria* cultivar Aladdin, cut stems held in GA_3 (75ppm) + BA (75ppm) delayed the onset of flower senescence as indicated by days to 50% petal fall and days to 50% leaf yellowing.

3.10 MICROBIOLOGY

3.10.1 Recycling of Agricultural Residues and their Utilization for Sustainable and Organic Agriculture

3.10.1.1 Development of microbial consortia for rapid decomposition of organic residue

A consortia consisting of hyper lignocellulytic fungi *Aspergillus awamori*, *Phanerochaete chrysosporium*, *Aspergillus nidulans and Trichoderma viride* was developed for rapid decomposition of agro residues and to develop enriched compost. Unchopped wheat straw obtained after

crop harvest was used as a primary substrate to prepare the compost in cemented pits of 1m^3 dimension. The high initial C: N ratio of wheat straw (80:1) was lowered to 50:1 by mixing with poultry droppings in the ratio of 8:1. Udaipur rock phosphate was added @1% to provide phosphorus nutrition. The assessment of chemical parameters after 90 days showed that finished product had a pH range of 6.8 - 7.0, electrical conductivity < 2.5 dScm^{-1}, C/N ratio <12.0 and humus content >10.0%. High available P and low dehydrogenase activity confirmed its maturity. Phytotoxicity test conducted by using radish seeds showed that finished compost had a germination index of >100% and could be safely applied to soil under crop growth.

Compost application and soil health. A field experiment was conducted to assess the effect of straw compost on soil physico-chemical and biological parameters with wheat var. HD 2687 as the test crop. The treatments used were: T1- N120 P60 (full recommended dose); T2 - Compost @ 6 t/ha; T3 - Poultry manure 3 t/ha; T4 - N60 P30+compost 3 t/ha, and T5 - N60 P40+poultry manure 1.5 t/ha. All the treatments were replicated four times. Both chemical and biological parameters were estimated in the soil drawn during different intervals of crop growth. The pH of the soil varied between 8.0 and 8.65 whereas the electrical conductivity ranged between 0.25 and 0.45 dS cm^{-1}. Microbial activity estimated in terms of fluorescent diacetate (FDA) hydrolysis and dehydrogenase activity was found to be higher in T4 and T3 treatments, respectively.

3.10.1.2 Integrated uses of organic inputs in sustainable and organic agriculture

In a long term experiment, the effect of vermicompost and enriched compost on the growth and yield of organically grown wheat-mungbean-rice was assessed. The analysis of soil samples during the growth of all the three crops revealed a significant build up of organic matter from 0.37% to 0.72% over a period of four years of experiment. Soil samples collected from treatments involving vermicompost application exhibited higher dehydrogenase activity and total nitrogen as compared to those in which enriched compost was applied indicating better soil quality in the former. Vermicompost along with *Azotobacter*, PSB and AM gave the maximum grain yield of wheat (3.99 t/ha) and was superior to treatment with enriched compost along with Azotobacter, PSB and AM (3.09 t/ha). On the basis of data generated on nitrogenase activity, alkaline phosphatase, soil chlorophyll values and grain yield, the application of vermicompost can be recommended along with *Azotobacter* +PSB +AM for wheat crop. Mungbean crop was raised after harvest of wheat and incorporated in the soil as green manure. The application of vermicompost along with *Rhizobium* and PSB was better and increased the soil organic C to 1.08%. Rice crop was taken in the *kharif* and significant differences in the grain yield were obtained among the treatments. Amendment with vermicompost and combined inoculation of BGA and PSB gave the highest nitrogenase activity, soil chlorophyll, alkaline phosphatase activity and grain yield (2.79 t ha^{-1}).

3.10.1.3 Evaluation of cyanobacteria - PGPR combinations in wheat

A pot experiment was undertaken to evaluate the influence of PGPRs (three selected bacterial P1, P2 and P3 and cyanobacterial C1, C2 and C3 strains) along with 40 kg of N, 60 kg of P and 40 kg of K in wheat crop. A total of 51 treatments were evaluated. Treatments involving a combination of all six strains exhibited the highest panicle weight of wheat plants followed closely by inoculation of P1+P3+C3. Soil microbiological parameters (dehydrogenase activity, FDA, alkaline phosphatase and microbial biomass C) were observed to be significantly higher in the treatments involving various combinations of strains as compared to inoculation with individual strains and chemical controls. This study illustrated the dynamic interactions among bacterial and cyanobacterial strains and their promise in integrated nutrient management of wheat crop.

3.10.2 Exploitation of Microorganisms for Crop Production

3.10.2.1 Identification of efficient *Rhizobium/ Bradyrhizobium* strains for chickpea, pigeonpea, soybean and mungbean

Significant genetic variations among eight varieties of soybean released by IARI with regards to nodulation, growth and yield were observed in a field experiment. Among the

eight varieties, var. DS 9814 recorded maximum nodule number per plant, var. Pusa 37 maximum nodule dry biomass, var. DS 9712 maximum shoot biomass (6.8 g plant^{-1}), and var. DS 9814 the maximum grain yield (3217 kg ha^{-1}). These variations could be exploited in soybean breeding program.

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

A field study was undertaken to compare the efficacy of two different formulations (solid carrier based and liquid) of phosphate solubilizing bacteria by using maize, wheat and mungbean as test crops. The growth and yield for maize and wheat crops were significantly higher in treatments with 40 kg SSP ha^{-1} (100% RDP) as compared to treatments with 30 kg SSP ha^{-1} (75% RDP) along with either of the formulations of PSB. Thus, the PSB inoculant could not substitute for 25% SSP. Among the formulations, no significant differences were observed in plant height and yield of maize and wheat indicating that both the solid carrier based and liquid formulation are equally efficient. The results were confirmed by using mungbean as the test crop.

Development of liquid bioinoculants for Azotobacter chroococcum with longer shelf life. In the pursuit to develop liquid bioinoculants of *A. chroococcum* with a longer shelf life (> 1 year), fourteen different liquid formulations of *Azotobacter chroococcum* incubated at room temperature were evaluated. The population of *A. chroccoccum* was monitored at an interval of one month and the survival data were recorded for 7 to 18 months. Nine formulations considerably improved the survival of *A. chroococcum* up to eighteen months and maintained the population as high as 10^8 cfu ml^{-1}. These formulations appeared to be promising.

Plant growth promoting attributes of long term stored liquid bioinoculant. The plant growth promoting attributes – nitrogen fixing ability and production of IAA – were compared among the fresh culture and the one stored as liquid bioinoculant for a period of one year. Most of the formulations appeared to have a positive effect on both the PGP activities. Formulation U appeared to have a negative effect on both the PGP activities while formulation V had a negative effect on ARA activity.

3.10.2.3 Development of *Azotobacter* inoculants for low organic carbon conditions

Organic matter is known to stimulate the population of *Azotobacter* in soil. However, most of the Indian soils are very poor in organic carbon content, which could be an important reason for observed low population of *Azotobacter* in soil. Keeping these facts in view, *A. chroococcum* strains capable of either growing in the presence of low carbon or those capable of utilizing resistant carbon sources were selected and their survival was evaluated in the rhizosphere of wheat amended with different levels of organic matter in a pot experiment. In addition, the influence of inoculation on plant growth parameters was evaluated.

In general, no significant effect of amendment of organic matter as farm yard manure (FYM) was observed on the population build up of *Azotobacter* in the rhizosphere of wheat. The population was more for all strains tested in treatments without FYM as compared to treatments with 10 tonnes ha^{-1} FYM (full dose) and 5 tonnes ha^{-1} FYM (half dose).

Differential response was obtained due to the inoculation of *A. chroococcum* strains for plant growth parameter, per cent root and shoot nitrogen and grain yield. The shoot dry weight was significantly influenced due to the amendment of organic matter both at 45 days after sowing (DAS) and 75 DAS. Inoculation with strains A41 and JMS100b significantly enhanced the shoot dry weight when compared to uninoculated control at 45 DAS and 75 DAS, respectively. Similar results were obtained for root dry weight. The per cent N in roots and shoots was significantly higher after 75 DAS when compared to samples harvested after 45 DAS. In general, the per cent N in roots and shoot was higher in the presence of full dose of FYM as compared to half dose or no FYM treatment. Maximum grain yield of 18.50 g pot^{-1} was obtained due to the inoculation of JL 104 at full dose of FYM.

3.10.2.4 Microorganisms as biocontrol agents

Development of standard and stable insecticidal spinosyns from Saccharomyces spinosa. Media and incubation time were optimized for the production of toxic metabolite from *Streptomyces albus*, an isolate obtained from leaf compost. The metabolite was extracted at an interval of 7

days up to 30 days of incubation and bioassayed against *Macrophonica phaseolina* as test fungus.

Among the four different media, viz, malt extract yeast extract medium (MEYE), glycerol aspargine medium (GA), Bennet medium and Casein starch medium (CS) tested, Bennet medium supported the maximum production of metabolite. The metabolite production increased gradually with the time of incubation up to 30 days.

Screening of different media for maximum production of metabolite by *Streptomyces albus* using *Macrophomina phaseolina* as test fungus

	Control	Malt extract yeast extract medium	Glycerol aspargine medium	Casein starch medium	Bennet medium
Radius (cm)	3.1	2.0	2.5	1.8	1.7
% inhibition	0	35.48	19.35	41.93	45.16

Optimization of incubation time for maximum metabolite production by *Streptomyces albus* by the use of *Macrophomina phaseolina* as test fungus

	Control	7 Days	10 Days	15 Days	30 Days
Radius (cm)	3.75	3.0	2.7	2.55	2.25
% inhibition	0	20	28	30	40

The active fraction was characterized further to understand the biochemical nature. It was subjected to heat shock (121 °C, 60 min.), treated with proteinase K (1mg/ml, 120 min. 37 °C) and sodium dodecyl sulphate (1 %, 120 min. 37 °C), and bioassayed against *Macrophomina phaseolina.* The metabolite was found to be heat stable and retained the activity even after treatment with detergent (SDS), but lost its activity after treatment with proteinase K. The metabolite when further screened for its activity against three different soil borne plant pathogenic fungi, namely, *Fusarium oxysporium, F. moniliforme* and *Rhizoctonia bataticola*, was found to inhibit the growth of all fungi. It, thus, has the potential to inhibit a wide array of fungi.

Biochemical characterization of active fraction of *Streptomyces albus* by using *Macrophomina phaseolina* as test fungus

	Heat treatment (121 °C, 60 min.)		Proteinase K (1mg/ml)		SDS (1 %)	
	Control	Treatment	Control	Treatment*	Control	Treatment
Radius (cm)	2.6	2.6	3.2	3.2	2.0	1.5
% inhibition	24	24 (100)	0	0	37.5	53.12

Studies on antagonistic mechanism of cyanobacterial metabolites towards Pythium species. A set of eighteen cyanobacterial strains belonging to the genus *Anabaena* was evaluated in terms of inhibition against *Pythium debaryanum* and *Pythium aphanidermatum* employing disc diffusion assay as a prelude to their utilization as biocontrol agent (s) in agriculture. Among them, six strains inhibited the fungal growth significantly. Microtitre plate assays were optimized for evaluating the minimum inhibitory concentration (MIC) of the culture filtrates of two cyanobacterial strains (*Anabaena laxa* and *A. iyengarii*) and their aqueous/ organic phase fractions against *Pythium debaryanum* by using time course and dose based studies. ELISA reader based evaluation revealed MIC values of 2.5 µl of culture filtrate of *A. laxa* and 5µl of *A. iyengarii*. Microscopic examination indicated that along with growth inhibition, the metabolite (s) also induced morphological abnormalities in the encountering hyphae of *Pythium.* Distinct curling of hyphae, disorganization of the cell contents and some needle-like outgrowths were observed in the target fungus.

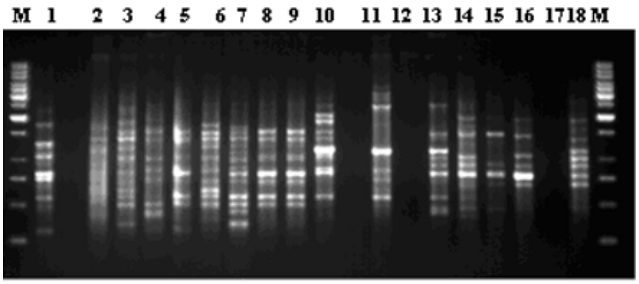
3.10.3 Exploration and Exploitation of Cyanobacterial Genetic Resource for Agriculture and Industry

3.10.3.1 Genetic evaluation of cyanobacteria for H-production and N_2 fixation

Out of 12 strains taken for the study, *Anabaena variabilis* (CCC 441), *Nostoc muscorum* (CCC 442), *Anabaena doliolum* (ATCC43530) and *Nostoc* sp (929150) showed better hydrogen production. The possible genes (*hox* H, *hox* Y, *hox* E, *hox* F) coding for bidirectional hydrogenase were successfully amplified by using the primers designed. *Hox* H gene was cloned into *E. coli,* further sequenced and submitted to the NCBI GenBank with the Accession No. FJ655264.

3.10.3.2 Molecular characterization of BGA isolates from high/low fertilizer input *basmati* rice

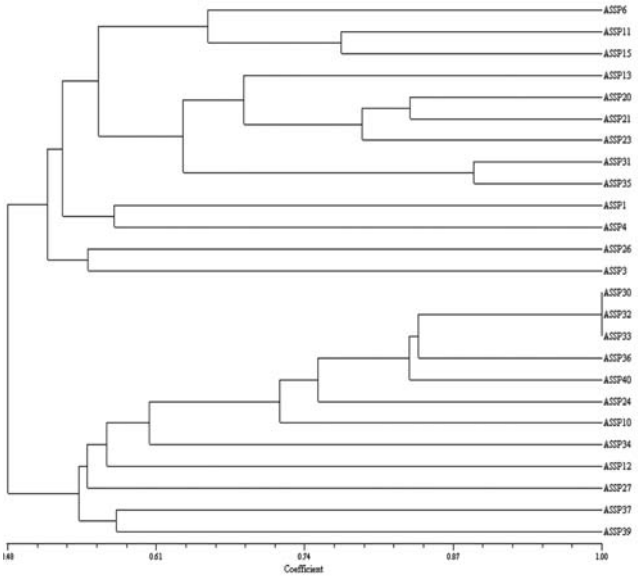
The genetic diversity of cyanobacteria was analyzed in soils where organic farming was practiced for growing rice and wheat crop. RAPD-PCR with seventeen single different oligonucleotide



RAPD-PCR profiles of *Nostoc* isolates by the use of HIP-GC (lanes 1-9) and HIP-TG (lanes 10-18) primers

primers was employed to fingerprint the genomic DNA of isolates from organic field. A total of 519 DNA fragments were obtained for nine isolates belonging to the genus *Nostoc*. Among the primers, OPD-20 seemed to be a useful primer for molecular analysis of cyanobacteria as it provided maximum polymorphism as compared to other primers.

Clustering analysis based on RAPD profiles grouped all the isolates into two major clusters with a similarity co-efficient of about 0.52. All the *Nostoc* isolates irrespective of the crop of isolation (rice or wheat) were grouped in cluster I whereas all the *Anabaena* isolates were grouped in cluster II. The other isolates, viz., *Cylindrospermum* and *Phormidium*, were grouped in cluster I or II depending upon the crop from which they were isolated. The ones isolated

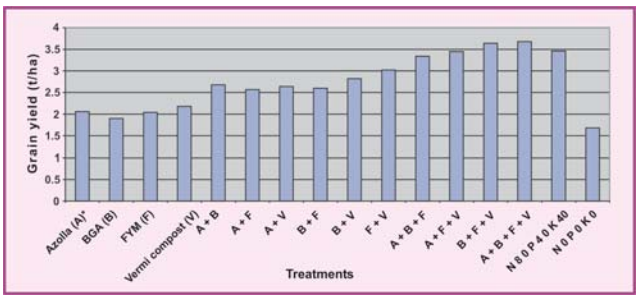


Clustering analysis of cyanobacterial isolates by the use of RAPD primers

from rice crop were grouped in cluster I where as the others isolated from wheat crop were grouped in cluster II except *Cylindrospermum* sp. (ASSP12).

3.10.3.3 Interactive potentials of BGA/*Azolla* and other bio-inoculants in rice-wheat-green gram cropping system

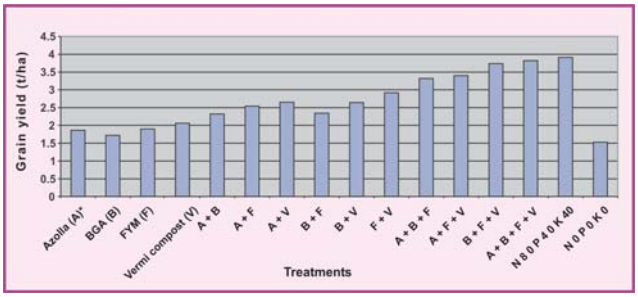
A protocol was developed for 'organic *basmati* rice cultivation' under rice-wheat-green gram cropping system on the basis of field experiments conducted during 2003-08. Inoculation of two bioinoculants, viz., blue green algae (BGA) @ 2.0 kg/ha, *Azolla* @1.0 tonne/ha and two organic amendments vermicompost and farm yard manure (FYM) at 5.0 tonnes/ha each, applied alone or in combination were evaluated on a scented rice variety Pusa Sugandh 4 (Pusa 1121) and on wheat var. Vishesh (HD 2851). Biomass of green gram was incorporated in soil after picking of pods and wheat was sown using zero tillage practice. Significant enhancement in grain yield of rice and wheat over absolute control due to the application of different bio-inoculants applied alone or in combinations was recorded. The rice grain yield increase was found to be ranging between 13% to 30% due to single organic amendment. However, yield increase over absolute control was119% when all four bio-inoculants were applied together. The rice grain yield (3.68 t/ha) obtained under combined application of four bio-inoculants was the highest among all the treatments though it was statistically on a par with the yield recorded under recommended dose of chemical fertilizer application (3.46 t/ha).



Effect of different organic treatments on grain yield of *basmati* rice

The wheat grain yield under combined application of four bio-inoculants was recorded as 3.82 t/ha and was statistically on a par with the yield recorded under

recommended dose of chemical fertilizer application (3.9 t/ ha). Soil microbial population (Actinomycetes, bacteria, fungi and BGA) and soil organic carbon was found to be continuously enhanced due to the application of bio-inoculants in comparison to absolute control as well as recommended fertilizer application that in turn resulted in a notable enhancement in soil dehydrogenase enzyme activity. Rice grain analysis for mineral nutrients showed a significant increase in iron, zinc and manganese contents in the treatments having 3 or 4 bio-inoculants than that of control treatment.



Effect of different organic treatments on grain yield of wheat

3.10.3.4 Bioremediation of waste waters by the use of *Azolla*

Growth of *Azolla microphylla* was studied under varying concentration (0-200 ppm) of ammonium ions. *Azolla* fronds depicted very good growth up to 50 ppm of ammonium indicating that *A. microphylla* can be used to remove ammonium ions in partially treated domestic wastewaters.

A. microphylla was grown on primary and secondary treated domestic effluents for a period of seven days and the results showed that the strain studied could remove organic carbon, total nitrogen and phosphorus. There was no available P recorded in the effluents after the *Azolla* growth. There were no significant decreases in biological oxygen demand (BOD) and chemical oxygen demand (COD) values, and dissolved oxygen levels also did not show significant change. The results indicated that *A. microphylla* is able to reduce nutrient load in wastewaters by consuming thesenutrientsforitsowngrowth.The results indicated that *Azolla* can be applied for secondary or tertiary treatment of sewage effluents in wetland systems.

Change in the physico-chemical parameters of partially treated sewage effluents due to growth of *Azolla microphylla*

Effluent parameter	Keshopur treatment plant		Biological stabilization pond (Nehru Vihar Pumping Station)	
	Initial level	Final level after *Azolla* growth	Initial level	Final level after *Azolla* growth
pH	7.5	8.7	6.8	7.2
DO	2	2.2	low	low
Free ammonia (ppm,Nesseler's reagent method)	24	22(8%)	30	25(16.7%)
Organic C (%)	0.07	0.04(43%)	0.998	0.589(41%)
Organic matter (%)	0.120	0.076(36.6%)	0.172	0.099(42%)
Total organic N (%)	0.007	0.004(43%)	.0089	.006(32.6%)
Reactive P (ppm)	~2	<2	3	~1
Total P (ppm)	98	15.9(16%)	150	122 (18.6%)
EC (mmhos cm^{-2})	0.82	1	1	1

Figures in parentheses show per cent removal

3.10.3.5 Salt tolerance mechanism in *Azolla-Anabaena* system

In the present experiment, five *Azolla* genotypes, viz., *A. pinnata*, *A. filiculoides*, *A. rubra*, *A. microphylla* and *Azolla* sp., were grown in normal Espinase and Watanabe medium and saline medium containing NaCl (0.5%). The response of *Azolla* to salinity was studied in terms of lipid peroxidation, peroxide accumulation and activities of antioxidant enzymes such as superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT). The results suggested that salinity induced reduction in plant growth in different species of *Azolla* is a function of increased lipid peroxidation and accumulation of peroxides despite an increase in the activities of some antioxidant enzymes. It appears that better protection mechanism employed by *A. microphylla* due to the maintenance of high levels of antioxidant enzymes could be one of the reasons for salinity tolerance. The results may be useful in the successful exploitation of *Azolla* as a bioinoculant for salt affected paddy fields.

Lipid peroxidation, cellular peroxide content and activity of antioxidant enzymes in various species of *Azolla* exposed to salinity

Organism	Lipid peroxidation [n mol (g F.W.)$^{-1}$]		Cellular peroxide content [n mol (g F.W.)$^{-1}$]		Superoxide dismutase [Unit(mg protein)$^{-1}$]		Peroxidase [Unit(mg protein)$^{-1}$]	
	Control	Saline	Control	Saline	Control	Saline	Control	Saline
A. pinnata	105.6	172.3	58.3	83.6	28.3	32.8	1.18	1.43
A. filiculoides	104.9	191.6	64.0	93.8	31.5	33.8	1.26	1.41
A. rubra	112.3	196.9	64.5	98.3	32.0	38.5	1.36	1.64
A. microphylla	103.7	150.4	49.0	62.3	30.5	50.2	1.58	3.87
A. species	97.5	135.8	42.4	57.6	32.6	47.7	1.73	2.95
C.D. (0.05)	9.11		5.41		2.82		0.141	

3.11 ENVIRONMENTAL SCIENCES

3.11.1 Impact of Elevated Temperature and CO_2 on Chickpea Yield

In order to assess the impact of rising atmospheric temperature and CO_2 concentration on its productivity, the chickpea variety BGD 72 was grown under elevated temperature (+1- 4 ^{0}C) and CO_2 (560 ppm) under temperature gradient tunnel (TGT) and Free Air CO_2 Enrichment (FACE). The crop exhibited gradual increase in its biomass and seed yield up to 3 °C increase in temperature, and thereafter there was decline both in biomass and seed yield. This was mainly attributed to change in its harvest index. Contrary to this, elevated CO_2 level in the air enhanced the biomass and seed yield of chickpea substantially (15-20%). Enhancement in yield was attributed to marked increase in biomass and marginal increase in seed size.

3.11.2 Effect of Elevated Temperature on Quality Characters of Crops

Three legumes, namely, soybean, greengram and chickpea, and a tuber crop, namely, potato were grown in temperature gradient tunnel (TGT) and exposed to elevated temperature of 1-4 °C. Protein content of soybean, greengram and chickpea increased marginally with the rise in temperature. In potato tubers, gradual increase in temperature reduced starch content and tuber density while it enhanced the content of total sugars and protein marginally.

3.11.3 Calibration of Free Air Carbondioxide Enrichment (FACE) and Temperature Gradient Tunnel (TGT) in Field

Free-air CO_2 enrichment (FACE) technology is used in open fields to study the response of plants to higher CO_2 in field environments. FACE facility was set up in the farm of Indian Agricultural Research Institute, New Delhi with computerized regulation of CO_2 injection for maintaining the desired level of CO_2 inside the rings. This facility was calibrated in the field for maintaining the desired CO_2 level. CO_2 concentration inside the FACE setup was studied by Infra Red Gas Analyzer (IRGA), and throughout the crop season, 550 ppm CO_2 level was maintained. A gradient of 20-30 ppm CO_2 concentration was observed inside the FACE ring from the point of injection of CO_2 gas to the centre of the ring. Besides FACE ring temperature gradient tunnels (TGT) were also established in the field to study the impact of increased temperature on crop plants. A temperature gradient of 3-4ºC was maintained inside the tunnels.

3.11.4 Impact of Climate Change on Mustard Crop Production

A simulation study showed that increasing temperature reduced mustard grain yield while increasing CO_2 concentration increased the yield of the crop irrespective of the region. Future climate change scenario analysis showed that mustard yields are likely to reduce in both irrigated and rainfed conditions. Increasing temperature lowered days to flowering and days to maturity, which, in turn, lowered the total crop duration and crop yield. Spatial variation was noticed in terms of its yield loss with western and northern India being more vulnerable in terms of yield reduction of the crop. Central India and eastern Indo-Gangetic plains would be less affected due to less future variation in rainfall in these two regions. The above result supports the adverse impacts of future anticipated climate change on mustard growth and yield.

3.11.5 Effect of Elevated Temperature on Greenhouse Gases Emissions from Soil

Measurement of carbon dioxide and nitrous oxide emissions from soil was carried out in temperature gradient tunnels to study the impact of elevated temperature on the greenhouse gases emissions. The soil temperature inside the temperature gradient tunnel ranged from 20.2 °C to 38.8 °C over the study period and was, on an average, 3.6°C higher than the ambient soil temperature over a period of 90 days. The emissions of carbon dioxide under elevated temperature did not follow any pattern and varied from 0.12 $gm^{-2}d^{-1}$ to 1.78 $gm^{-2}d^{-1}$ in soil having organic carbon content of 0.33%. The cumulative flux of carbon dioxide did not significantly increase with an average increase of temperature by 2.8°C over a period of 135 days.

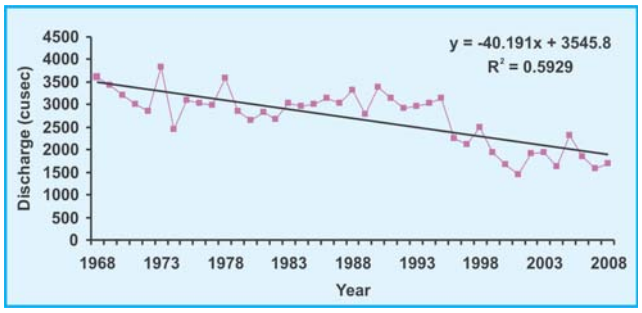
3.11.6 Estimation of Methane and Nitrous Oxide Flux from Soils under Cereals, Pulses and Oil Seed Crops

Emission of greenhouse gases is responsible for climate change. Estimates of greenhouse gases (GHGs) emission from soils are important for preparing national inventories of GHGs emission and for developing mitigation strategies. We need to measure country specific emission coefficients for preparing a precise inventory. Therefore, measurements were conducted from soils under sorghum, maize, soybean, groundnut, *arhar*, mungbean and pearl millet crops to quantify the flux of nitrous oxide (N_2O). The seasonal integrated flux of N_2O was found to be 520.09, 464.85, 484.62, 478.01, 365.00, 640.67 and 481.46 g N_2O/ha from sorghum, pearl millet, soybean, groundnut, *arhar*, maize and mungbean cropped soils, respectively. Loss of applied N as N_2O-N ranged from 0.36% to 0.39% for oilseeds, from 0.58% to 0.68% for pulses, and from 0.25% to 0.28% for millets; it was 0.34% for maize.

Emission coefficients of CH_4 and N_2O from sewage and organic manure treated soils in rice were also estimated. Fluxes of methane fluctuated between 0.015 and 2.62 kg $ha^{-1}d^{-1}$ (PRH 10) and 0.01 and 2.83 kg $ha^{-1}d^{-1}$ for PS 5. Seasonal integrated flux of methane was the highest in PS 5 in all the treatments as compared to that of the hybrid PRH 10. Methane emission was higher in 25% sewage treatment as compared to 25% organic treatment by 16% in PS 5. Fluxes of nitrous oxide during the rice cropping season ranged from 0.49 kg to 0.89 kg/ha. Replacement of 25% urea-N by sewage sludge decreased the cumulative emission by 15.6- 25% in comparison to that of urea. Total GWP ranged from 217 to 390 kg CO_2/t grain yield for PS 5 and 114-240 kg CO_2/t grain yield for PRH 10.

3.11.7 Long Term Variability of Annual Discharge in a Rain, Snow and Glacier Fed Watershed of the Upper Beas Basin

A study was undertaken in the Parvati watershed of upper Beas basin to know the long term variability of annual discharge in the light of the global warming. The investigation showed that glaciated area over the watershed had receded 11.55 km^2 from 1962 to 2001 due to global warmingin the watershed. Forty-one years' discharge data were collected from Bhakra Beas Management Board, Pandoh to know the impact of glacial reduction on water availability. Global warming reflections on the water discharge were not observed accordingly, and a significant decrease in the discharge was observed in the annual discharge of the watershed from 1968-2008. This reduction in water availability will influence agricultural activities in the downstream areas affecting local as well as national economy.



Long term variability of annual discharge in Parvati watershed

3.11.8 Utilization of Industrial Wastewaters for Ferti-irrigation in Agricultural Fields

Distilleries in India are sporadically distributed in different states representing varying agroclimatic conditions. In an effort to devise an agro-climatic region-wise protocol for the utilization of wastewaters of distilleries, agriculture experiments were carried out on the farm of Jubilant

Organosys, Gajraula, distt. J P Nagar, U.P., representing a semi-arid alluvial soil region of Indo-Gangetic plains. It was found that 25 per cent nitrogen compensation through effluent not only helped in 25% saving in nitrogenous fertilizer use but also saved 100% on potassium. Mustard, maize, rice and wheat all showed similar responses to effluent application.

Application of paper mill effluent on sugarcane at ABC Paper Mill at Sailakhurd, Hoshiarpur, Punjab showed that the effluent mixed with irrigation water @ 75% gave the best yield 104.2 t/ha. However, Brix value of the juice was higher in the crop irrigated with 50% effluent (20.0).

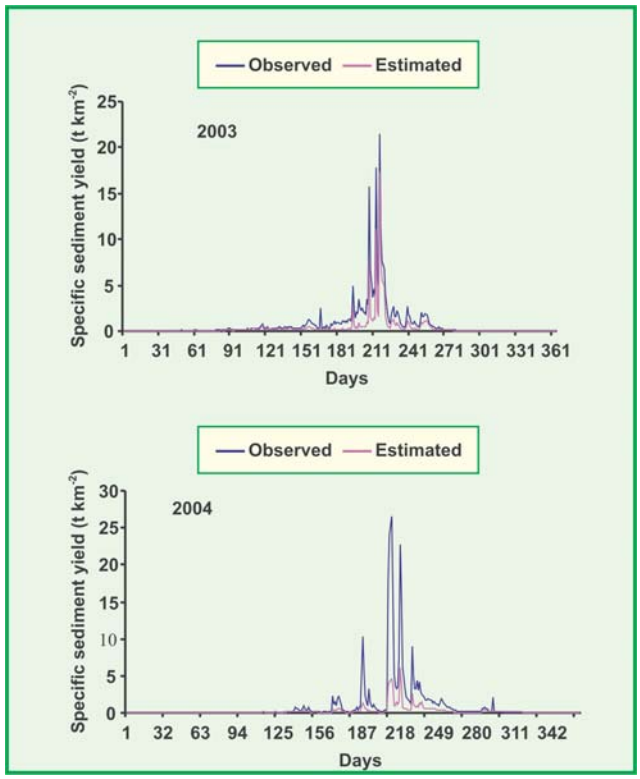
Physico-chemical composition of treated effluent from common effluent treatment plants (CETP) at Okhla, DSIDC, Udyog Nagar, Jhilmil, Badli and Wazirpur in Delhi metropolitan area was examined. It was found that TDS(2300-9000 mg/l) was very high in the treated effluent of all these CETPs. In some of the samples, it was even three times higher than the EPA standard (2100 mg/l). The treated effluent from these CETPs is not suitable for direct irrigation in parks and gardens and would require *in situ* feasibility studies.

3.11.9 Ecological and Economic Impact of Organic Farming on Agroecosystem Services

Kaithal district in Haryana was selected for the evaluation of economic and ecological impacts of organic and conventional farming systems on ecosystem services. Currently, over 2500 acres of land is under organic certification in and around Kaithal. Organic cultivation is being carried out under contract system. Initial base line socio-economic survey of contract farmers under organic cultivation indicated that medium farmers (<10 ha) constituted 23.63% and large farmers (>10 ha) constituted 76.36%. The percentage area of total land under organic contract farming with medium and large farmers was 32.6% and 61.4%, respectively. Distribution of farmland indicated that 36.2% and 34.2% of total arable area belonging to medium and large farmer are under certified organic cultivation and the rest is being put to organic cultivation in stages. Further analysis would be done for ecological and economic evaluation of ecosystem services provided by organic farming systems.

3.11.10 Sediment Yield Estimation in the Lesser Himalayan Region

Sediment yield refers to the amount of sediment transport by a basin over a period of time. Dynamics of sediments in streams and rivers is a complex process and it depends on a variety of variables and parameters. An estimate of sediment transport rates from watersheds is important in the context of erosion, sedimentation and flood control. In the present study, an assessment of sediment yield was made for a watershed, which flows through the lesser Himalayan region, through empirical approach. This empirical approach gives annual sediment yield based on various watershed parameters such as geo-morphology, land use, topography, etc. These parameters were generated by the use of remote sensing (RS) and geographic information system (GIS) technique. At present, the annual sediment yield for the watershed was estimated only for two years, i.e. 2003 and 2004 and compared with the observed values. The trend of difference between computed and observed sediment yield suggested an effect



Comparision between daily observed and estimated sediment yield

of physical features of the mountains. The used empirical relationship was, therefore, revised by incorporating a watershed parameter in the equation. Using the revised empirical relationship, the sediment yield was further estimated and a good match between computed and observed sediment yield was found for the lesser Himalayan watershed.

3.11.11 Evaluation of Recyclable Agri-residue and Selected Crop Non-edible Oilseed Cakes for their Suitability for Producing Biogas

The agro-industrial wastes are available in substantial quantities at processing sites unlike other biomass wastes such as crop residues, animal wastes, etc. In a recent survey on organic resources and on their best possible utilization, the rice milling industry was chosen for the initial indicative studies on biomass availability in NCT, Delhi. Rice husk and rice bran are the two main by-products of rice milling industry. The availability of rice husk is estimated to be about 13 million tonnes annually in northern India. Paddy husk contains mainly cellulose, lignin, pentosan and ash. The N content in rice husk varies from 0.3% to 0.5%, indicating that it is a poor source of manure. It can be used as fuel and for improving physical conditions of saline and alkali soils. It is also being used as bedding material for animals.

Lab scale experiments were conducted to estimate the biogas production from castor oil seed cake alone and in combination with cattle dung in the proportions of 1:1; 1:2; 1:3; 2:1; and 3:1 by batch phase anaerobic digestion process. The results showed that the treatment containing 2:1 ratio of cattle dung and castor oil seed cake produced the highest biogas yield, i.e., 1976 dm^3/ kg dry matter in ten weeks hydraulic retention time (HRT). The per cent methane contents of the biogas are found on a par with or a little higher than that obtained from the anaerobic fermentation of cattle dung alone.

3.11.12 Isolation and Characterization of Cellulolytic Thermophiles from Different Hotsprings

Extremophiles are a valuable source of novel enzymes like proteases, lipases and polymer-degrading enzymes such as cellulases, chitinases and amylases. Thermostable enzymes isolated mainly from thermophilic organisms have found a number of commercial applications because of their overall inherent stability. Water samples were collected from the hot spring Agnikunda at Bakreshwar in the Birbhum district of West Bengal and also from Vajreshwari, Maharastra in India. Four promising celluolytic strains labelled as MVS1, MVS2, MVS3 and MVS4 from Vajreshwari and three other strains labeled as WBS1, WBS2, and WBS3, from Agnikunda were isolated. Based on nucleotides homology and phylogenetic analysis, the microbe (Sample MVS3) was detected to be *Bacillus* sp. (GenBank Accession Number: EU070407). The nearest homolog genus-species was found to be *Bacillus sonorensis* (Accession No. AF302118).

3.11.13 Impact of Surface Ozone on Growth and Productivity of Rice

Tropospheric ozone is a secondary air pollutant and may impact crop growth and productivity. Thirteen varieties of upland and lowland rice were screened in a laboratory experiment for tolerance to elevated ozone concentrations. Among the seven upland varieties, PS 5 was found to be most sensitive and P 44 was found to be most tolerant to elevated ozone concentrations (100ppb O_3, 7 h d^{-1} for 5 days) based on percentage germination and other growth parameters. A field experiment was subsequently conducted by growing PS 5 and P 44 varieties of rice under four different levels of ozone in open top chambers (OTCs). There was a reduction in all the growth parameters under elevated ozone concentration. A significant decrease in photosynthetic rate, LAI, biochemical parameters, growth and yield parameters was observed in the elevated ozone treatment, whereas a significant increase was observed under sub-ambient ozone levels of charcoal filtered treatment. There was a decrease to the tune of 13% to 17% in grain yield under elevated ozone.

3.11.14 Impact of Elevated Ozone on Pollen Sterility of Wheat

Wheat crop was grown in open top chambers (OTC) to study the impact of elevated ozone (O_3) concentration on crop growth and yield. Both *aestivum* (PBW 343) and *durum*

varieties (HD 2936) were exposed to 25-30 ppb higher O_3 concentration than ambient throughout the crop growth period. Pollen sterility as well as pollen germination percentage on stigma was quantified. Results showed that high O_3 concentration increased the pollen sterility percentage in both the varieties. Percentage of sterile pollen grains increased from 6.6% to 16% in PBW 343, and from 8.5% to 25.7% in HD 2936. On the other hand, ozone exposure reduced the germination of pollen grains on stigma in wheat in both the cultivars.

3.11.15 Innovative Multi/Hyper - Spectral Remote Sensing Techniques for Improved Natural Resource Characterization

The hyper-spectral sensor technology over the last few years has enhanced our abilities to accurately characterize our natural resources from both air and space-borne platforms. A new technique was developed with greater capabilities such as (i) land-use and soil boundary delineation with 20% higher accuracy than the conventional digital image processing methods, (ii) generation of radiometrically enhanced outputs leading to superior clarity and edge detection, (iii) substantial reduction in the multi/hyper-spectral data storage space requirement, (iv) simplified (1 Dimensional) clustering analysis and faster processing of hyper-spectral data, (v) superior speed, clarity and resource characterizing and discriminating capabilities and (vi) identification of systemic noise (generally not recognizable through the existing spectral data analyzing methods) in hyper-spectral sensors. The improved technique has several industrial applications such as land use/land cover mapping, degraded area/wasteland mapping, agricultural crop acreage and yield estimation, drought monitoring and assessment, forest/grassland productivity estimation, flood monitoring and damage assessment, water resource management, marine resource surveys, urban planning, mineral targeting and environmental impact assessment.

4. CROP PROTECTION

4.1 PLANT PATHOLOGY

4.1.1 Fungal Diseases

4.1.1.1 Wheat

Inheritances of resistance in bread wheat cultivars to stem rust. Genetic analyses of three wheat cultivars, viz., GW 322, HUW 533 and HW 2045 with three pathotypes of *Puccinia graminis* f.sp. *tritici*, i.e., 21(9G5), 40A (62G29) and 117A (36G2), showed the presence of three dominant independent genes for resistance in GW 322 and HUW 2045 and two dominant independent genes for resistance in HUW 533 in F_2 population. Analysis of BC_1 and BC_2 with pathotype 117A (36G2) confirmed the above findings. F_2 segregation of inter-crosses (diallel crosses) of test cultivars to pathotype 21 (9G5) did not show any susceptible segregant, indicating the presence of at least one common gene in these cultivars. An adult plant resistance gene *Sr2* was also identified in GW 322 and HW 2045 based on the mottling effect of the seedlings.

Development of protocols for evaluation of rust resistance in durum and bread wheats. Seedling tests of 120 genotypes each of *durum* and bread wheats with 40 pathotypes of leaf rust, and 24 of stem rust revealed that leaf rust pathotypes 162-2, 12-5, 12-2, 104-2, 162-3, 11, and 106, and stem rust pathotypes 117-6, 117A, 117-1, 117A-1 and 117-3 are to be used for evaluation of rust resistance in *durum* wheat, while leaf rust pathotypes 77-6, 77-5, 77-7, 77-2 and 77-1, and stem rust pathotypes 40A, 40-1, 295, 11 and 117-4 need to be included for evaluating resistance in bread wheat, based on the relatively high virulence frequencies of these pathotypes on the two wheat species.

Wheat varieties with high field resistance to stem rust race Ug99. Released and popular *durum* wheat varieties HD 4672 and HI 8498, and a bread wheat variety HI 1500 showed high levels of field resistance in Kenya to the newly emerged stem rust race *Ug99*, virulent on *Sr31*.

Released wheat varieties resistant to *Ug99*

Variety name	Pedigree	1st score 2006	2nd score 2006	Retested 2007
***Durum* wheat**				
HD 4672	Bijaga Red/PBW 34 //Altar 84	20 S	20 MS	Moderately resistant
HI 8498	CR 'S'-GS 'S' /A-9-30-1 //Raj 911	10 MS	10-15 RMR	Resistant
Bread wheat				
HI 1500	HW 2002*2// Strempalli/ PNC 5 TR	TR	10 RMR	Highly resistant

Identification of diverse genes for resistance to leaf rust in bread wheat. Seedling tests involving F_2 and F_3 populations derived from 'susceptible × resistant' crosses showed that resistance to leaf rust pathotype 77-5 was conditioned by a single dominant gene each in HP 1761, HS 365, HUW 468, PBW 498 and VL 832. Allelic tests involving 'resistant × resistant' crosses showed that these genes were different from each other, except a gene common between HUW 468 and PBW 498. Thus, a total of four diverse dominant genes were identified for leaf rust resistance among the five above mentioned leaf rust resistant bread wheat genotypes. While the gene in HP 1761 appears to be *Lr9*, based on parentage and infection type, no inference could be drawn regarding the identity of the other resistance genes.

Validation of PCR based diagnosis of Chaetomium globosum. A PCR based diagnostics developed for the biocontrol agent *C. globosum* was validated. The biocontrol agent was detected by the use of species specific primers and the standardized protocol at its site of application, i.e., leaf when used as foliar spray, and soil when amended in soil.

Efficacy of Chaetomium globosum bioformulation. A WP bioformulation of *C. globosum* (Cg2) proved effective

in reducing the severity of leaf rust infection (*Puccinia triticina*) to 10% in comparison to control showing 100% severity when used as pre-inoculation foliar spray @10^7 cfu/ml. The bioformulation also reduced the incidence of late blight of potato to 0.25% as compared to control showing 6% incidence. There was 30% increase in the yield of potato in treated plots over that of control.

Variability in Bipolaris* spp. *based on ITS region. Twelve isolates of *Bipolaris sorokiniana* and two isolates each of *B. specifera*, *B. tetramera*, *B. maydis* and *B. oryzeae* were analysed for genetic variability based on ITS region. Sequence analysis of ITS-1 region showed that *B. sorokiniana* isolates which shared 99-100% sequence identify among themselves and 92% identity with *B. specifera* and *B. tetramera* isolates, while there was only 30% sequence identity with *B. oryzeae* and *B. maydis* isolates.

Screening for resistance against diseases. Twelve out of 632 advanced wheat entries from IARI were identified as resistant to all three rusts across the test locations. Of the105 advanced wheat lines developed from IARI, 51 were free from loose smut infection when artificially inoculated with *Ustilago segetum tritici.*

4.1.1.2 Rice

Molecular characterisation of Rhizoctonia solani isolates causing sheath blight. Twenty-five *R. solani* isolates were characterized through PCR-RAPD technique. Of the 23 primers screened, 10 primer pairs exhibited reproducible and scorable bands with high percentage of polymorphism. Primers, namely, OPZ-20 and OPF-06 were useful for differentiating isolates. On the basis of Jaccard's similarity coefficient, four major groups were formed. Maximum similarity (84%) was observed between RS-14 and RS-15 isolates originating from Kerala. The lowest similarity (17%) was observed between RS-25 (New Delhi -Maize) and RS-20 (Sikkim) isolates.

Efficacy of fungicides in field. Five fungicides, namely, Metominostrobin 20 SC, Sanit 70 WDG (Metiram), Taqat 75 WP (Captan + Hexaconazole), Contaf 5 SC (Hexaconazole) and Dhanteam 75 WP (Tricyclazole) were evaluated against sheath blight at different concentrations in Pusa Basmati 1. All the fungicides were effective against sheath blight. Taqat 75WP @ 1.5 g/l was the most effective showing a disease reduction of 53.1% followed by Contaf 5 SC @ 2.0 ml/l (50%) and Metominostrobin 20 SC @ 2.0 ml/l (48.2%).

Screening for resistance against sheath blight. Of the 408 entries from IARI and the Directorate of Rice Research, Hyderabad evaluated against sheath blight under artificial epiphytotic conditions in field, RP 4092-365-117(IET 15120 × IR64), OR 2351-6 (Mahanandi PSRBC2), CN 1387-51-10-4 (IR 29429 × Swarna), IHRT- MS 7 (IET 20740), NDR 621, TKM 6, Sonasal, Binam, CR 2340-5, HBC 19 and SPS of Pusa 1554 series were observed promising.

Outbreak of blast on basmati rice. An unusual outbreak of blast was noticed in the rice growing areas of Uttar Pradesh and Haryana during *kharif*. The incidence was observed during nursery to flowering and maturity. Pusa Basmati 1 and Pusa 1121 were severely infected in most of the locations surveyed. In Mathura, up to 40% neck blast on Pusa Basmati 1 was recorded in farmers' fields.

Efficacy of different soil and seed treatments on control of bakanae disease caused by Fusarium moniliforme in paddy variety Pusa 1121. A field trial was conducted during *kharif* 2008 to assess the efficacy of different seed and soil treatments against bakanae disease caused by *Fusarium moniliforme* in paddy variety Pusa 1121. The disease incidence was minimum in soil amended with FYM+*Trichoderma viride* followed by that in soil amended with only *Trichoderma viride* and the maximum incidence in untreated soil. Also, the nursery raised from Bavistin treated seed gave significantly low incidence of disease followed by nursery raised from *Trichoderma viride* treated seed. The nursery from untreated seed transplanted in untreated soil had maximum disease incidence.

4.1.1.3 Maize

Resistance to diseases. Of the 219 elite maize genotypes evaluated against Maydis leaf blight (MLB) and banded leaf and sheath blight (BLSB) in artificial inoculation conditions, 18 lines, namely, DMR 428, DMR 432, DMR 365, DMR 383, DMR 389, DMR 391, DMR QOM-3, DMR QOM-5, DMR 1301, DMR 1306, DMR 1307, DMR 1313, DMR 1315, DMR 1322, DMR 1324, DMR 1325, DMR 1329 and DMR

1343 exhibited tolerance to both the diseases. Of the 90 inbreds evaluated against MLB and BLSB, three lines (pedigree 72278-7; 6589-2 and 6584-2) showed resistance against MLB, whereas none were resistant to BLSB. Inbred line SC 24-(92)-3-2-1-1 was registered (INGR 08117) with the National Genbank, NBPGR, New Delhi as a resistance source for MLB.

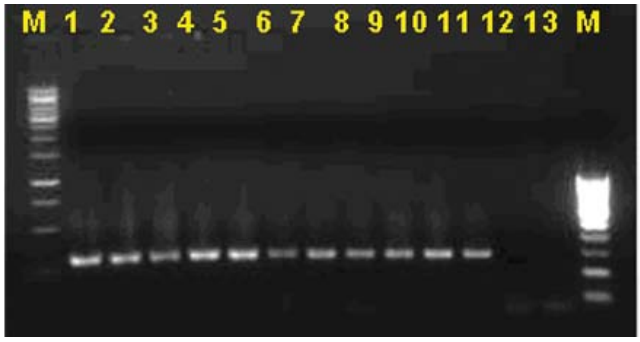
4.1.1.4 Chickpea

Evaluation of Pusa 5SD and Pusa Bio-pellet formulations against Fusarium wilt. The interaction of soil application of *Trichoderma viride* based Pusa Bio-pellet 4G (PBP 10G) and seed treatment with *T. harzianum* based Pusa 5SD + carboxim was the best for seed germination (59.1%), shoot length (54 cm), root length (15.3 cm) and grain yield (1.89 t/ha), and for lowest wilt incidence (9.4%).

Diversity among Rhizoctonia bataticola and R. solani isolates. The virulence analysis of 23 isolates of *R. bataticola* on a set of 10 chickpea cultivars grouped the isolates into 6 pathotypes but the groups were not strictly correlated with agro-ecological zones. Unweighted pair-group method with arithmetic averages (UPGMA) analysis of 226 RAPD markers generated by 26 ten-mer primers grouped the isolates into 6 clusters at 0.40 genetic similarities. The primers OPN 4, OPN 12 and OPN 20 were observed suitable for area specific grouping of the isolates.

Three hundred sixty isolates of *R. solani* isolated from different pulse crops varied in their cultural and morphological characters such as growth diameter, hyphal width, number and size of sclerotic. Majority of the isolates were pathogenic to cowpea, mungbean and urdbean as revealed in pathogenicity tests.

PCR based diagnostics of F. oxysporum* f. sp. *ciceris. PCR based diagnostics using primers derived from ITS region (FOC F2: AAACCCCGTGTGAACATACC and FOC R2: TTGAAATGACGCTCGAACAG) were developed for the detection of *F. oxysporum* f. sp. *ciceris* causing wilt of chickpea. The protocol was validated against 11 isolates originating from different locations, viz., New Delhi, Ranchi, Gurdaspur, Ropar, Faridkot, Ludhiana, Jaipur, Ganganagar, Udaipur, Sardargarh and Hisar.



Detection of *Fusarium oxysporum* f. sp. *ciceris* (FOC) isolates (lanes 1-11) by PCR amplification of ITS region. Lane 12: *F. oxysporum* f. sp. *cucumerinum,* lane 13: *Rhizoctonia bataticola,* lane M: 1kb molecular markers on left side

***Characterization of secondary metabolites and cell wall degrading enzymes produced by Trichoderma* spp.** Some of the secondary metabolites of *Trichoderma* spp. characterized by using GS-MS/MS were: 6-nonylene alcohol, massoilactone, 3-(2-propenyl)-4-(hexa-2", 4-dineyl)-2(5H furanone), 1-methyl cyclohexane, palmitic acid, 2-methyl heptadecanol, methyl-cyclopentane, N-methyl pyrollidine, 3-methyl heptadecanol, dermadin, ketotriol and koningin-A. Production of cell wall degrading enzymes when monitored revealed that β-1, 3 glucanase activity was the highest in *T. viride,* followed by *T. virens* and *T. harzianum,* whereas chitinase activity was the highest in *T. virens,* followed by *T. viride* and *T. harzianum.*

Evaluation of genotypes against major diseases. Of the 127 genotypes evaluated against their major diseases, ten chickpea genotypes, namely, H 04-31, H 04-87, WCG 2000-H, BG 391, GNG 1778, IPC 2005-64, Phule G 311-01, HK 04-178, IPCK 2003-56 and HK04-162 were observed to be resistant against wilt, whereas, only H 04-11 and H 99-9 were resistant to *Ascochyta* blight.

4.1.1.5 Urdbean

Resistance sources against major diseases. Three entries P 1059, P 1065 and P 1070 showed multiple resistant reactions against major diseases like *Cercospora* leaf spots, *Macrophomina* blight and *yellow mosaic virus.*

4.1.1.6 Mungbean

Integrated management of major diseases. A strategy for integrated management of major diseases was evolved.

A combination of seed treatment with thiamethoxam 70%WS (Cruiser) + Pusa 5 SD (*T. virens*) @ 4 g/kg each followed by two foliar sprays of the mixture of thiamethoxam 25% WG (Actara) 0.02% and carbendazim (Bavistin) 0.05% at 21 and 35 days after sowing showed maximum seed germination, shoot and root lengths, and grain yield along with minimum development of wet root rot (WRR), *Cercospora leaf spot* (CLS) and *yellow mosaic virus* (MYMV). However, a combination of similar seed treatment with one spray of the above mentioned mixture was more economical (Rs. 10.91 per rupee return) in comparison to two sprays (Rs. 7.92 per rupee return).

4.1.1.7 Pea

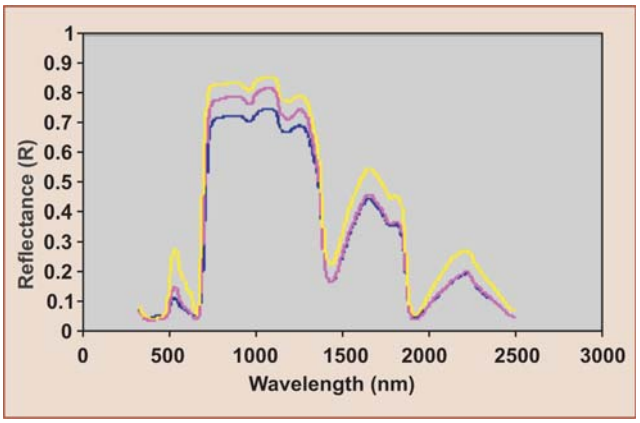
Resistance sources against powdery mildew. Sixteen field pea genotypes, viz., IFPS-19T, Pant P25D, Pant P 79, Pant P107T, VL 47T, DDR 7D, DDR 81T, KPMR 745T, KPMR 747, KPMR 814, KPMR 815D, NDP 7-101, NDP 7-201D, HFP 528D, HFP 531D and HFP 4R were found to be resistant against powdery mildew.

4.1.1.8 Pigeonpea

Components of slow wilting. The number of plants colonized (N) and the incubation period (IP) were identified as components of slow wilting in genotypes and these showed significant correlation. The relationship between AUDPC and the resistance components was AUDPC= 4845.799 – 16.127 (N) – 139.302 (IP), which explained the statistical relationship between the two variables with a coefficient of determination (R^2) of 0.986. This relationship may be viewed as an estimated resistance index (RI) for each genotype.

4.1.1.9 Soybean

Infrared reflectance to monitor yellow mosaic infection. For monitoring yellow mosaic infection, spectral indices of R565, R888, R1133, R1700 and R2250 were used. Soybean canopy reflectance (R) in visible, near infrared and shortwave infrared regions was influenced due to yellow mosaic infection. YMV infected soybean canopy showed an increase in R in visible (R565), near infrared (R888 and R1133) and shortwave infrared (R1700 and R2250) regions.



Spectral reflectance pattern in YMV infected soybean leaves: healthy (blue); severity grade 2 (pink); and severity grade 7 (yellow)

4.1.1.10 Rapeseed and mustard

Identification of resistance sources of Brassica against different diseases. Entries PBC 9221 and GSL 1 showed resistance against white rust (WR), downy mildew (DM), and stem rot (SR). Entries EC 338997and NRCDR 515 showed resistance to white rust (WR) and powdery mildew (PM), and NRCDR 513 showed resistance to white rust (WR) and stem rust.

4.1.1.11 Vegetables

Colonizing ability of biocontrol agents. Root colonizing ability of biocontrol agents viz., *Trichoderma harzianum* (Th3), *Aspergillus niger* (An27), *Pythium oligandrum* (F1524) and *P. lycopersicum* (KS121) was studied in vegetable crops infected with *Sclerotinia sclerotiorum,* and rice and maize infected with *Rhizoctonia solani.Trichoderma harzianum* (Th3) was a better root colonizer in comparison to *Aspergillus niger* (An27). *Pythium oligandrum* (F1524) and *P. lycopersicum* (KS121) were poor root colonizers, though showed antagonism against *S. sclerotiorum,* and *R. solani* in dual culture.

Validation of Trichoderma based bioformulation (Pusa Th3 SD). Powdered bioformulation (Pusa Th3 SD), effective against soil and foliar pathogens of vegetable crops, was patented. Field trials to demonstrate the efficacy of Pusa Th3 SD of *Trichoderma harzianum* in crops like

wheat, barley, cauliflower, cabbage, chillies, onion, and brinjal were conducted in three locations of Rajasthan (Samod, Chaksu and Degodh).

PCR based diagnosis of black rot of cole crops. A protocol for the specific diagnosis of black rot of cole crops (*X. campestris* pv . *campestris*) was standardized by using specific primers. Amplification of 619 bp was obtained from all the isolates of *X. campestris* pv. *campestris* and there was no amplification in other species of *Xanthomonas, Erwinia* and *Pseudomonas*.

4.1.1.12 Fruits

Bacterial blight, *Xanthomonas campestris* pv. *punicae-Xcp* which has become increasingly important in many pomegranate growing areas was studied for its isolates. Eight isolates from Delhi and Maharashtra were grouped into three major clusters at 50% similarity level based on genomic fingerprints generated through ERIC-PCR. An ERIC amplicon of 400 bp was exploited as scar marker for specific detection of Xcp.

For the management of seedling blight (*Sclerotium rolfsii*) and white root rot *(Dematophora necatrix)* of apple in nursery soil solarization was carried out during summer months. The rise in soil temperature was studied by using single or double layered of polythene sheet (25 µm) with or without vermicompost layer (2 cm) for ten weeks. The increase in temperature under only single layer tarp by 10 °C was observed at upper 10 cm depth, which reduced with the increasing soil depth. The maximum temperature of 37.57 °C at 10 cm and 33.28 °C at 20 cm soil depth was observed during the second week of June, reducing the survival of propagules of *Dematophora necatrix* (31.66 %) and *Sclerotium rolfsii* (46.66%).

A few promising biocontrol agents under *in vitro* conditions evaluated in pots against white root rot revealed that *Trichoderma viride* isolates (4 no.) were more effective in restricting the mortality of plants in the range of 6.25 to 12.5 per cent as compared to 37.5% in control, 25% in *Trichoderma hamatum* and *Azotobactor.* However, 81.25% plants showed disease symptoms in control and 50% in *Azotobactor* and 37.50% in *Trichoderma hamatum.*

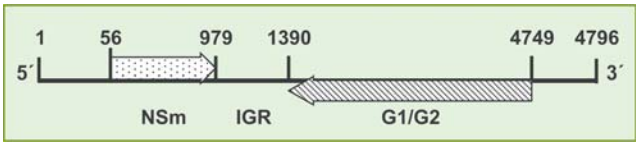
The volatile compounds released during the decomposition of these materials checked the growth of *D. necatrix* and *S. rolfsii* in petri plates, buried at 10 cm depth. The decomposing leaves of garlic inhibited mycelial growth of *Dematophora necatrix* and *Sclerotium rolfsii* by 67.50% and 36.85%, respectively. It was followed by lantana in the case of *D. necatrix* and cannabis in the case of *S. rolfsii*. Pre-inoculation application also reduced the disease incidence. The lowest root rot incidence was in the case of garlic leaves amended pots (31.25%) and banana (31.25%) followed by wild marigold (43.75%).

4.1.2 Viral Diseases

4.1.2.1 Viral genomics

Sequencing of medium (M) RNA of Groundnut bud necrosis virus (GBNV). The complete genome sequence of the medium MRNA (AY 871097) segment of GBNV (mungbean isolate) was determined. MRNA was 4815 nt long and had two non-overlapping ORFs in an amber sense arrangement separated by an intergenic region (IGR) of 422 nt, 14 and 75 nt longer than that of GBNV-type isolate and GBNV-tomato isolate, respectively. The IGRS shared 56-89% sequence identity, which was reflected in secondary structure. No definite biological function has yet been attributed to IGR sequence differences. The long ORF (2366 nt) was in viral sense stand (V) and encodes glycoprotein precursors (G1/G2) of 1122 aa long. The small ORF (924 nt) in viral complementary sense (VE) encodes 308 aa non-structural (NSm) protein.

Sequencing of medium (M) RNA of Watermelon bud necrosis virus (WBNV). WBNV was isolated from watermelon showing bud necrosis in the experimental field of IARI. MRNA of the genome was sequenced, which comprises 4796 nucleotides. MRNA contained two open reading frames (ORF) encoding movement protein (NSm) (from 56-979 nt, 307 aa, 34 kDa) and the precursors of G1 and G2 glycoprotein (from 1390-4749 nucleotides, 1119 amino acids, 124.44 kDa). MRNA shared 75.1-78.6% identity with WSMoV and GBNV, the two close relatives of WBNV; and only 44.9% identity with the TSWV, the type species under the genome *Tospovirus*. This is the first report of complete MRNA genome sequence of WBNV occurring in India.



Genome organisation of medium-RNA of *Watermelon bud necrosis virus* (WBNV). NSm: movement protein; G1/G2: precursor of glycoprotein. 1-4796 are nucleotide positions

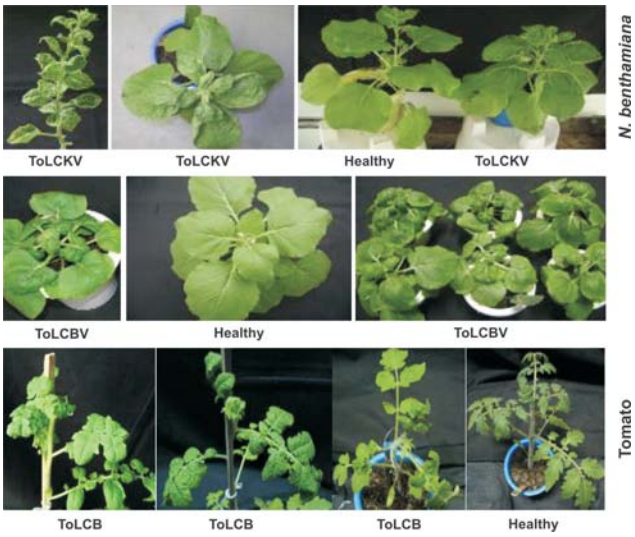
Complete genome sequencing of Papaya ring spot virus (PRSV). The complete genome of PRSV pathotype P from India (EF017707) is 10317 nt long excluding the 3 terminal poly (A) tail. The genome consists of a single ORF of 10023 nt commencing at position 86 and terminates with UGA at position 10109-11, followed by a 3 UTR of 206 nt. The ORF potentially encodes a polyprotein of 3341 aa. Comparative sequence analyses revealed that PRSV-P from India shared 83-89% and 90-92% overall sequence identities at the nucleotide and amino acid levels, respectively, with PRSV isolates from other countries.

***Partial genome sequencing of Citrus tristeza virus* (CTV).** Of the 19.3 kb genome of (CTV), about 8.1 kb genome from CTV isolate K9 from Darjeeling hills consisting of a part of ORF 1a and ORFs 6-11 was sequenced.

***Complete genome sequencing of Citrus yellow mosaic virus* (CMBV).** The complete genome of CMBV infecting Sathgudi sweet orange collected from Nagri village of Chittoor district of Andhra Pradesh was sequenced. The full genome is 7558 nt long and has six ORFs. Comparative sequence analyses revealed that CMBV under study shared 87-96% sequence identities with other CMBV isolates. Comparative sequence analyses with other badnaviruses showed that *Cacao swollen shoot virus* (CSSV), *Dioscorea bacilliform virus* (DaBV) and /*Dracaena mottle virus* (DaMV) had maximum identity of 44.1% to 48.3% with CMBV.

Role of pre-coat protein (ORF AV2) and coat protein (ORF AV1) of Mungbean yellow mosaic India virus (MYMIV) in pathogenicity. The role of pre-coat protein ORF AV2 and coat protein, ORF AV1 of *Mungbean yellow mosaic India virus* (MYMIV- cowpea and blackgram isolates) in pathogenesis was examined by making nested deletion spanning ORF AV2 and AV1 of DNA A of MYMIV. Nested deleted fragments of the six deletion mutants for coat protein gene (ORF AV1) region-three for N' terminal (AV1- Δ75, AV1- Δ150, and AV1- Δ211) and three for C' terminal (AV1- Δ57, AV1- Δ108, and AV1- Δ160), and two deletion of AV2 were completed. Partial tandem repeat (PTR) constructs of these two mutants pBinBgAV1-Δ150 (1.4 mer) and pBinBgAV1-Δ57 (1.55 mer) were mobilized into EHA 105 strain of *Agrobacterium tumefaciens* through triparental mating. *Agrobacterium* mediated infectivity of wild and AV1-mutants of MYMIV on French bean, cowpea and blackgram revealed that coat protein dependant pathogenicity in mungbean and cowpea was different from French bean. In French bean, the wild type showed 100% infectivity; however, BgAV1-Δ57 and BgAV1-Δ150 showed 71.4% and 88.5%, respectively. The mutants BgAV1-Δ57 and BgAV1- Δ150 did not show any symptom in cowpea and mungbean. Efforts to inoculate other mutants are in progress.

Infectivity of tomato begomoviruses. *Agrobacterium*-mediated infectivity was studied on *Nicotiana benthamiana* and tomato (Pusa Ruby) using partial tandem repeat (PTR) constructs of genomic components, DNA A DNA β of *Tomato leaf curl Bangalore* (ToLCBV) and *Tomato leaf curl Karnataka (ToLCKV) viruses* mobilized into *A. tumefaciens* strain EHA105. ToLCBV was infectious in both *N. benthamiana* and tomato, while TOLCKV was infectious only in *N. benthamiana.* Infectivity in *N. benthamiana* was seen at all the temperatures (23-35 ˚C), while infectivity was seen at 26-30 ˚C in tomato. ToLCKV in *N. benthamiana*



Agrobacterium* mediated infectivity of tomato begomoviruses on tomato cultivar Pusa Ruby and *N. benthamiana

exhibited vein thickening, crinkling in leaves and twisting of the petioles, while ToLCBV exhibited more backward curling, mottling and stunting. In tomato, ToLCBV constructs were readily infectious and produced puckering, mosaic, leaf curl and stunting symptoms.

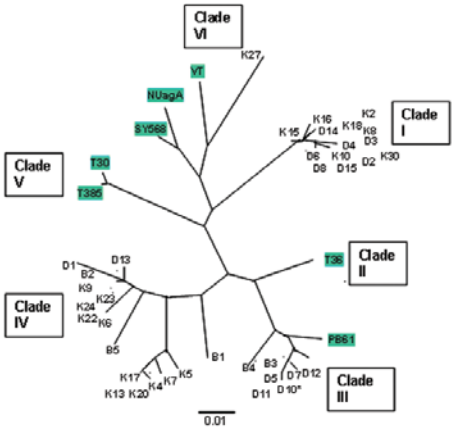
4.1.2.2 Molecular diagnosis

Detection of a new Mandarivirus from citrus. Mixed infection of a *Mandarivirus* with CMBV was observed in Sathgudi sweet orange sample collected from Chittoor district of Andhra Pradesh. The virus was decorated with polyclonal antibodies of *Indian citrus ring spot virus* (ICRSV), the type species of the genus *Mandarivirus*. A comparison of 1119 bp sequence of triple gene block TGB region with ICRSV revealed 67% nt sequence identity, suggesting a new *Mandarivirus* species infecting citrus in India.

PCR based diagnostic kit for citrus pathogens. A PCR based diagnostic kit for detection of RNA and DNA pathogens affecting citrus was developed. This could be used for simultaneous detection of two pathogens as mixed infection, i.e., CMBV and ICRSV in Sathgudi sweet orange, CMBV and CTV in sweet orange, and CMBV and greening bacterium in sweet orange.

4.1.2.3 Genetic diversity

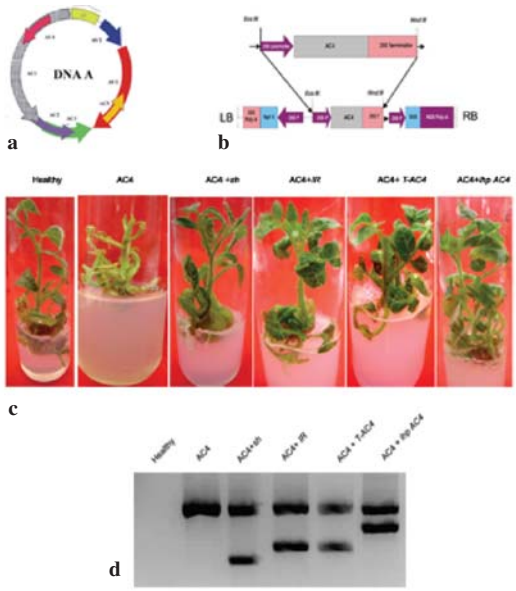
Citrus tristeza virus. A comparison of CP gene sequences of 38 CTV isolates: 19 from Darjeeling hills, 14 from Delhi and 5 from Bangalore revealed 89-99% identity among them. Out of these, 29 isolates were differentiated into four distinct phylogenetic clades. Clade I contained 14 isolates from Darjeeling hills and Delhi, clade III contained 7 isolates from Delhi and Bangalore, clade IV contained 7 isolates from Darjeeling, and Delhi, and clade VI contained 1 isolate from Darjeeling hills. Clade II and clade V did not contain any of the Indian isolates. Clade I and Clade IV are very distinct. Members of Indian CTVs in Clade III are related to an Australian CTV isolate PB 61 and Clade VI are related to Californian CTV isolate SY568, Japanese isolate NUagA and Israeli isolate VT.



A figure consisting of an unrooted phyllogenetic tree based on coat protein (CP) gene and revealing relationship of Indian CTV isolates with other international CTV isolates, and Indian CTV isolates forming four distinct phyllogenetic clades

4.1.2.4 Transgenic resistance

Role of RNAi suppressor AC4 in Tomato leaf curl New Delhi virus (ToLCNDV) pathogenesis. AC4 transgenic tomato *calli,* when transformed with various RNAi based



Expression of AC4 gene of TolCV and its silencing in healthy tomato: (a) DNA A particle of ToLCV genome carrying AC4, (b) diagram demonstrating the development of AC4 construct, AC4 ORF of ToLCV cloned directly into pUC118-35S at Noti site and full cassette containing 35S promoter, AC4 ORF and 35S terminator cloned in pCAMBIA 2301 at *BamH*I and *Hind*III site, (c) transformed tomato plants with AC4 expressing and silencing construct, showing phenotypic changes with overexpression of AC4 alone and with its silencing construct, (d) transgene confirmation of healthy tomato, and transgenic line expressing AC4 alone and with AC4 silencing construct through RT-PCR

AC4 gene constructs (short hairpin, inverted repeat, truncated and intron hairpin spliced) showed recovery in phenotypic aberrations, suggesting that AC4 protein is involved in host developmental biology by influencing miRNA pathways.

Agrobacterium-mediated transformation of citrus. Of the putative citrus transformants of *kagzi* lime generated through *Agrobacterium*-mediated transformation using coat protein (CP) gene (K9) in antisense orientation, 20 transformants were PCR positive. The transformants will be further confirmed by Southern analysis.

4.1.2.5 Citrus

Survey, collection and maintenance of virus and virus-like pathogens. Citrus *tristeza* virus (CTV) isolates were collected from orange orchards at Magarjung (Darjeeling), Sitong (Darjeeling), Soreng (Darjeeling) and 8th Mile (Kalimpong), indexed and maintained on *kagzi* lime (*Citrus aurantifolia*). Isolates of greening pathogen were collected from Magarjung (Darjeeling) and Soreng (Darjeeling). The isolates were indexed on Darjeeling orange (*Citrus reticulata*) and mausambi (*Citrus sinensis)*.

A survey conducted around Pune and Baramati revealed the occurrence of greening disease in sweet orange, acid lime and mandarin orchards and nurseries. The PCR result showed the presence of greening bacterium in sweet orange and acid lime. Representative samples of sweet orange plants from nursery were found infected with both CTV and ICRSV.

Biological characterization of citrus tristeza virus isolates from Darjeeling hills. Of the 23 CTV isolates from Sikkim and Darjeeling hills being maintained at IARI Regional Station, Kalimpong, results of indexing of six isolates on five species, viz., *kagzi* lime (*C. aurantifolia*), Darjeeling orange (*C. reticulata*), mausambi (*C. sinensis*), rough lemon (*Citrus jambhiri*), Rangpur lime (*Citrus limonia*) were obtained. The variations in the symptoms in these isolates and species of citrus were documented which could help in the diagnostics of the disease.

Transmission studies on virus-like pathogens. An isolate of greening pathogen from Darjeeling orange and two from pummelo (*Citrus grandis*) were indexed on Rangpur lime and rough lemon by top-cleft grafting. Three isolates of greening pathogen, one each from Darjeeling orange, pummelo and sour orange (*Citrus aurantium*), were successfully graft-transmitted to periwinkle (*Catharanthus roseus*) with per cent graft union being 20.

Citrus rubbery wood phytoplasma was indexed from *kagzi* lime to *kagzi* lime, Rangpur lime and rough lemon. The same isolate of phytoplasma could be successfully transmitted to eight month-old periwinkle plants by using dodder (*Cuscuta reflexa*). Initial symptoms of rubbery wood phytoplasma infection in periwinkle appeared after four months of indexing with dodder. The symptoms comprised downward curling of leaves, severe distortion of midrib and marginal chlorosis in leaves.

Rubbery wood-infected *kagzi* lime

Population monitoring and control of insect vectors. 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 1408 aphids/trap in the last week of January. The trap placed at 1' height recorded the maximum aphid catches compared to those placed at other heights. Fortnightly sprays of acetemaprid (0.01%) or imidacloprid (0.01%) or their combination at reduced doses (0.005%) with neem oil (1%) or sprays of dimethoate (0.05 %) alone could effectively control aphid and psyllid vectors on citrus.

4.1.2.6 Papaya

Monitoring of vector population. The visual observations on aphid colonization on papaya plants revealed the maximum number of aphids (nymphs and adults)

(10.47/plant), mummified (parasitized) aphids (0.7/plant) and predatory beetles (0.2/plant) on plants transplanted in October.

Alternate hosts of Papaya ring spot virus (PRSV), its incidence and varietal screening. Electron microscopy of leaf samples of infected weed plants such as *Xanthium indicum, Cassia tora,* and *Physalis minima* found in papaya fields showed flexuous PRSV particles confirming the above weed plants as alternate hosts of the virus.

By transplanting papaya during the lean period (spring season), PRSV infection could be delayed till monsoon, by which time the plants would cross the fruit bearing stage. The incidence of PRSV till fruit set was minimum on plants transplanted in early February (18.25%), followed by plants transplanted in mid (22.91%) and late (33.33 %) spring.

Effect of roguing of PRSV infected plants on productivity of papaya. Plant height and collar diameter at flowering and fruit maturity were significantly higher in the treatment combinations where PRSV infected plants were uprooted. Maximum yield was recorded in the case of no roguing; it was minimum when plants showing both mild and severe symptoms were uprooted. Roguing decreased the percentage infection in papaya plantation when compared with no roguing 100 days after transplanting. Roguing of PRSV infected plants increased the time taken for PRSV infection in neighbouring plants. However, the maximum yield was found in no roguing.

Plant height and collar diameter were significantly more in the case of farmers' practice when compared with control (no inorganic input) and recommended inputs. Yield and fruiting length were significantly higher than those of control both in the cases of recommended inputs and farmers' practice. During the initial 100 days after transplanting, the rate of PRSV spread was more in the cases of recommended inputs and farmers' practice than that in the control (no inorganic inputs).

In a screening trial, out of seven papaya cultivars tested, variety CO 2 showed the minimum PRSV incidence (54%).

Papaya cv. Red Lady showed higher yield and TSS, while Pusa Dwarf showed higher flesh thickness but lesser fruit length and TSS.

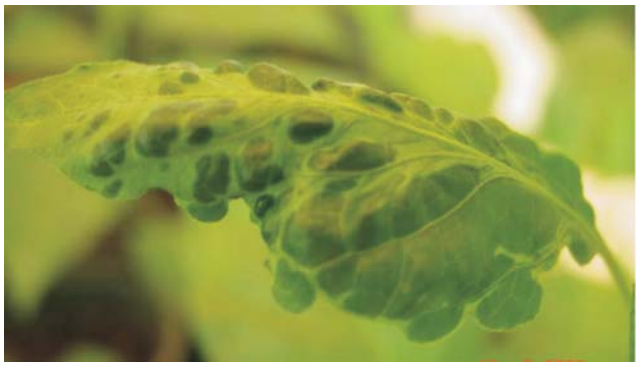
4.1.2.7 Peri-urban vegetables

Survey. A survey of virus diseases in muskmelon revealed the occurrence of ZYMV (10-15 %) and a strain of poty virus (80-100%) which resulted in total loss of crop to the farmers due to the decline of vines.

A survey of polyhouse grown capsicum varieties, Bomby and Lario, revealed the occurrence of tobamovirus (50-52 %).

Cucurbits virus diseases. In muskmelon, seven commercially grown varieties screened for virus diseases revealed the occurrence of a strain of poty virus causing severe losses to farmers due to the decline of muskmelon vines and cracking of fruits. Incidence of WBNV in watermelon could be effectively reduced to 5-10% by using silver colour polythene mulches even when the sowing and transplanting were carried out in February.

Chilli mosaic. Chilli cv. Bhoot Jalakiya or Naga Jalakiya (*Capsicum chinense*) was highly susceptible (infection percentage, 80) to chilli mosaic caused by PVY (incubation period, 10 to15 days). Infected Bhoot Jalakiya plants exhibited severe mosaic, blistering, downward curling and cupping of leaves, filiform leaves, and mosaic streaks on twigs and branches. The symptoms produced in chilli cv. Ghew Jalakiya were very mild and the virus had longer incubation period of 3 to 4 weeks.



Mosaic blisters in chilli cultivar Bhoot Jalakiya

4.1.2.8 Large cardamom

Evaluation of cultivars for resistance against chirke disease. Altogether six large cardamom cultivars comprising both high yielding and traditional, namely, Bharlangey, Dzongu Golsai, Green Golsai, Ramsai, Sawney and Seremna,

Screening of large cardamom cultivars against *chirke* disease

Cultivar	Plants inoculated (no.)	Plants infected (no.)	Per cent transmission	Days to symptom expression	Average incubation period (days)
Bharlangey	20	15	75	63 – 91	78.4
Dzongu Golsai	20	12	60	77 – 105	88.1
Green Golsai	20	9	45	84 – 112	96.4
Ramsai	20	14	70	70 – 98	81.5
Sawney	20	16	80	63 – 91	76.1
Seremna	20	4	20	98 – 126	112.0

were screened by mechanical inoculation of infective sap under glass house condition. Cultivars Bharlangey and Sawney were highly susceptible with 75% and 80% infection, respectively. Days to symptom expression ranged from 63 to 126 days. Seremna was relatively tolerant with only 20% of plants exhibiting symptoms, and the average incubation period was 112 days while it was 76.1 days for highly susceptible cv. Sawney.

***Evaluation of cultivars for resistance against mosaic disease*.** Six cultivars comprising both high yielding and traditional, viz., Bharlangey, Dzongu Golsai, Green Golsai, Ramsey, Sawney and Seremna, were mechanically inoculated with the sap extracted from mosaic-infected plant under glass house condition. Cultivars Bharlangey, Ramsai and Sawney showed 100% infection with the average incubation period ranging from 49.4 to 52.9 days; in cv. Seremna only 45% got infected and an average incubation period was 73.9 days.

Screening of large cardamom cultivars against mosaic disease

Cultivar	Plants inoculated (no.)	Plants infected (no.)	Per cent transmission	Days to symptom expression	Average incubation period (days)
Bharlangey	20	20	100	35 – 70	49.4
Dzongu Golsai	20	17	85	42 – 91	57.2
Green Golsai	20	14	70	49 – 98	64.5
Ramsai	20	20	100	42 – 84	52.9
Sawney	20	20	100	35 – 77	51.5
Seremna	20	9	45	63 – 98	73.9

4.1.2.9 Orchids

Host range of Cymbidium mosaic virus (CymMV) and Odontoglossum ring spot virus (ORSV). CymMV, upon mechanical sap inoculation, produced blotchy and chlorotic local lesions on inoculated leaves of *Chenopodium amaranticolor* and chlorotic local lesions (approximately 3 mm dia.) with necrotic centre in *Chenopodium quinoa*. ORSV, when sap-inoculated to orchid genera *Cymbidium* and *Phaius*, caused mosaic mottling consisting of rhomboid, mildly chlorotic blotches, blackish-brown necrotic spots and sunken brownish spots and streaks in the leaves. Colour break symptoms were exhibited by the flowers of ORSV-infected *Phaius walichii*. ORSV induced pin-point, chlorotic lesions which later turned necrotic in *C. amaranticolor,* and depressed, pin-point necrotic lesions in *Datura stramonium*. ORSV also spreads systemically in *C. amaranticolor* and induces mild vein clearing in uninoculated leaves.

Local lesions caused by ORSV in *Datura stramonium*

Flower colour break caused by ORSV in *Phaius walichii*

4.2 ENTOMOLOGY

4.2.1 Insect Pest Management

4.2.1.1Cereals

InfoCrop model. InfoCrop model was validated for growth and yield, and damage mechanism of planthoppers on rice variety Pusa Basmati 1. Simulated and observed days to 50% flowering were 73 and 74, respectively, while simulated days to physiological maturity were 106 compared to 110 observed days during *kharif* season.

The simulated yields in different treatments of the experiment were close to their observed counterparts varying by only 2.5% to 11.7 %, while the simulated yield loss varied from 15.4% to 41.7 % as compared to 8.1% to 42.3% observed yield loss. Likewise, simulated total dry matter (TDM) differed by only 1.4% to 9.9% from their observed values. Simulated TDM loss in these treatments varied from 9.0% to 20.8% as compared to 5.4% to 18.5% observed TDM loss. Proximity of simulated and observed yields as well TDM in different treatments indicated that damage mechanism of planthoppers was validated appropriately on Pusa Basmati 1. Further, the validated InfoCrop model was used for establishing the economic injury levels (EILs) of planthoppers for two insecticides, viz., monocrotophos and imidacloprid.

Simulated and observed reduction in yield of rice variety Pusa Basmati 1 due to incidence of planthoppers in different treatments

Insecticidal * application	Yield on dry weight basis (kg/ha)			
	Simulated (kg/ha)	Simulated loss (%)	Observed (kg/ha)	Observed loss (%)
60 DAT**	2409.5	34.1	2308.0	35.3
70 DAT	2147.1	41.3	2398.0	32.8
80 DAT	2967.6	18.9	2864.7	19.7
90 DAT	2780.1	24.0	2614.3	26.7
60 & 80 DAT	3093.9	15.4	3278.7	8.1
70 & 90 DAT	3044.9	16.8	3189.3	10.6
60, 70, 80 & 90 DAT (Healthy crop)	3658.0	-	3567.2	-
Untreated control	2131.7	41.7	2057.3	42.3
S.Em±			290.84	
C.D. (0.05)			623.79	

*** Monocrotophos 36 WSC @ 500 g a.i/ha; **DAT= Days after transplanting**

Brown plant hopper. The data on light trap catches of rice brown planthopper (BPH), *Nilaparvata lugens,* and weather factors, viz., maximum temperature (T_{max}), minimum temperature (T_{min}), morning relative humidity (RH_1) and evening relative humidity (RH_2) during 2000 - 2007 at Maruteru, Andhra Pradesh, were used for the development of multiple linear pest-weather regression model. Stepwise regression analysis was done to explore the most relevant combination of weather factors that could explain the variability in light trap catches. The pest-weather model involving three weather parameters, viz., T_{max}, T_{min} and RH_2, was found to be the best fit as all the three weather factors showed significant influence on light trap catches with the coefficient of determination (R^2) being 0.674. The eventual pest-weather model was established as:

$$\log BPH = 27.961 - 0.266\ T_{max} - 0.507\ T_{min} - 0.056\ RH_2 \quad (R^2 = 0.674)$$

The pest-weather model was interpolated with the Geographic Information System (GIS). A map of incidence was developed and categorized into four severity classes for ecological zoning purpose. This depicted severe and high level of incidence in central to western parts of Andhra Pradesh while moderate levels were shown for northern parts of Andhra Pradesh and in a strip in central parts of Andhra Pradesh running from north to south. On the other hand, low incidence of BPH was found in Nellore and north-eastern parts of the state. The agroecological zoning map was validated at different locations in Andhra Pradesh.

Termite incidence. Under rice-wheat cropping system, termite incidence (16.4 infested tillers/plot) was more in wheat grown after non-puddled rice (t = 4.72, 395 d.f.) than in the one that followed puddled rice (7.1 infested tillers/plot). Therefore, puddling in rice proved effective in reducing the termite incidence in wheat under rice-wheat cropping system.

4.2.1.2 Mustard

One hundred thirteen lines of mustard were screened against aphid *Lipaphis erysimi.* Infestation Index varied

between 0.4 and 2.5 at flowering and between 0.9 and 3.7 at pod formation stage. Studies on the bioefficacy of certain newer insecticides were undertaken on *Pieris brassicae* infesting "Swarnim" Ethiopian mustard (*Brassica carinata* L.). Indoxacarb (0.005%) caused 100 % mortality, followed by ethofenprox (0.01%) which gave 99.76% mortality, followed by treatment with insecticide mixture of chlorpyriphos-cypermethrin (0.05%), and triazophos (0.05%) which reduced larval population by 99.65% and 99.21%, respectively.

4.2.1.3 Soybean

Ninety-three lines of soybean were evaluated against stem fly and *yellow mosaic virus* (YMV) disease transmitted by white fly. Varieties DS 2207 and DS 2309 showing resistance continuously were identified as a promising source of resistance. Seed treatment with imidacloprid @ 10 g/kg seed or thiamethoxam 70 WS @ 1.5 g/kg seed were found equally effective against major pests of soybean.

4.2.1.4 Cotton

Evaluation of insecticides carried out in cotton variety PS 8-6 revealed less incidence of sucking pests but high incidence of bollworm *Earias* spp. Spinosad 45SC at 75 g a.i./ha was highly effective in controlling terminal bud damage. Similarly, spinosad and indoxacarb 45 SC at 75 g a.i./ha each were equally effective in controlling the damage of shedded reproductives. Third treatment at 108 days after sowing with profenofos 50EC at 1000 g a.i./ha was most effective in controlling the damage of green boll, open ball and seed cotton besides the larval incidence, and gave the highest yield of 2.67 t/ha.

Nine different combinations of insecticides evaluated against major pests of cotton indicated endosulfan 35EC @ 750 g a.i./ha and emamectin benzoate 5SG @ 11 g a.i./ha sprayed 55 days after sowing to be most effective against terminal bud damage while a second spray of profenofos 50EC @ 1000 g a.i./ha and spinosad 45SC @ 75 g a.i./ha effectively reduced the damage of shedded reproductives. A third spray at 110 days after sowing with triazophos 40EC @ 750 g a.i./ha and spinosad 45EC @ 75 g a.i./ha was most effective in controlling the damage of green boll, open boll and seed cotton besides larval incidence, and gave the highest yield of 3.05 t/ha. All the insecticidal treatment combinations gave higher yield compared to their single sprays.

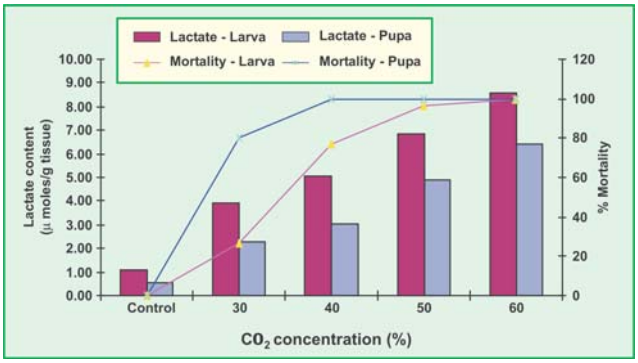
4.2.1.5 Vegetables

Insect pest management schedule developed earlier was validated for okra var. A 4 in the farmers' fields at Kanpur and Muradnagar. Border cropping of baby corn seed treatment with thiamethoxam (70 WS) @ 5g/kg seed and imidacloprid (70 WS) @ 5g/kg seed, roughing of YVM affected plants and clipping off shoots damaged by borer, spray of acetamiprid @ 20 g a.i./ha after 30 days of sowing followed by a spray of emamectin benzoate @ 10 g a.i./ha after 45 DAS and a third spray of spinosad @ 80 g a.i./ha were validated as IPM measures. Farmers could be benefited to an extent of 15-20 per cent over normal yields.

Studies on brinjal (var. Pusa Kranti) shoot and fruit borer revealed the superiority of thiamethoxam- spinosad and emamectin benzoate with the highest yield of 24.35 t/ha.

4.2.1.6 Storage entomology

In studies on the modified atmosphere in storage, toxicity of carbon dioxide was evaluated against *Trogoderma granarium*. An exposure period of four days made egg and adult stages more susceptible compared to larval and pupal stages. The mortality of the egg, pupal and adult was directly proportional to their age; it was lower in the fifth instar larvae, while young adults showed more tolerance. Complete mortality was observed for egg, larva, pupa and adult at higher concentrations. Further the lactate content in larvae and pupae of *T. granarium* was found to increase



Effect of CO_2 on the lactate levels(µ moles/g tissue) in the larvae and pupae of *T. granarium* exposed to different CO_2 concentrations (%) at 35 °C and 4 days' exposure period

Effect of CO_2 on *T. granarium* with 4-day exposure period at 35 °C

CO_2 concentration (%)	Egg stage			Larval stage			Pupal stage			Adult stage		
	1-day old	2-day old	3-day old	I instar	III instar	V instar	2-day old	4-day old	6-day old	2-day old	4-day old	6-day old
5	10.00 (18.43)	16.67 (23.85)	26.67 (30.99)	-	-	-	-	-	-	-	-	-
10	16.67 (23.85)	23.33 (28.78)	40.00 (39.23)	-	-	-	10.00 (18.43)	23.33 (28.78)	30.00 (33.22)	3.33 (6.75)	6.67 (12.59)	6.67 (12.59)
15	33.33 (35.22)	40.00 (39.23)	76.67 (61.22)	6.67 (12.59)	6.67 (12.59)	0.00 (0.90)	16.67 (23.85)	36.67 (37.22)	36.67 (37.22)	13.33 (21.15)	26.67 (30.99)	26.67 (30.99)
20	50.00 (45.00)	66.67 (54.78)	86.67 (68.85)	20.00 (26.57)	10.00 (18.43)	3.33 (6.75)	30.00 (33.22)	46.67 (43.08)	46.67 (43.08)	26.67 (30.99)	36.67 (37.22)	43.33 (41.15)
25	76.67 (61.22)	83.33 (66.15)	96.67 (83.25)	33.33 (35.22)	20.00 (26.57)	10.00 (18.43)	36.67 (37.22)	53.33 (46.92)	70.00 (56.79)	46.67 (43.08)	56.67 (48.85)	56.67 (48.85)
30	90.00 (71.57)	100.00 (89.09)	100.00 (89.09)	40.00 (39.23)	30.00 (33.22)	26.67 (30.99)	66.67 (54.78)	76.67 (61.22)	80.00 (63.44)	63.33 (52.78)	66.67 (54.78)	76.67 (61.22)
35	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	66.67 (54.78)	56.67 (48.85)	50.00 (45.00)	83.33 (66.15)	93.33 (77.41)	93.33 (77.41)	80.00 (63.44)	86.67 (68.86)	93.33 (77.41)
40	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	86.67 (68.85)	80.00 (63.44)	76.67 (61.22)	93.33 (77.41)	100.00 (89.09)	100.00 (89.09)	90.00 (71.57)	96.67 (83.25)	00.00 (89.09)
45	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	93.33 (83.25)	96.67 (83.25)	86.67 (68.85)	96.67 (83.25)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)
50	-	-	-	100.00 (89.09)	100.00 (89.09)	96.67 (83.25)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)
55	-	-	-	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	-	-	-	-	-	-
60	-	-	-	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	-	-	-	-	-	-
Control	0.00 (0.90)	0.00 (0.90)	0.00 (0.90)	0.00 (0.90)	0.00 (0.90)	0.00 (0.90)	0.00 (0.90)	0.00 (0.90)	0.00 (0.90)	0.00 (0.90)	0.00 (0.90)	0.00 (0.90)
Mean	57.67 (52.35)	63.00 (57.00)	74.67 (64.08)	58.79 (53.52)	54.55 (49.20)	50.00 (45.00)	53.33 (48.43)	63.00 (56.28)	65.67 (57.93)	52.33 (46.88)	60.33 (53.65)	60.33 (53.65)
CD at 5%	(3.76)	(4.53)	(6.68)	(8.09)	(7.50)	(8.17)	(8.90)	(6.94)	(6.03)	(6.86)	(8.96)	(8.62)
S.E.	1.70	2.17	3.20	3.90	3.62	3.94	4.27	3.32	2.89	3.29	4.29	4.13

proportionately with dose of CO_2. Within the same levels of CO_2 concentrations, the larvae accumulated higher amount of lactate compared to that of the pupae.

4.2.2 Biological Control

In the Biological Control Laboratory, a total of 36 insect species comprising 15 parasitoids, 6 aphidophagous and 4 coccophagous (*Brumoides lineatus, cryptolaemus montrouzierim Nephus regularis, Scymmus coccivora*), 4 predatory green lacewings and their 6 laboratory hosts and parthenium beetle were maintained. Laboratory rearing technique of an endoparasitoid, *Aenasius* sp. was successfully developed. Suitability of frozen grubs of *Tribolium castaneum* for the mass production of *M. astur*

and *M. basalis* was evaluated, and an alternative host in place of *Corcyra cephalonica* accomplished.

Molecular differentiations among the green lacewings sourced from cotton field revealed the presence of 1166 base pairs in *C. carnea* and 1142 in *M. boninensis* in their rDNA sequence, indicating that ITS region was a reasonable target for their molecular diagnostics. These sequences have been submitted to NCBI, GenBank and designated with the accession numbers EF 650642 and EF 650643 for *C. carmea* and *M. boninensis*, respectively.

Sixteen recipes of WP formulations of *Bacillus thuringiensis* var. *kurstaki* (HD-1) were developed in laboratory using eight carriers, $BaSO_4$, bentonite, dolamite, Fuller's earth, kaoline, precipitate of silica, pyrophyllite and talc. Bioassays were conducted against 3rd instar larvae of *H. armigera* by diet-incorporation method using six concentrations of these recipes. On the basis of laboratory performance, two best recipes (recipe-7 and recipe-8) were selected for field efficacy studies through LC_{50}.

Results showed that the LC_{50} (%) ranged between 0.015 and 0.078. On the basis of the results, two of the recipes were found to be more effective.

Behavioural studies with males and females of *A. angaleti* indicated that infochemicals from its host *Pectinophora gossypiella* and host habitat elicited weaker response from the males compared to the females. The basis of differential response was further probed by using SEM studies which indicated that variation in the response of the sexes may be due to the presence in large number of the olfactory receptors and, basiconic sensilla, which are distributed in large numbers at the tip of the last flagellal segment of female *A. angaleti*.

4.2.3 Insect Physiology

The protease inhibitor (PI) isolated from a tree legume *Acacia nilotica* (ANPI), inhibited the total proteolytic activity of *H. armigera* gut to a maximum of 86.25% when sodium caseinate was used as the substrate. This inhibitory activity was significantly higher than that of all the other PIs tested and on a par with that of standard SBTI which caused 86.27% inhibition. Similarly, specific activities of 3,693 and 3,313 units/min/mg protein was observed for ANPI and SBTI, respectively, which were significantly different from those of other PIs, viz., SBPI, ASPI and FBPI. Among these, FBPI caused higher inhibition of 80.72% though not significant from others.

Inhibition of *H. armigera* larval gut protease activity by proteinase inhibitors

Inhibitor source	Specific activity (Units min^{-1} mg^{-1} protein)	Per cent inhibition over control
Glycine max (SBPI) 5.0µg	5733 ± 1621.40*	78.66 ± 2.00*
A. senegal (ASPI) 5.0µg	5193 ± 362.95	80.67 ± 1.00
Phaseolus vulgaris (FBPI) 5.0µg	3693 ± 11.55	86.25 ± 1.00
A. nilotica (ANPI) 5.0 µg	5180 ± 385.74	80.72 ± 5.00
Standard SBTI 5.0µg	3313 ± 358.51	87.67 ± 2.00

Substrate: sodium caseinate, * values are mean +SD for at least three replications (P<0.05)

The midgut esterase activity in three different populations of the cotton bollworm *Helicoverpa armigera* revealed that Nagpur strain has the highest esterase activity followed by the Delhi strain. Consequently the Nagpur strain could degrade the pyrethroids more efficiently as signified by four fold esterase specific activity when compared to a susceptible strain. Studies were carried out on detection of *Cry1Ac* and *Cry2Ab* toxin in F_1 and F_2 seeds of some Bt cotton hybrids with ELISA based Bt detection strips. The ELISA strip tests indicated that the Bt-F_1 seeds of JKCH-1947 and JKCH-555 were generally pure with respect to *cry1Ac* gene but the Bt-F_2 seeds were genetically less pure with respect to *cry1Ac* gene JKCH-1947 (74.5%) and JKCH-555 (85.3%). Similar trend was found in the plants. Genetic purity of F_1 cotton seeds belonging to Bollgard-II series carrying *cry1Ac* + *cry2Ab* genes varied in KDCHH-441 (86.66%), MRC-7301 (88%), KDCHH-621 (94.67%) and MRC-7326 (100%). The genetic purity of Bt-F_2 seeds of four Bollgard-II cotton ranged from 36%-63%. As high as 12% seeds of MRC 7301Bt F1 were either with *Cry1Ac* or *Cry2Ab* expression. The above results indicate the necessity of maintaining rigorous seed quality standards of Bt cotton hybrids.

Studies were conducted on the inheritance of Cry1Ac resistance. Nine pairs of DNA primers (1F, 9R) were used to amplify the full-length of DNA of susceptible, resistant, and F_1 progeny. Out of these, only the 7th pair (7F-CGAGGAACATCATGTGTGAAG;7RAGTGTAGAAGCCTG CAGGAC) showed difference between the susceptible and resistant genotypes. The banding pattern showed that all the susceptible parents had a 588 bp fragment, while the resistant parent specifically had a 553 bp fragment. In addition to this, 28.6% resistant parents were found to have a 717 bp fragment and 71.4% adults had a 507 bp fragment. Among the progeny of S@&RB& cross, 42.1% individuals had both 507 and 588 bp fragments, and 31.6% individuals had 553 and 588 bp fragments. While in the reciprocal cross R@&SB&, 52.6% individuals were found to have a fragment of 588 and 717 bp, 42.1% individuals had 553 and 717 bp fragment. The amplicon of 717 bp was found to be present only in the resistant parents and R@&SB& individuals, while it was absent from the SR progeny.

4.2.4 Insect Toxicology

Outbreak of brown planthopper (BPH), *Nilaparvata lugens,* on rice witnessed in Delhi, Haryana and western Uttar Pradesh during September-October of 2008 led to toxicological studies with eleven insecticides treatments taking into account the tolerance of neonicotinoids even at double the recommended concentration. Two populations of BPH from Delhi and the nearby Palla village were evaluated and these confirmed the tolerance of populations to neonicotinoids. It was concluded that endosulfan was the most effective insecticide and showed be recommended against the brown plant hopper under such outbreak conditions.

Field efficacy of insecticides was evaluated against okra fruit borer in var. Varsha Uphaar. Two dosages of each insecticide were used in the first foliar spray while a second spray of endosulfan was given in all the treatments after a fortnight. Borer damage in marketable fruits in different treatments ranged from 1.81% to 12.23% as compared to 15.09% in control. All the treatments except one proved highly effective ($p>0.01$). On the basis of number of fruit borer infestation varied from 1.38% to 12.84%, compared to 17.65% in the untreated check.

Jatropha aqueous extract was bioassayed against the neonates (0-24 h old) of *H. armigera* by artificial-diet surface incorporation assay under controlled conditions (temp. 27+2 ^{0}C, RH 60-70%, 16: 8-h scoto/photophase). Aqueous extracts at 0%, 1%, 3%, 5%, 10%, 15% and 20%, wt/v were incorporated on the surface of wheat germ-based diet. The larval mortality recorded was 3.34%, 46.67%, 43.34%, 46.67%, 33.34%, 43.34%, and 60% till pupation. Mortality plus the abnormal individuals constituted 10%, 76.67%, 60%, 60%, 60%, 63.34%, 66.67% and 10% at 0%, 1%, 2%, 3%, 5%, 10%, 15% and 20% dose of aqueous extract. As the bioassay was topical artificial-diet-incorporation, complex feeding behaviour of the test-insect interfered with avoidance, and feeding deterrence differentially to various test-concentrations and accounted for the resultant discrepancies (inconsistent outcomes, not dose-dependent) in the data-set obtained. Larval- and pupal-weights recorded also exhibited no definite trend. There was delayed larval- (>21-day) and pupal-periods (>10-day) as against normal (control), i.e., 15

Toxicity of different insecticides against *Nilaparvata lugens* - Delhi and Palla populations

Insecticide	$LC5^0$ (%)		Relative toxicity of insecticide		Relative susceptibility of insect	
	D	P	D	P	D	P
Imidacloprid 17.8 SL	0.003	0.002	1.86	1.80	1.00	1.50
Acetamiprid 20 SP	0.0237	0.0212	0.23	0.16	1.00	1.75
Thiomethoxam 25 WG	0.0134	0.0091	0.41	0.39	1.00	1.47
Fipronil 5 SC	0.0030	0.0037	2.15	0.63	1.00	0.45
Flubendamide 39.35 EC	0.3685	0.3685	0.01	0.009	1.00	1.00
Endosulfan 35 EC	0.0007	0.0007	8.00	5.14	1.00	1.00
Monocrotophos 36 WSC	0.0056	0.0036	1.00	1.00	1.00	1.55
Clothianidin 50 WDG	0.0160	0.0158	0.35	0.22	1.00	1.01
Buprofezin 25 EC	0.0056	0.0051	1.00	0.70	1.00	1.10
Flubendamide+ Fipronil	0.0081	0.0061	0.69	0.59	1.00	1.32
Chlorpyriphos 20 EC	0.0015	0.0013	3.7	2.76	1.00	1.15

Evaluation of field efficacy of insecticide against okra shoot and fruit borer *Earias vittella*

Insecticide/ treatment	Dose (g a.i./ha)	Per cent infestation (number basis)	Per cent infestation (weight basis)
Bifenthrin-endosulfan	25700	5.83 (13.34)	6.62 (11.27)
Bifenthrin-endosulfan	50700	1.79 (7.75)	3.17 (10.21)
Indoxacarb-endosulfan	70700	2.58 (8.98)	2.47 (9.00)
Indoxacarb-endosulfan	140700	3.81 (11.05)	3.13 (7.76)
Fipronil-endosulfan	50700	3.51 (10.77)	2.83 (9.65)
Fipronil-endosulfan	100700	4.10 (11.60)	3.73 (11.04)
Acetamiprid-endosulfan	25700	4.54 (12.09)	3.21 (10.32)
Acetamiprid-endosulfan	50700	1.38 (6.70)	1.81 (7.70)
Thiamethoxam-endosulfan	25700	10.60 (18.75)	9.69 (17.98)
Thiamethoxam-endosulfan	50700	10.73 (19.12)	9.03 (17.48)
Imidacloprid-endosulfan	20700	12.84 (20.73)	12.23 (20.35)
Imidacloprid-endosulfan	40700	4.03 (8.57)	4.85 (12.69)
Miocene (50% chlorpyriphos + 5% cypermethrin)-endosulfan	1 lit/ha 700	3.88 (11.33)	5.25 (13.06)
Miocene (50% chloropyriphos +5% cypermethrin)-endosulfan	2 lit/ha 700	5.44 (13.48)	6.16 (14.35)
Control	-	17.65 (24.82)	15.09 (22.81)
S.E.		1.93	1.49
C.D.(0.05)		3.96	3.05
C.D.(0.01)		5.34**	4.11**

Note: Figures in parentheses are angular transformed values

and 10-day. More detailed research is envisaged to appreciate the bioactivity of this botanical.

Antifeedant activity of five neem formulations, viz., azadirachtin (Aza, 60%), Econeem®, Achook®, Vijayneem® and neemoil were studied against third instar larvae of *Pieris brassicae*. Although larval growth inhibition was noted for all the test-concentrations, Aza exhibited consistently good result.

4.3 NEMATOLOGY

4.3.1 Biodiversity

4.3.1.1 Plant parasitic nematodes

Nematode biodiversity. Analysis of nematode communities in 55 soil samples from the rhizosphere of different field crops and fruit trees growing in 8 districts (Imphal, Churachandpur, Chandel, Tamenglong, Senapati, Ukhrul, Thoubal, Bishnupur) of Manipur and 21 samples from Pasighat, Twang, Dibang valley of Arunachal Pradesh was done. In Manipur, *Rotylenchulus reniformis, Meloidogyne incognita, Hirschmanniella oryzae, Helicotylenchus dihystera* and *Tylenchorhynchus nudus* were the predominant ones associated with field crops. *Helicotylenchus dihystera, Aphelenchus avenae* and dorylaimids were the most frequently occurring nematodes in the samples of Arunachal Pradesh along with a few *Pratylenchus thornei* and *Acrobeles* sp. In general, criconematid nematodes were abundant in association with fruit trees. The presence of rice-root nematode *Hirschmaneilla oryzae* was encountered in rice growing areas (Nilokheri and Kamalpur) in Karnal district of Haryana, whereas *Meloidogyne incognita* and *Tylenchorhynchus brevilineatus* were found in vegetable growing areas of *Khaddar* (along the river Yamuna) region of Karnal district of Haryana. The Dominance of root-knot nematode *Meloidogyne incognita* was observed in vegetable-based cropping system being followed in Bareilly district of Uttar Pradesh.

4.3.1.2 Entomopathogenic nematodes

For ecological characterization, infectivity and development of *Steinernema* sp. from J&K was studied at five temperature conditions (10 ^{0}C, 15 ^{0}C, 20 ^{0}C, 25 ^{0}C, and 30 ^{0}C). The optimum temperature for the infectivity and

reproduction was 25 °C with an optimal range 23-25 °C. To know the optimum moisture required, its infectivity was recorded at different moisture levels (3%, 7%, 9%, 11%, 13% and 16% w/w). The nematode could successfully penetrate the insect at 7- 13% moisture, the maximum penetration being at 11% level. Two new strains of *Steinernema,* one each from Orissa and Assam, were isolated. Based on the morphological and morphometrical features of the infective juveniles, males and females of two generations, the strains were identified as *S. carpocapsae* from Orissa, and *Steinernema bicornutum* from Assam.

Bioefficacy studies of 6 entomopathogenic nematode species/strains against scarab larvae showed 100% mortality of the larvae within 5-6 DAI, with *S. glaseri* being highly efficacious, followed by *S. thermophilum, H. indica, S. riobrave, S. carpocapsae, Heterorhabditis* (Haryana-2 strain), *H. bacteriophora* and *Heterorhabditis* (Haryana-4 strain). Of the four culturing media tested for *in vitro* mass production of *S. thermophilum,* egg yolk medium was found to be most suitable and efficient for obtaining maximum harvest (5×10^6 infective juveniles/ 500 ml flask), followed by Wout's medium (3.5×10^6 infective juveniles/ 500 ml flask). Nematode suppressive metabolites were found in culture filtrates of an actinomycete *Streptomyces purpeofuscus* MTCC 6473. The cell free filtrate caused *in vitro* mortality of 59.4% in second stage juveniles and 41.5% decline in egg hatch of root-knot nematode *M. incognita*.

4.3.1.3 Molecular characterization

Important genes from cereal cyst nematode *Heterodera avenae* required for feeding and infection processes were cloned using cDNA library of infective juvenile stage for the first time to explore their potential use for management. The functional validation of these genes is being done by using RNA interference technique. Similarly, such genes are also being cloned from root-knot nematode *Meloidogyne incognita* and validated by RNAi technique. A synthetic peptide was identified that could reduce the egg production by about 60% in *M. incognita*.

4.3.1.4 Host-parasite interaction

PR protein synthesis was observed on root-knot nematode inoculation as well as on salicylic acid application in chickpea. Changes in chitinase activity with respect to systemic acquired resistance in cowpea were observed with the spray of salicylic acid (SA). The 27 kDa and 35 kDa proteins were visible only in SA spray and inoculated cowpea plants. Also the spray of jasmonic acid (JA) on pigeonpea reduced the penetration of pigeonpea cyst nematode *Heterodera cajani*.

4.3.1.5 Management

Two field trials were conducted at Jhundpur village of Sonepat district –one in rice against root-knot nematode *Meloidogyne graminicola* and the other in bottle gourd against *M. incognita.* Carbofuran and triazophos were effective and showed maximum reduction in population (about 23.5%), and increase in yield. Carbofuran @ 1.0 kg a.i./ha and neem seed kernel were found effective in reducing the population by 14.3% and increasing the yield.

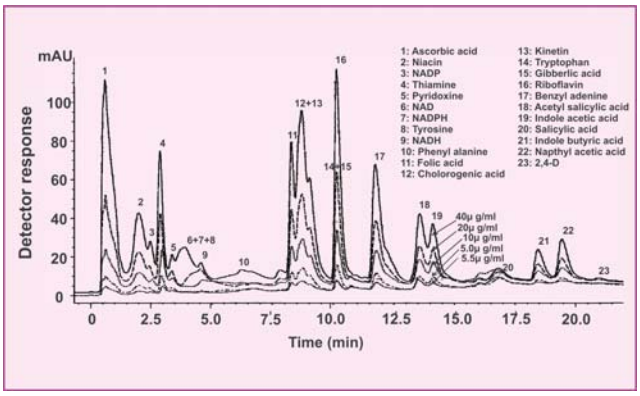
Experiment on soaking of root-knot infected tuberose bulbs with carbosulfan, triazophos and dimethoate at 500, 1000, 2000 and 4000 ppm concentrations for two hours showed that the treatment with carbosulfan @ 4000 ppm was most effective in reducing over 70% of nematode galls, egg masses and soil population of root-knot nematodes, 70 days after tuberose planting. Similarly, a temperature of 50 °C for 45 min was most effective resulting in a reduction of over 43% in the number of galls, egg masses and soil population of nematode.

Studies on the management of *Meloidogyne incognita* with Sannhemp both in yellow and black types revealed that the penetration of nematode in test plant was a bare minimum of 10% of inoculation, which further did not develop suggesting its importance as good antagonist. It was also observed that the penetrated juveniles left the root quickly may be because of unfavorable conditions in the root.

A field trial was undertaken with *Calotropis procera* leaves + twigs @ 200 g/plot (one week before sowing), neem Aza @ 100 kg/ha and carbosulfan 36 STD @ 1 kg a.i./ha. All the treatments were found to be effective in reducing *R. reniforms* population. However, maximum reduction was observed in the treatment where all three components were used together, and the yield was also maximum.

On okra. cv. Pusa Acra the field efficacy of neem oil emulsion @ 250 ppm seed dip for 6 h, neem Aza @ 100 kg/ha, carbosulfan @ 1 kg a.i/ha, and various combinations was evaluated. Maximum reduction of *R. reniforms* was found in 3 combinations treatment and accounted for the highest yield of okra (cumulative pickings of okra fruits). All the treatments significantly reduced *R. reniformis* population and enhanced the yield.

A new low-cost technology for simultaneous metabolomics of 23 major biochemical chemotypes - selected amino acids, coenzymes, growth regulators and water soluble vitamins from tomato and chickpea was developed with a limit of detection (LOD) 1-2 µg/ml and a limit of quantification (LOQ) 5 µg/g by liquid chromatography. A new liquid chromatographic (LC) method for estimation of free and bound glutathione in oxidized and reduced forms from tomato and chickpea was also developed.



Chromatogram of amino acids, coenzymes, growth regulators and water soluble vitamins by liquid chromatography

4.3.2 Insect Management

A water soluble formulation of anhydrobiotic entomopathogenic nematode developed was found to be most effective against the white grubs (*Holotrichia* spp.). Field trials were carried out in sugarcane fields heavily infested with white grubs in Modipuram areas of western Uttar Pradesh. Soil inundation with the nematode formulation @ 2.5x 10^5 IJ/2 m^2 plots was able to control 70% of the white grubs. The combined dose of nematode and chlorpyriphos @ 80 ml/2 m^2 showed a synergistic effect by controlling 85% of the white grubs.

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 anthraquinone derivatives from Rheum emodi (Indian Rhubarb). Four anthraquinone related compounds, namely, chrysophanol [MH^+ 264], physcion [MH^+ 284], emodine [MH^+ 270] and aloe-emodine [MH^+270], were identified from chloroform extract of the roots of Indian Rhubarb. These showed better antifungal activity as compared to methanol and ethyl acetate extracts against *Macrophomina phaseolina*, *Sclerotium rolfsii* and *Fusarium oxysporum* (ED_{50} = 77.5, 150.9 and 98.8 ppm, respectively).

Isolation, identification and antifungal activity of essential oil constituents of Lanatana camara. The oil obtained by hydrodistillation of dried and fresh leaves of *L. camara* L. was found to be a complex mixture of numerous sesquiterpenes, namely, caryophyllene, humulene, curcumene, germacrene, limonene, cadinene, sabinene, longifolene, nerolidol, phellandrene, and 1, 8-cineole. The leaf oil at 1mg ml^{-1} concentration exhibited 100% growth inhibition of the two test fungi, namely, *Rhizoctonia solani* and *S. rolfsii.*

Identification of antagonist microbe colonizing rice. Twelve microbial isolates were isolated and purified from rhizosphere soil of a healthy rice plant. One of isolates KM5 showed antagonist activity *in vitro* against *S. rolfsii* Saccardo, *Helminthosporium oryzae, Gibberella fujikuroi, R. solani* Nees and *F. udum.* KM5 was characterized as a species of *Bacillus* through microscopic biochemical and molecular techniques and confirmed as a new strain of bacterium named as *Bacillus* sp. KM5. Partial sequence of 16S rRNA gene was deposited to NCBI GenBank data base with Accession No. EU 266068 and deposited to MTCC with Accession No. MTCC-5413.

Antifungal activity of major chemical constituents isolated from Bacillus lichniformis. Chemical constituents such as 1-methyl pyrrolidene, furfural and hexadecanoic acid isolated from the hexane extract of *B. lichniformis* were evaluated for antifungal activity against *Botrytis cinerea*,

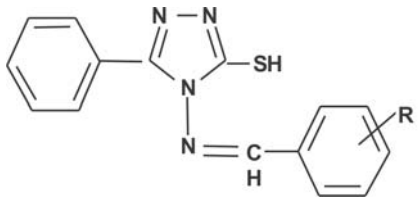
Antifungal activity of major metabolites identified from hexane extract of culture filtrate of *Bacillus licheniformis* MTCC 7445

Metabolites	*Botrytis cinerea*	*Candida albica*	*Microsporum canis*
	($ED_{50}\mu g^{-1}$)		
1-Methyl pyrrolidene	12.03	15.78	18.67
Furfural	8.59	2.30	15.72
Hexadecanoic acid	125.8	176.38	225.61

Candida albica and *Microsporum canis*. Maximum antifungal activity was observed in the case of furfural followed by 1-methyl pyrrolidene.

4.4.1.2 New synthetic products

Novel 4-arylidenamino-3-mercapto-5-phenyl-4H-1,2,4-triazole fungicides. A series of twenty Schiff bases of 4-amino-3-mercapto-5-phenyl-1,2,4-triazole having different substitutions in the aryl ring attached to imino group were synthesized and evaluated for fungitoxicity. Among these, 4-(3-methylbenzylidenamino-3-mercapto-5-phenyl-4H-1,2,4-triazole (ED_{50}=17 ppm) was identified as a potential fungicide against *R. solani*.



4-amino-3-mercapto-5-phenyl-1,2,4-triazole

In order to identify the exact structural features favourable for fungitoxicity, quantitative structure activity relationships (QSAR) were analyzed by using *in vitro* fungitoxicity data and various physico-chemical parameters for hydrophobic, electronic and steric properties of the benzylidene ring substituents, by means of multiple regression analysis technique. The QSAR models revealed that the fungicidal activity of 4-arylidenamino-3-mercapto-5-phenyl-4H-1,2,4-triazoles against *R. solani* had an inverse parabolic relationship with the hydrophobicity (π) with a minima at π=0.236 which implied that the farther the value of π from 0.236, the greater would be the fungicidal activity of the compounds in this series against *R. solani.*

Evaluation of various oxanilates, malonanilates and pyridones for their nitrification inhibitory activity. Twenty-three compounds belonging to various groups, viz., methyl/ethyl/isopropyl oxanilates, ethyl malonanilates and N-aryl pyridones were screened for their nitrification inhibitory activity at a dose of 5% of urea-N applied for a period of thirty days. All the test compounds were found effective. Ethyl 3'-nitro oxanilate, ethyl 4'-cyano oxanilate, ethyl 4'-bromo malonanilate and ethyl 3'-methoxy malonanilate were the potential ones among all three categories of compounds.

4.4.2 Pesticide Formulations

4.4.2.1 Controlled release formulation

Controlled release (CR) formulations of acephate and metribuzin in polyvinyl chloride, PVC (emulsion), carboxy methyl cellulose, CMC and carboxy methyl cellulose-kaolinite adducts were developed and evaluated for their bioefficacy. The release of acephate and metribuzin from (CR) formulations was up to 63 days in water and soil, respectively, as compared to commercial formulation (28 and 35 days, respectively).

The bioassay of CR formulation of acephate conducted against the mustard aphid, *Lipaphis erysimi* revealed that the CMC-Kaolinite followed by PVC provided a sustained release and hence was able to control the aphids' population throughout. The CR formulations resulted in a considerable increase in mustard yield. The bioefficacy of CR and commercial formulations of metribuzin evaluated against weeds in wheat crop revealed that the weeds population and their dry weight were effectively reduced by the application of the CR formulations compared to commercial 75 DF formulations. These formulations showed a positive impact on yield and yield attributes.

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 and alphamethrin. Experiments were conducted to study the persistence and risk assessment of imidacloprid on chickpea, and alphamethrin on okra and tomato. Imidacloprid was

sprayed @ 20 and 40 g a.i. ha^{-1} at pod formation stage while alphamethrin was applied @ 15 and 30 g a.i. ha^{-1}, with a spray fluid rate of 500 l ha^{-1}. The initial deposits of cypermethrin declined with the time and reached non detectable level by 7-10 days in both okra and tomato, whereas the residues of imidacloprid were found to persist up to 10 days. The chickpea grains at harvest were free from residues of imidacloprid.

Persistence of betacyfluthrin from combination mix (betacyfluthrin + imidacloprid). The persistence and dissipation of combination mix (betacyfluthrin + imidacloprid) on tomato were evaluated through field and laboratory experiments. Decontamination studies were also carried out with simple culinary processes to see how much insecticides can be dislodged from contaminated samples. The initial deposit of betacyfluthrin ranged from 0.992 mg kg^{-1} to 2.133 mg kg^{-1} from all the treatments. The results of persistence studies showed that betacyfluthrin was detectable only up to 7–10 days after the application from betacyfluthrin alone formulation, but it persisted up to 15 days from lower and higher rates of application from combination mix. This showed higher persistence from combination mix. The half-life values of betacyfluthrin residues ranged from 2.03 to 2.69 days. The safety parameters evaluated showed that betacyfluthrin would not pose any undue hazard. Washing of zero day contaminated tomato fruit samples with tap water dislodged 38.59-41.44% betacyfluthrin from all the treatments. Washing and steaming of zero day contaminated fruit samples dislodged 62.69 - 65.58% betacyfluthrin from all the treatments. Hence, washing of contaminated fruits followed by steaming was the best method to reduce the residues and ensure further safety margin.

Persistence of ready mix formulation of chlorpyrifos and cypermethrin on mustard. Supervised field trials were conducted by using randomized block design to study the residues of ready mix formulation of chlorpyrifos and cypermethrin on mustard (var. Pusa Bold) when used as foliar application. The crop was sprayed with ready mix formulation of cypermethrin and chlorpyrifos Nagraj 506 EC (5 + 50%) at 50% pod formation stage @ 20 g a.i. and 40 g a.i. /ha. Residues of chlorpyrifos persisted till day 15 in green pods and were below the detectable limit in harvest grains (< 0.03 mg/kg); residues of cypermethrin persisted till day 15 in green pods and were below the detectable limit in harvested grains (< 0.05 mg/kg).

Persistence of fipronil, cypermethrin and ethion in chilli. Investigations were undertaken to study the residues of fipronil, cypermethrin and ethion on chilli variety Soldier-MH-1, F_1 following spray treatment with fipronil (Regent 5 SC) @ 25 g a.i. and 50 g a.i. ha^{-1}, cypermethrin (Cold Cyp 10 EC) @ 20 g a.i. and 40 g a.i. ha^{-1}, ethion (Fosmite 50% EC) @ 20 g a.i. and 40 g a.i. ha^{-1}. Two foliar sprays were given at fortnightly interval beginning at flowering/fruiting stage. No residues were detected in fruits from 20th day onwards in the case of fipronil and after 10 days in the case of cypermethrin, whereas ethion residues could be detected until 25th day. Half-life values calculated following first order dissipation kinetics model were 1.70 and 1.57 days for fipronil, 1.98 and 2.68 days for cypermethrin and 7.56 and 8.17 days for ethion at the recommended and double the recommended doses, respectively.

Persistence of indoxacarb on brinjal. The residues of indoxacarb (Dhawa 14.5% SC), when used as foliar application @ 70 g a.i. and 140 g a.i. /ha, at fruiting stage on brinjal (var. Pusa Kranti) were studied. A second spray was done 15 days after the first application. Residues persisted beyond 6 and 10 days in fruits at the recommended dose and double dose with the overall dissipation of 93-96%, and half-life of 1.96 and 2.33 days at the recommended dose and double dose, respectively. From the consumer's safety point of view, a waiting period of 1-day is suggested.

Persistence of fluchloralin, pendimethalin and oxyflourfen in/on onion and soil. A field experiment was conducted on onion with fluchloralin, pendimethalin and oxyflourfen applied @ 1 kg a.i./ha, 1 kg a.i./ha and 0.25 kg a.i./ha, respectively as pre-emergence application. One treatment was kept where sequential second application at the same rate was given at 30 days after the first application. The samples of green onion (bulb and leaf) were taken at 60 days while ripe onion was analyzed at harvest (110days). The results revealed that at harvest (ripe bulb, 110 days), the residues of fluchloralin, pendimethalin and oxyflourfen were 0.0078 and 0.0173; 0.021 and 0.056; 0.005 and 0.008 mg/kg, respectively for recommended and 2 sequential

applications. At leafy stage, the residues varied between 0.021 and 0.1 mg/kg. The applications were safe with respect to MRL.

4.4.3.2 Environmental fate of pesticides

Adsorption-desorption behaviour of carpropamid. Adsorption-desorption of carpropamid were studied in Kerala soil (pH 7.64, organic carbon 1.2%, and clay 49.3%) collected from a rice field. Studies were carried out using batch equilibration technique in the concentration range 2.0 - 0.05 µg/ml. Distribution coefficient values varied from 1.25 to 5.02 showing high adsorption of carpropamid on the soil surface. Adsorption data fitted well (r=0.99) into the linear form of the Freundlich equation. The value of constant K_F = 4.79 shows that the soil has relatively high capacity for the adsorption of carpropamid and the value of n = 0.74 reveals the strong adsorption of carpropamid on the soil surface. Desorption studies were carried out in 4 cycles at three different initial concentrations of 0.1, 0.5 and 2 µg/ml. About 22.6 - 25.5% of the adsorbed carpropamid desorbed in four desorption cycles for the different concentrations. In all the concentrations, desorption was slower than adsorption indicating a hysteresis effect. Calculated hysteresis coefficient values ranged from 9.36 to 11.77 clearly indicating a strong effect.

Effect of moisture on the leaching profile of metsulfuron methyl: a study by dual method. The effect of moisture on the leaching profile of metsulfuron methyl was studied by dual method. Three hundred µg of metsulfuron methyl (as solution) was applied at the top of soil packed PVC columns, and two moisture conditions were applied. In the first experiment 1000 ml of water was added continuously at a speed of 100 ml/h (excess irrigation) while in the second set, water was added at the rate of 200 ml/10days (normal irrigation). The leaching column of soil after conducting the experiment was split half longitudinally. The soil of half portion was analyzed by HPLC while in the other half seeds of lentil were sown to study the herbicide content by bioassay (root length). Results indicated that under normal irrigation, maximum amount of herbicide leached down to the depth of 30-60 cm. From this layer it can reach by capillary action to the plough layer during dry season and can cause phytotoxicity to the following crops in rotation. Experiment on excess irrigation indicated that because of sudden rainfall herbicide can leach up to a depth more than 90 cm; small quantity of metsulfuron methyl was recovered from collected fractions of leachates.

Leaching behaviour of azoxystrobin. Leaching behaviour of azoxystrobin was studied in the packed and the intact soil columns under different irrigation regimes. The results indicated that azoxystrobin was fairly immobile in the sandy loam soil columns, but mobility increased with the increase in the volume of the percolating water. However, azoxystrobin did not leach out of the column and was not detected in the leachate. After percolating water equivalent to 126 mm rainfall, azoxystrobin leached down to 5-10 cm depth and nearly 90% of the applied fungicide was retained in the top 0-5 cm layer. Increasing the amount of percolating water (362 mm rainfall) further increased the downward mobility of azoxystrobin and the fungicide leached down to 10-15 cm soil depth, and a major portion of the soil-applied azoxystrobin (50%) moved down to 5-10 cm soil section.

The intact soil cores better simulate the conditions as observed in the field; therefore, azoxystrobin leaching was also studied in the intact soil columns. Results indicated that even after 362 mm rainfall, azoxystrobin did not leach out of the intact column and was not detected in the leachate. After percolating water equivalent to 126 mm rainfall, azoxystrobin leached down to 5-10 cm depth, and a major portion of the azoxystrobin (86%) was retained in the top 0-5 cm layer. Nearly the same results were obtained for the azoxystrobin leaching in the packed soil column suggesting that after an average rainfall (126 mm), which is possible in a day, azoxystrobin was practically immobile in the sandy loam soil as >85% of azoxystrobin still remained in the application zone itself (0-5 cm). However, after percolating water equivalent to 362 mm rainfall, the fungicide leached down to 15-20 cm layer and was evenly distributed in the 0-15 cm soil profile. If we compare the leaching behaviour of azoxystrobin in the packed and the intact columns following 362 mm rainfall, its pattern is quite different. Certainly, azoxystrobin is more mobile in the intact columns than in the packed soil columns. Preferential flow through macropores that are likely to be maintained in the intact columns greatly reduces the

retention of the solute in the soil profile and, thus, may increase the hazards of ground water contamination, while in the packed columns, water along with applied pesticide passes through the soil matrix and considerable retardation of pesticide is observed.

4.5 WEED MANAGEMENT

4.5.1 Economic Threshold of *Chenopodium album* L. in Wheat

A field experiment with different *Chenopodium album* L. densities, viz., 8, 16, 32, 64 and 128 plants/m^2, unweeded control with *Chenopodium* weedy check, weed free check and unweeded control without *Chenopodium* (all weeds but no *Chenopodium*) in the main plot, and nitrogen levels, viz., N_0 (0 kg N/ha), N_1 (60 kg N/ha) and N_2 (120 kg N/ha) in the sub-plot was undertaken in split plot design with three replications.

The dry weight of *Chenopodium* was significantly influenced by *Chenopodium* weed densities. Unweeded control with *Chenopodium* produced significantly higher dry matter compared to all other treatments except unweeded control without *Chenopodium* and *Chenopodium* at 128 plants/m^2, which were on a par. At lower densities, significantly lower dry matter was observed. Nitrogen levels had significant effect on *Chenopodium* weed dry weight, and nitrogen level at 120 kg N/ha produced significantly higher dry matter compared to that of others. Nitrogen at 60 kg/ha was, however, intermediate on dry weight of *Chenopodium*/weed.

Wheat grain yields was significantly higher in weed free check and *Chenopodium* at 8 plants/m^2 compared to those of other treatments. The yield was the lowest in *Chenopodium* at 128 plants/m^2 and this reflected higher weed competition in this treatment. Nitrogen at 120 kg and 60 kg/ha produced comparable grain yield, but significantly higher than that of no nitrogen. The straw yields was significantly higher in weed free check and *Chenopodium* at 8 and 16 plants/m^2 compared to that of other treatments. It was significantly lower in *Chenopodium* at 128 plants/m^2 and *Chenopodium* at 64 plants/m^2. Nitrogen at 120 kg/ha was superior to 60 kg N/ha and no nitrogen with respect to straw yield. The predicted and observed wheat yield by using

***Chenopodium* dry weight (g/m^2) and wheat grain and straw yields as influenced by *Chenopodium*/weed infestation and nitrogen levels**

Treatment	*Chenopodium* dry weight at 90 DAS (g/m^2)	Wheat grain yield (t/ha)	Wheat straw yield (t/ha)
***Chenopodium*/weed infestation**			
Chenopodium 8 plants/m^2	8.92* (79.2)	4.25	5.97
Chenopodium 16 plants/m^2	11.77 (138.5)	4.00	5.89
Chenopodium 32 plants/m^2	15.93 (255.0)	3.70	5.61
Chenopodium 64 plants/m^2	19.24 (370.8)	3.04	4.55
Chenopodium 128 plants/m^2	23.14 (536.3)	2.89	4.45
Weed free check	0.71 (0.0)	4.51	6.16
Unweeded control with *Chenopodium*	24.19 (586.5)	2.82	4.97
Unweeded control without *Chenopodium*	23.62 (558.9)	3.26	4.94
LSD (P=0.05)	1.44	0.13	0.07
Nitrogen levels			
0 kg N/ha	15.05 (281.6)	3.19	4.84
60 kg N/ha	16.00 (317.1)	3.61	5.38
120 kg N/ha	16.77 (348.3)	3.88	5.85
LSD (P=0.05)	0.18	0.18	0.27

***Square root transformed values; values in parentheses are original**

regression model gave a good prediction (R^2=0.87) of yield loss at various *Chenopodium*/weed infestation levels. At the lowest *Chenopodium* density of 8 plants/m^2, the predicted yield loss was 7.08%. The maximum loss of 37.93% was observed at a *Chenopodium* density of 128 plants/m^2. The economic threshold level of *Chenopodium* in wheat was 4.89 plants/m^2.

Predicted wheat yield and per cent yield loss at *Chenopodium album* densities by fitting yield loss-weed density model

C. album density/m² (plants/m²)	Observed yield (kg/ha)	Predicted yield (kg/ha)*	Observed yield loss (%)	Predicted yield loss (%)**	
0	4507	4545	0.00	0.00	$R^2 = 0.87$
8	4251	4223	5.68	7.09	
16	4001	3976	11.23	12.52	
32	3701	3623	17.88	20.29	
64	3041	3209	32.53	29.41	
128	2896	2821	35.74	37.93	

***By fitting the equation Y = Ywf[1-(id/ 100(1+id/A)]; ** By fitting the equation YL = id/1+idA**

4.5.2 Control of Complex Weed Flora in Wheat with Clodinafop and Metsulfuron

Among the herbicides, clodinafop-propargyl 15 WP (Topic) and different doses of clodinafop+metsulfuron @ 45+3 g, 54+3.6 g and 60+4 g significantly reduced the density of *Phalaris minor* as against the weedy check and metsulfuron methyl. Clodinafop propargyl was found ineffective against broadleaved weeds, whereas metsulfuron methyl 20WP alone and clodinafop+metsulfuron @ 45 g +3 g, 54 g+3.6 g and 60 g+4 g efficiently controlled the broadleaved weeds. Higher weed control efficiency was recorded in clodinafop+metsulfuron treatments due to control of mixed weed flora. All the herbicide treatments except metsulfuron methyl recorded significantly higher seed yield of wheat as compared to that of the weedy check. The highest seed yield was recorded in the treatment clodinafop+metsulfuron (@ 60 g+4 g), which was 39.8% and 28.4% higher than that of the weedy check and metsulfuron methyl, respectively. Significantly lower grain yield was recorded with metsulfuron methyl 4 g/ha compared to that recorded with different doses of clodinafop+metsulfuron. This may be due to higher density of *Phalaris minor* contributing to higher weed dry weight and lower weed control efficiency in metsulfuron methyl.

4.5.3 Herbicide Tank-mixes *versus* Sequential Application for Weed Management and Soybean Yield

A field study was undertaken to find out the effect of tank-mixes and sequential application of herbicides on weed competition and soybean yield in randomized block design (RBD) with three replications. Eight weed control treatments were: GA_3 (400 ppm) + pendimethalin (1.0 kg/ha) PE followed by imazethapyr (100 g/ha POE at 20 DAS), GA_3 (400 ppm) + tank-mix of pendimethalin (0.75 kg/ha) and imazethapyr (100 g/ha) PE, KNO_3 (6%) + pendimethalin (1.0 kg/ha) PE followed by imazethapyr (100 g/ha POE at 20 DAS), KNO_3 (6%) + tank-mix of pendimethalin (0.75 kg/ha) and imazethapyr (100 g/ha) PE, GA_3 (400 ppm) + one hand weeding at 30 DAS, KNO_3 (6%) + one hand weeding at 30 DAS, unweeded control and weed free check. Broad-leaved weeds were completely controlled by all tank-mixes and sequential applications of pendimethalin and imazethapyr. *Cyperus* control, however, was significantly greater in the tank-mixes of all the herbicides compared to their respective sequential applications. All herbicide treatments irrespective of tank-mixes and sequential application being comparable with weed-free check recorded significantly higher soybean grain yield than that of unweeded control.

Broad-leaved weed and *Cyperus* dry weight and grain yield of soybean across the treatments

Treatments/herbicides (kg/ha)	Broad-leaved weed dry weight (g/m²)	*Cyperus* dry weight (g/m²)	Grain yield (t/ha)
GA_3 (400 ppm) + pendi (1.0) PE *fb* imaze (0.1) POE at 20 DAS	0	5.7	2.837
GA_3 (400 ppm) + tank-mix of pendi. (0.75) and imaze. (0.1) PE	0	1.9	2.861
KNO_3 (6%) + pendi. (1.0) PE *fb* imaze. (0.1) POE at 20 DAS	0	6.0	2.824
KNO_3 (6%) + tank-mix of pendi. (0.75) and imaze. (0.1) PE	0	1.8	2.824
GA_3 (400 ppm) + HW at 30 DAS	0	2.8	2.935
KNO_3 (6%) + HW at 30 DAS	0	3.3	2.972
Unweeded control	153.3	7.6	1.187
Weed free check	0	0	3.083
LSD (P = 0.05)	—	1.69	0.2890

4.5.4 Evaluation of Clodinafop-propargyl, Sulfosulfuron and Pinoxaden towards Cross-Resistance Across *Phalaris minor* Retz. Biotypes

The treatments consisted of 221 isoproturon-resistant *Phalaris minor* biotypes collected from 221 villages of Punjab and Haryana, clodinafop-propargyl (at 30 g, 60 g, and 120 g/ha), sulfosulfuron (at 16.25 g, 32.5 g, and 65 g/ha) and pinoxaden (at 25 g, 50 g and 100 g/ha) and a control replicated thrice in a completely randomized design. The experiment was carried out initially in the growth chamber and then in the green-house of the National Phytotron Facility, IARI, New Delhi. Of the 221 *Phalaris* biotypes, 118 biotypes were collected across 10 districts of Haryana, and 103 biotypes from 9 districts of Punjab. The response of *Phalaris minor* biotypes to clodinafop was variable across doses. Eight biotypes from Haryana, namely, HR116 and HR118 (from Karnal), HR18, HR 21, HR 22, HR 26 and HR 28 (from Fatehbad) and HR 30 (from Jind), and 3 biotypes from Pubjab, namely, PN 41(from Ludhiana), PN 64 (from Sangroor) and PN 83 (from Patiala, had shown varying degrees of cross-resistance to clodinafop across doses under a green house study. Seven biotypes, HR 118 (from Karnal), HR18, HR 21, HR 22 and HR 26 (from Fatehbad), HR 30 (from Jind) and PN 41(from Ludhiana), however, had shown cross-resistance to both clodinafop and sulfosulfuron.

Mean per cent control of *Phalaris* bio-types by clodinafop-propargyl in green house

Biotype code	Clodinafop-propargyl (30 g/ha)	Clodinafop-propargyl (60 g/ha)	Clodinafop-propargyl (120 g/ha)
HR 116	0	0	0
HR 118*	0	0	50
HR 18*	0	0	0
HR 21*	0	60	100
HR 22*	0	0	0
HR 26*	0	0	0
HR 28	0	0	0
HR 30*	0	0	0
PN 41*	0	0	0
PN 64	0	0	0
PN 83	0	0	0
Rest (210)	100 (susceptible)	100 (susceptible)	100 (susceptible)

*** Biotypes showing cross-resistance to both clodinafop and sulfosulfuron**

5. BASIC AND STRATEGIC RESEARCH (Covers partly NRCPB)

5.1 PLANT BIOTECHNOLOGY

5.1.1 Enhancement of Productivity through Exploitation of Heterosis

5.1.1.1 Heterosis in hybrids based on *Moricandia arvensis* CMS system

Experimental hybrids involving selected combiner lines were produced and evaluated in replicated yield trials to assess the extent of their heterosis. The hybrids showed 7%-18% superiority over the check variety, Varuna for seed yield. Hybrid 24-04 which recorded the highest seed yield was also the earliest to mature (131 days). Seeds of Hybrid 22-04 and Hybrid 13-04 were medium bold and brown in colour.

Mustard Hybrid 24-04

Performance of selected hybrids

Hybrid	Parents	Yield (t/ha)	Superiority (%) over check (Varuna)
Hyb. 24-04	CMS (mori) CSR-499 × R2	2.913	18.3
Hyb. 22-04	CMS (mori) YSR × R2	2.830	14.9
Hyb. 13-04	CMS (mori) 322-93 × JMG 401	2.644	7.3
Hyb. 14-04	CMS (mori) 322-93 × BIO-467-95	2.635	7.0
Varuna (Check)		2.463	-

5.1.2 Isolation of Genes and Promoters for Development of Transgenics

5.1.2.1 Isolation and construction of mungbean lectin gene construct

Lectin gene was isolated from mungbean [*Vigna radiata* (L.) R. Wilczek.] by the using 5′ and 3′ RACE (rapid amplification of cDNA ends) technique. The amplicon was PCR amplified by using cDNA at both the ends and cloned into pGEMT easy vector. It was confirmed that the sequence had 828 bp ORF (open reading frame) of lectin gene which coded for 276 amino acids. The gene was cloned in binary vector pBINAR.

5.1.2.2 Molecular analysis of *Brassica* transformants carrying chickpea lectin gene

Genomic DNA of T_o plants (Pusa Jaikisan) was isolated and PCR amplified by using *nptII* primers which gave a product of ~ 750 bp as expected. Southern analysis of the genomic DNA of the putative transformants showed stable integration of chickpea lectin gene.

5.1.2.3 Insect bioassay of mustard transgenics

Bioassay experiments were conduced on T_o plants to assess the efficacy of transformants against aphids. Experiments were carried out under controlled conditions at 23 °C temperature.

Percentage mortality of aphids in insect bioassay

Plant No.	No. of aphids inoculated	No. of surviving aphids	No. of dead aphids	Mortality %
Control	75	73	2	2.67
$T1^{A}$	75	71	4	5.34
$PT1^{F}$	75	69	6	8.0
$PT1^{5}$	75	68	7	9.34
$PT1^{C}$	75	70	5	6.67

5.1.2.4 Prevalence of *cry*2 type genes in native Bt isolates

The presence of *cry*2 genes among 83 native Bt isolates and 22 known Bt strains, used as reference was determined by PCR amplification using two sets of primers specific for *cry*2 family genes and five sets of primers specific for *cry*2-subtype genes. These genes were found to be present in 32 Bt isolates and 7 known Bt strains.

5.1.2.5 Isolation and characterization of a trichome specific promoter from *Arabidopsis thaliana*

An *Arabidopsis* mutant line harboring promoter trap vector pGKB5 showed trichome specific GUS expression. This line was used to isolate trichome specific promoter sequence. This was confirmed by southern analysis and PCR using primers from the suggested sequences.

The upstream sequences of both insertion sites were cloned in binary vector pBI 101, and GUS expression was analyzed in the transgenics of T_2 generation. From the two, only upstream sequence of ethylene response factor was found to drive the trichome specific expression as observed in the mutant line.

An *Arabidopsis* mutant showing trichome specific GUS expression

5.1.2.6 Identification of stress inducible RD26/ NAC transcription factor from chickpea (*Cicer arietinum* L.)

The cDNA SSH library was made to identify differentially induced transcript during terminal drought stress in chickpea. A clone of 350 bp size that possesses a conserved NAC domain was selected for full-length cDNA isolation by using 3′- and 5′-RACE method. The deduced amino acid sequence showed significant similarity with *Arabidopsis* NAC domain containing RD26 gene and was named as *C. arietinum* RD26/ NAC.

5.1.3 Development of Transgenic Crops for Resistance to Biotic and Abiotic Stresses

5.1.3.1 Construction of chimeric delta-endotoxin specific to Lepidopteran pests

Study of Cry1Jb toxin. *Bacillus thuringensis* strains EG 5092 that harbor *cry1Jb* gene was obtained from the ARS Patent Culture Collection, USA. Based on the published *cry1Ja* and *cry1Jb* sequences, gene-specific primers were designed to amplify these genes. PCR amplified and purified product was cloned in *E.coli* expression vector pET29a. Recombinant pET29a vector having *cry1Jb* was transformed into protein over-expressing *E.coli* host BL21 (DE3).

Cry1Jb was over-expressed in *E.coli* strain BL21 and the inclusion bodies that contained the Bt toxin were solubilized in carbonate buffer. SDS-PAGE analysis of sodium carbonate buffer solubilized protein showed an over-expressing band of ≈ 130 kDa size. In order to confirm the stability of Cry1Jb toxin, trypsin digestion analysis was carried out. Digestion of Cry1Jb with trypsin (trypsin: total *E.coli* protein 1: 5 w/w) for various time intervals (30, 45, 60 and 90 min) at 37 ºC showed a ≈ 60 kDa size trypsin resistant band on 8% SDS-PAGE. Insect bioassays were performed by "Artificial-diet Surface Incorporation Technique" against the larvae of *Helicoverpa armigera, Chilo partellus, Spodoptera litura,* and *Earias vittella* and the mortality was recorded up to 8 days.

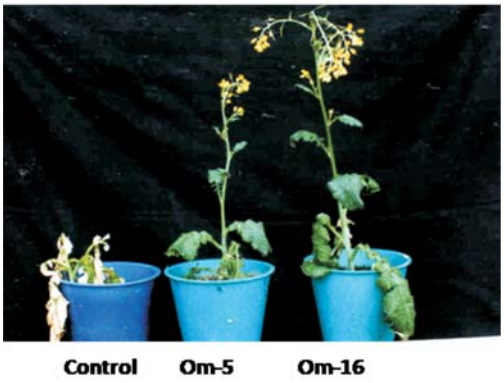
5.1.3.2 Development of *cry1Ac-J-Ac* transgenic tomato

Genetic transformation of tomato (Pusa Ruby) with Bt-*cry1Ac-J-Ac* was carried out by using leaf-derived callus. Kanamycin resistant shoots were regenerated and rooted followed by hardening of plants in the phytotron facility. All putative transgenic plants were analyzed for integration and expression of *cry1Ac-J-Ac* gene. Single copy *cry1Ac-J-Ac* transgenic tomato lines were tested against neonates of *H. armigera* by leaf bioassay. Insect bioassay data showed that *in plant* expression of *cry1Ac-J-Ac* in tomato provided protection against *H. armigera* and resulted in up to 87% of larval mortality.

Leaf disc bioassay of *cry1Ac-J-Ac* transgenic tomato with *Helicoverpa armigera* neonate larvae. A: control tomato leaf, and B: *cry1Ac-J-Ac* transgenic tomato leaf

5.1.3.3 Development of mustard and tomato transgenics tolerant to abiotic stresses

The NRC on Plant Biotechnology successfully developed transgenic mustard and tomato expressing osmotin gene. The transgenics performed well when subjected to water deficit stress under glass house and field conditions. The transgenic mustard was developed with more genes such as *AtDREB1a*, *BcZF1* and *otsB-A* operon.



Response of transgenic osmotin mustard plants to salt stress (150 mM NaCl for 2 weeks)

5.1.4 Genomics and Molecular Markers

5.1.4.1 Marker assisted selection for multiple BLB resistance genes in *basmati* rice

In the previous years, two genes for bacterial leaf blight (BLB) resistance were pyramided in the back ground of *basmati* variety Pusa Basmati1, and a new variety named Improved Pusa Basmati1 was developed through marker-assisted selection. With the objective of combining three or four genes for BLB resistance, in the *basmati* background, the non-*basmati* rice line IRBB60 carrying four genes namely, *Xa4*, *xa5*, *xa13* and *Xa21* for BLB resistance, was used as donor and crossed with Basmati 370. During the year under report, 1250 F_5 generation recombinant inbred lines (RILs) from this cross were screened for grain shape and size. One hundred lines possessing *basmati* type grains were screened for resistance to BLB and 23 highly resistant lines having < 3cm lesion length identified. Marker-assisted selection carried out so far for *xa13* and *Xa21* revealed the presence of these two genes in four recombinants having the desired *basmati* traits including aroma.

5.1.4.2 Development of mapping population segregating for drought tolerance in rice

Upland rice variety Nagina 22 is known to have high level of tolerance to drought. It maintains high spikelet fertility under severe moisture stress. In order to map the quantitative trait loci (QTLs) for drought tolerance present in this variety, Nagina 22 was crossed with the popular variety IR64 in the previous year. During the *kharif* season 2008, a total of 1500 F_2 plants from this cross were grown in the field. A wide range of variation was observed for plant height, tiller number, panicle length, grains per panicle and yield per plant. These plants were selfed to generate later generations and obtain recombinant inbreds, which will be used for QTL mapping.

5.1.4.3 Development of transgenic rice by the use of *AtDREB1A* gene

A total of 32 independent transgenic events of rice variety Pusa Sugandh 2 were generated in the previous year

through biolistic transformation by using *AtDREB1A* gene under stress inducible rd29A promoter and *npts*II selection marker. Out of these, T_1 seeds of 9 independent events were screened on hygromycin (50 mg/l) containing medium and the surviving plants were transferred to pots in the phytotron. Drought stress was imposed by withholding irrigation for 6 days**.** After stress cycle, the relative leaf water content (RWC) and soil moisture level were determined**.** One independent event T1-PS2-B1-C4-1 that recovered better than the controlled was found to maintain a higher relative leaf water content (66%) under 14% of soil moisture content as compared to that of the control (14.78% RWC at 14.86% soil moisture level).

5.1.4.4 Genetic transformation of rice by the use of *cry1Aabc* gene

A gene construct carrying *cry1Aabc* gene under the CaMV35S promoter in pUC 19 vector was prepared earlier. Keeping in view the advantages of maize ubiquitin promoter, instead of CaMV35S promoter, for a better transgene expression in monocot system, the CaMV35S promoter was replaced with maize ubiquitin promoter. The plasmid was named as p*ubi-cry1Aabc*. The vectors p*ubi-cry1Aabc* and p*hpt* were used for the co-transformation of the elite *indica* rice variety IR 64. Eighteen putative transformants were obtained from one thousand five hundred transformed calli. The putative transformants will be tested for the presence of the transgene.

5.1.4.5 Functional genomics of *Alternaria blight* resistance in wild relatives of *Brassica*

In order to identify the genes conferring resistance to *Alternaria,* wild relatives of *Brassica* having resistance against the pathogen were subjected to candidate gene based screening, microarray analysis and suppression subtractive hybridization. Candidate gene based approach utilizing nine known R-genes from *Arabidopsis thaliana* by the use of semi-quantitative PCR was employed in *Camelina sativa* and *Diplotaxis erucoides*. The candidate genes, which exhibited upregulation in *D. erucoides* were *ATLP*3, *4CL*3, *GLIP*1 and *LOX*3. In *C. sativa*, genes PR4 and ATCHIB1 were upregulated.

5.1.4.6 Functional genomics of drought tolerance in *Brassica*

To understand the molecular basis of drought tolerance and identify the underlying major genes for this complex trait, phenotyping was carried out on forty genotypes. Based on screening, *B. juncea* genotypes RGN 73, CS 52, RH 30, PBR 210, and RN 393 and one genotype of *Sinapis alba* were found to be drought tolerant. Genotypes BioYSR, BEC 144, PBR 97 and RLM 619 were drought susceptible. In order to understand the molecular basis of drought tolerance, candidate gene based approach was used for expression analysis of 13 genes in *S. alba*, Varuna, RLM 619 and BEC 144. Significant differential expression was observed for four drought responsive genes (*HAL*3A, *NCED*3, *AAO*3, and *HB*6). Microarray based expression analysis under drought stress by using *Arabidopsis* chips identified 85 genes showing more than two-fold change at $p < 0.01$ in Varuna. Twelve genes having possible role in stress tolerance were shortlisted for further characterisation.

5.1.4.7 Characterization of rice blast resistant transgenics

Rice blast resistant transgenics were characterized at molecular and cellular levels after inoculating them with the *Magnaporthe oryzae*. Major QTLs were identified for sheath blight resistance on chromosome 11 of rice.

5.1.5 Development of Genetically Engineered Microbes for Effective Microbe Plant Interaction

Sub-genomic library of Tn5 mutant of *Bacillus pumillus*, the isolate antagonistic to *Rhizoctonia solani*, was constructed in vector pUC19 to identify the gene responsible for antagonism towards fungal pathogens. The clones obtained were screened for the presence of Tn5 insert by PCR analysis. Dual bioassay studies showed that the isolated microbe *Bacillus pumillus* was antagonistic to plant pathogenic fungus *Helminthosporium oryzae*, the causal organism of brown spot disease in rice besides the already confirmed *Rhizoctonia solani*.

5.1.6 Micro Propagation and Improvement through Tissue Culture of Vegetable Crop

5.1.6.1 Cauliflower

In vitro establishment protocol was standardized in cauliflower by the use of shoot tip as an explant. MS medium supplemented with BAP (2mg/1) + NAA (0.5 mg/1) + GA_3 (0.5 mg/1) was found to be the best for the establishment of cauliflower shoot tips.

5.1.7 Molecular Characterization of Mango

5.1.7.1 DNA fingerprinting of mango genotypes (*Mangifera indica* L.)

Fifty mango genotypes representing different geographic regions were analyzed by using 28 simple sequence repeat (SSR). The genetic relationships between mango genotypes were determined based on Jaccard's similarity values which ranged from 0.45 to 0.88 with an average similarity coefficient of 0.612 indicating sufficient diversity among the genotypes studied. The dendrogram showed that cultivars related to each other by descent were grouped in one cluster, whereas majority of the northern and eastern cultivars grouped together and were distinct from the western and southern cultivars. Cultivar specific fingerprints were developed for the genotypes and represented as a barcode diagram. The probability of identity of molecular profiles of two genotypes taken at random was estimated to be 1.02 X 10-10 indicating high degree of confidence in the fingerprints.

5.1.7.2 Mango characterization by the use of ISSR markers

Twenty-eight ISSR primers used in the present study to characterize 63 mango genotypes generated a total of 334 scorable bands.

Primer UBC-811 and primer UBC-891 were identified with the highest number of genotypes with unique fingerprints (53). The highest numbers of different fingerprints (58) were obtained with primer UBC-812, while the lowest numbers of different fingerprints (17) were obtained with primer ISSR-5. Eight unique bands were obtained in 63 mango genotypes with 28 primers. The maximum resolving power was computed for primer ISSR-4 (8.38) while the minimum was recorded for primer ISSR-5. The range suggested the usefulness of ISSR primers in characterizing 63 mango genotypes successfully.

5.2 BIOCHEMISTRY

5.2.1 Isolation and Characterization of Differentially Regulated Genes under Moisture Stress in Rice

Transcription factors belonging to AP2/ERF family differentially expressed under water deficit stress (WDS) were isolated. A 964 bp genomic sequence of AP2/ERF transcription factor family gene, inducible under WDS, was PCR amplified by using gene specific primer from genomic DNA of *Oryza sativa* cv. Teipei 309 and *Oryza sativa* cv. N22. This gene, a single copy gene, encodes for a protein of 243 amino acids and has the conserved AP2 from 5 to 69 amino acids. An 800 bp cDNA sequence was amplified by using DREB 1A specific primers, cloned and designated as pDREN22; translation of gene gives a polypeptide of 238 amino acids. About 12% amino acids are positively charged, which may be enabling the transcription factor to interact with negatively charged DNA.

5.2.2 Starch, Soluble Sugar and Yield Parameters from Various Wheat Cultivars

Various heat tolerant and susceptible wheat cultivars were cultivated in the fields in replicates and analysed for heat shock proteins (HSPs). It was observed that HSP of molecular weight of about 100 kDa families showed weak bands in heat susceptible wheat cultivars as compared to those of heat tolerant cultivars, which indicated the role of these HSPs in imparting protection to plant against heat shock.

When thirty wheat cultivars grown under semi-irrigated and rainfed conditions were analysed, the starch content and 100-grain weight were almost similar, but the soluble sugar was 25% higher in rainfed wheat cultivars and the number of grains per ear was 21% lower than those of semi-irrigated cultivars. Decrease in grain yield from rainfed wheat could be because of the impairment of soluble sugar conversion into storage starch.

5.2.2.1 Alternative oxidase in various wheat cultivars

Alternative oxidase (AOX) pathway in heat tolerant wheat cultivars seemed to contribute substantially in the dissipation of redox equivalents compared to that of susceptible wheat cultivars. The Triose/PGA ratio in heat tolerant cultivars in the presence of AOX pathway inhibitor was 0.84 as compared to that of 0.48 in heat susceptible cultivars.

5.3 PLANT PHYSIOLOGY

5.3.1 Physiological Constraints Limiting Productivity in Cereals

5.3.1.1 Analysis of physiological constraints limiting photosynthesis and grain growth

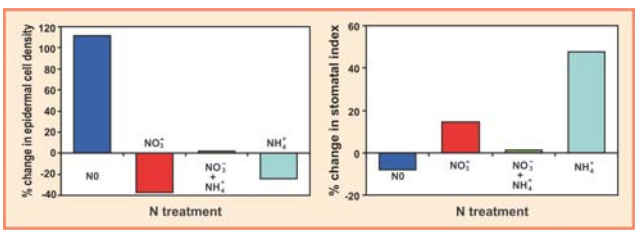
Kinetic constants of Rubisco as affected by elevated temperature in wheat. Wheat (*Triticum aestivum* L.) cultivars HD 2285 and HD 2329 were grown in control (C) and heated (H) open top chambers (OTCs) for the entire period of growth and development till maturity. The H-OTCs maintained a higher mean maximum temperature of around 3 °C compared to that of C-OTCs. RuBP carboxylase from flag leaf of H grown plants was assayed at 25 °C, and C grown plants at 25 °C and 40 °C. This also provided information on *in vitro* high temperature effect on RuBP carboxylase. The kinetic constants, V_{max} (carboxylase) and K_m (CO_2), were calculated from double reciprocal plots derived from the CO_2 saturation curves. Both V_{max} and K_m (CO_2) of RuBP carboxylase from C and H grown plants determined at the same assay temperature of 25 °C showed no significant differences. However, kinetic constants of C grown plants determined at two different temperatures (25 °C and 40 °C) showed that both V_{max} and K_m (CO_2) were higher when determined at 40 °C than at 25 °C in both the cultivars. This showed that higher temperature influenced the kinetic properties of Rubisco. Furthermore, the increase in V_{max} was always found to be associated with the increase in K_m (CO_2) indicating that the forms with high specificity have low maximum catalytic rate of Rubisco. An indirect result of higher specificity may be lower crop canopy photosynthesis because the detrimental effect of lowered catalytic rate may out weigh the beneficial effect of increased specificity.

Studies on heat shock proteins and thermotolerance for grain growth in wheat. Wheat (*Triticum aestivum* L.) cultivars DL 153-2 and HD 2285 (relatively tolerant), and HD 2329 and WH 542 (relatively susceptible) were exposed to post anthesis high temperature in heated open top chamber (H-OTC) and by late sowing. Under late (December 28) sowing, wheat cultivars were exposed to higher mean maximum temperature up to 3.6 °C compared to that of normal (November 27) sowing; whereas, under heated OTCs the mean maximum temperature was 3.2 °C higher than that of control OTCs during the grain growth period. Level of heat shock protein (HSP) 18 in the developing grains, 20 days after anthesis (20 DAA) was determined in C and H-OTC grown plants and at 10 and 20 DAA in normal and late sown plants by western blot. This moderately high temperature exposure increased the accumulation of HSP 18 in the developing grains. The relatively tolerant cultivars as revealed from heat susceptibility index showed a greater increase in HSP 18 compared to susceptible types in response to moderate heat stress. The low molecular weight HSP could, therefore, be important in providing increased tolerance to moderate heat stress during grain development.

5.3.1.2 Physiological approaches to improvement in nutrient use efficiency

Effect of nitrate and ammonium nutrition on growth and anatomical charactersistics of wheat grown under elevated CO_2. An experiment was conducted to determine the changes in morphological and anatomical characteristics of leaves of wheat cultivar PBW 343 in response to different nitrogen (N) forms and elevated carbon dioxide. The changes in growth, root system architecture, N accumulation, nitrate reductase activity, epidermal cell and stomatal parameters were examined in response to atmospheric CO_2 enrichment and ammonical and nitrate forms of N sources. The main aim was to observe if changing climate leads to changing pattern of fertigation.

N forms affected the metabolism, morphology (shoot and root weight) as well as anatomy of the leaves differently under elevated CO_2 (EC) and ambient CO_2 (AC). Stomatal density and epidermal cell length changed in response to EC and ammonium nutrition. There was inverse correlation between stomatal density and CO_2 concentrations.

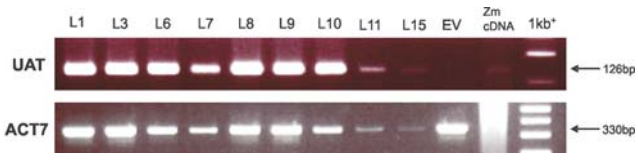


Effect of elevated CO_2 concentration on the per cent change in epidermal cell density and stomatal index in the leaves of wheat seedlings grown in various N forms (ACO_2 =100 %)

The mixed N nutrition in the form of NH_4NO_3 increased the shoot biomass and N content of the plants. Shoot: root ratios increased in ammonium treated plants grown in EC. Root NO_3^- absorption rate decreased in response to doubling of the atmospheric CO_2 concentration when the nitrate concentrations were high. It suggests that when the rate of carbohydrate supply to the root is limiting, NO_3^- is a less favorable form of N. Uptake and utilization of NO_3^- may, therefore, change with altered photosynthate and energy status of the root under elevated CO_2.

Cloning and over expression of genes from maize grown under nitrogen stress. Among cereals, maize is a heavy feeder crop which requires large quantities of nitrogenous fertilizers to attain the maximum yield. Little is known about the molecular basis of nitrogen (N) use efficiency in maize. In order to study the efficiency of maize crop under N stress, it is important to find out the expression of different genes at transcriptional level. An experiment was conducted on maize hybrid LH 244 with the aim to clone and over express maize genes that are differentially regulated in the roots under nitrogen deprived condition. Putative urea active transporter (*ZmDUR3*) was cloned from maize roots and over- expressed in *Arabidopsis*. The *ZmDUR3* has an open reading frame of 2193 bp. The *ZmDUR3* was successfully over-expressed in *Arabidopsis*. The urea active transport protein in *Arabidopsis* co-transports urea with protons at high affinity. This transporter belongs to the Sodium Solute Symporter Family (SSSF).

The RT-PCR of T2 lines of *ZmDUR3* showed that the transgenes were highly over-expressed in lines L1, L3, L6, L8, L9 and L10 while in L7 the expression was medium. Lines L11 and L15 showed very low-expression of the transgene.



RT-PCR of 35S::UAT lines (T2) by gene specific and reference primers

5.3.2 Improvements in Abiotic Stress Tolerance in Crop Plants: Physiological Approaches

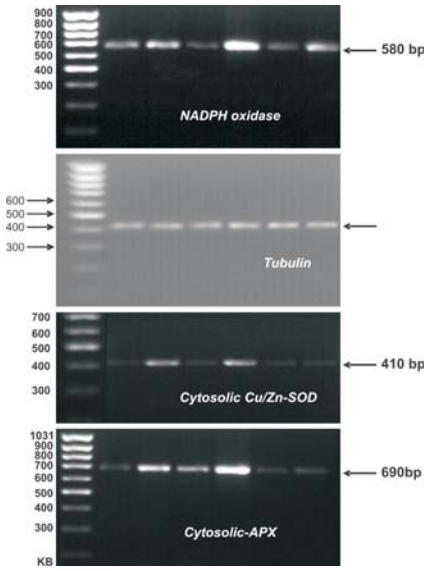
5.3.2.1 Identification of morpho-physiological traits associated with stress tolerance

Studies on high temperature stress tolerance in wheat. Impact of high temperature treatment (HTT) in polyhouse (5 °C-8 °C above ambient) was studied from anthesis to maturity in thirty-six genotypes representing all the wheat growing regions of the country under field conditions. On the basis of membrane stability index (MSI), heat susceptibility index (HSI) and dry matter production, yield and yield components, six genotypes showing high level of tolerance and susceptibility were selected and exposed to high temperature conditions. Observations were taken on grain growth rate (GGR), dry matter production, yield and yield components.

Highly significant and positive correlation was obtained between MSI and biomass production particularly under stress environment. In all the susceptible genotypes, significant reduction in GGR was observed because of high temperature exposure. The present study indicates that grain growth rate could be used as one of the parameters for screening a large number of genotypes. It is closely associated with increased starch deposition and hence higher test weight and grain density. For breeding genotypes tolerant to adverse temperature, physiological parameters like MSI, HSI and GGR may be used for screening large breeding populations as these are relatively simple and reliable parameters.

5.3.2.2 Understanding the mechanism of stress tolerance at cellular and biochemical levels

Role of antioxidants in water logging tolerance of mungbean. An experiment was conducted to investigate the role of antioxidant defence system in providing hypoxia tolerance in tolerant (T 44) and susceptible (Pusa Baisakhi) green gram (*Vigna radiata*) genotypes, and highly tolerant wild species *Vigna luteola*. Waterlogging induced decline in relative water and chlorophyll contents in leaves, and membrane stability index in leaves and roots was greater in susceptible genotypes, and was found to be associated with an increase in oxidative stress in the form of superoxide radical ($O_2^{\cdot-}$), hydrogen peroxide (H_2O_2) content and lipid



Expression analysis of NADPH oxidase (*NOX*) and tubulin, cytosolic Cu/Zn-superoxide dismutase (cyt. *Cu/Zn-SOD*) and cytosolic ascorbate peroxidase (cyt.-*APX*) genes under 24 h waterlogging stress and control conditions. Gene expression was determined by RT-PCR utilizing gene specific primer sets for each gene. (M: 1 kb ladder, 1 : control *V. luteola*, 2: treated *V. luteola*, 3: control T 44, 4: treated T 44, 5: control PB, 6: treated PB)

peroxidation. The hypoxia induced $O_2^{\cdot-}$ and H_2O_2 contents were found to be associated with the induction of Diphenylene iodonium chloride (DPI) sensitive membrane linked NADPH oxidase (NOX), while control and post hypoxia plant showed NADPH oxidase independent reactive oxygen species (ROS) generation. There was also an increase in antioxidant enzyme activities (superoxide dismutase, ascorbate peroxidase, glutathione reductase and catalase) during hypoxia, which was higher in tolerant genotypes (T 44, MH 96-1) and wild species *Vigna luteola* than in susceptible genotypes (Pusa Baisakhi, MH 1K-24). Expression analysis of *NOX*, *Cu/Zn SOD* and *APX* genes showed water logging induced increase in transcription in *Vigna luteola* and T 44. Results suggest that water logging induced increase in ROS level was due to increase in *NOX* gene expression and activity, and the tolerance of *Vigna luteola* and T 44 was due to the higher gene expression and activity of the antioxidant enzymes.

Response of green gram to thiourea foliar application under waterlogging. In two diverse green gram genotypes (MH-1K-24 and MH-96-1), waterlogging at vegetative stage was imposed for 7 days. Foliar treatment of thiourea @ 1000 ppm was found to be most effective in enhancing the values of growth parameters, membrane stability index, tolerance to water logging, level of photosynthetic pigments (chlorophylls and carotenoids), stomatal conductance, rate of photosynthesis, carboxylation efficiency, fast recovery after water logging termination, grain yield and its attributes under waterlogging in both genotypes. On an average, the optimum dose of thiourea was estimated to be approximately 750 ppm. However, the response was relatively better in susceptible genotype (MH-1K-24; V1) than that in tolerant genotype (MH-96-1; V2).

5.3.3 Evaluation of Heat Stress Tolerance in *Triticum aestivum* and *Triticum durum* Wheat Genotypes under Continual and Terminal Heat Stress Environments

Wheat crop is exposed to continual heat stress (throughout the crop growth period) and to terminal heat stress (during grain growth period). Characterization of genotypes in both continuous and terminal heat stress environments is necessary to identify the sources of heat tolerance for these environments. Hence, in this study, 20 genotypes of *T. aestivum* (hexaploid, BBAADD genome) and 16 genotypes of *T. durum* (tetraploid, BBAA genome) were evaluated for terminal and continual heat stress tolerance at Delhi, and Madhya Pradesh (MP), respectively. Normal and late sowings were done at both the locations to assess the genotypes under normal and heat stress environments, respectively. The late sown crop of Delhi experienced higher temperatures during grain development while in MP environments, the crop experienced moderately higher temperature during normal sowing, and extremely higher temperatures during late sown conditions throughout the crop growth period. Wide variation for continuous or terminal heat tolerance for yield and yield components was found between *T. aestivum* and *T. durum* genotypes. Heat tolerance of genotypes varied in continual or terminal heat stress environment. *T. aestivum* genotypes such as Lok1, HUW 234, Raj 3777, C 306, N 15439, NP 846 and Kalyansona, and *T. durum* genotype DHT 15 showed heat tolerance in both terminal and continual heat stress environments. Under both heat stress environments, high biomass production and

grains m^{-2} appear to be the two important traits for higher temperature during pre-heading and post-heading periods, while in terminal heat stress environment, the reduction in grain number was due to sudden increase in temperature during the grain growth period. Photothermal quotient correlated positively and significantly with both grain yield and grains per unit area under both continual and terminal heat stress environments. Reduction in grain number under continual but moderate heat stress environment acts as a compensation mechanism to maintain grain weight in wheat genotypes. *T. aestivum* genotypes Kundan and Lok1 and *T. durum* genotypes HI 8498 and DHT 15 maintained 1000-grain weight of >45g under heat stress environments. This study shows that wheat cultivars differ in their tolerance depending upon the nature of heat stress, i.e., continual or terminal heat stress.

5.3.4 Morpho - Physiological Traits for Drought Resistance in Advanced Generation Population of the Cross WL711 × C306 under Water Variable Environments

Experiments were conducted with parents and selected 27 lines in F_5 and F_6 generations from the cross WL 711 × C 306 under fully irrigated (I_5) and limited irrigation (I_2) environments. The parents and the selected lines were evaluated for different morphological traits like early vigour, growth habit, leaf rolling, phenology, etc., and physiological traits like CMS, CTD, ELRWC, water relation parameters, yield and yield components. Drought susceptibility index (S) in relation to I_5 environments was calculated for yield and yield components to measure the relative drought resistance of parents and selected lines. Drought resistant parent C 306 showed lesser reduction in yield as compared to drought susceptible parent WL 711 as was observed from the lower drought susceptibility index (S>1.0). Some of the selected lines in F_5 and F_6 generation behaved like C 306 under stress. A few selected lines, HT8, HT9, BR10, BL10 and W12 showed higher yield in normal conditions and lower reduction under water stress. Drought susceptibility index (S) of these lines for yield was lower than unity in both the generations showing better response under drought. The better response of C 306 and these lines for grain yield under water stress was found to be associated with compensation in yield components. The major compensation was observed in grain weight, grain number and HI. Lower grain number helped in the maintenance of higher grain weight under water stress while higher HI under water stress showed efficient mobilization of stored assimilates to the developing grains. Different physiological traits such as CMS, CTD and water relation parameters measured during post-anthesis stage showed significant correlations with yield and yield components under water stress. Parent C 306 and the above-mentioned lines showed higher CMS, and CTD, and maintained better water relations under drought. The traits such as CMS, CTD and RWC showed moderately higher broad sense heritability than yield and yield components under normal as well as water stress environment.

5.3.5 *Gamma* Radiation Induced Plant Responses, Pesticide Degradation and Post Harvest Quality Preservation of Agri-products

5.3.5.1 Sprout inhibition of red and white onion types

An experiment was conducted to assess the effect of *gamma* irradiation (0, 0.10 and 0.15 kGy) on post harvest shelf life and sprouting of red and white species of onion. A dose of 0.10 kGy was sufficient to completely inhibit sprouting in both the species for more than four months from harvest. Red onions showed better storability and low post harvest losses as compared to white onion cultivar. A higher dose of 0.15 kGy, although prevented sprouting, resulted in outer membrane injury which was again more in red onions as compared to white types.

0.15 kGy **0.10 kGy** **Control**

Effect of *gamma* irradiation on sprout inhibition in red and white onions

5.3.5.2 Nutritional quality of pulses and cereals during storage

Gamma irradiated (up to 5 kGy) chickpea and wheat seeds stored for more than 18 months at room temperature, although showed reduced protein content, remained unaffected in protein quality as evident from SDS-PAGE analysis. This was true irrespective of *desi* or *Kabuli* type of chickpea. Even a potentially harmful high dose of 5 kGy did not affect the protein quality. The decline in protein content ranged between 10% and 30%.

5.3.5.3 Phytase activity of chickpea seeds

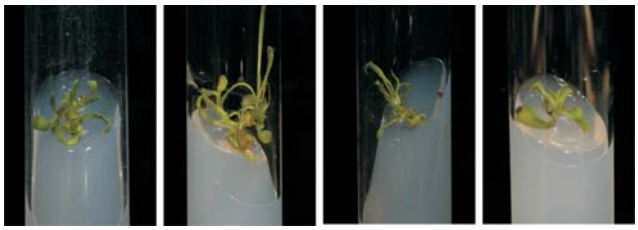
Phytase activity, responsible for the breakdown of phytate, was stimulated upon *gamma* irradiation (0, 0.2, 0.5, 3.0, 5.0 kGy) more in *Kabuli* type than in *desi* type of chickpea irrespective of the dose. No clear correlation could be drawn between an increase in dose of irradiation and stimulation of phytase. In *Kabuli* type, the increment in phytase upon irradiation over control was, in general, about 4 times while for *desi* chickpea type the increase was 0.5 times that of unirradiated control.

5.3.5.4 Nodulation attributes of *desi* and *Kabuli* chickpea types

An experiment was 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 0.1kGy) on the growth, nodulation and yield characteristics. In general, *Kabuli* type produced more plant-root and shoot mass, and nodule number, and 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* type chickpea.

5.3.5.5 Regeneration efficiency of *Helichrysum* spp.

Gamma irradiation (0.025, 0.050, 0.01 up to 1.0 kGy) was used to assess its utility in the control of excessive callus growth and for improved regeneration of plantlets per node from cotyledonary node of *Helichrysum bracteratum*, a flowering plant belonging to Asteraceae family, and for inducing mutations for color in ornamental Yucca "golden sword", by the use of leaf explant. The idea was to see if gamma irradiation could be used to substitute TIBA as callus



Control (x2.45) 0.0025 kGy (x2.16) 0.005 (x 2.16) 0.01 (x2.16)

Low dose of *gamma* irradiation (in kGy) stimulating formation of multiple shoots from cotyledonary node explants of *in vitro* raised seedlings of *Helichrysum bracteratum*

growth retardant. It was observed that low doses of 0.025 and 0.05 were very effective in reducing the callus growth and increasing the regeneration efficiency in terms of number of plantlets per node.

5.3.5.6 Degradation of pesticide residues

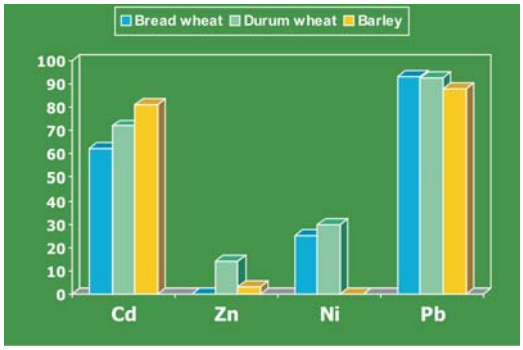
Gamma irradiation (0.5, 1.0, 3.0, 5.0 kGy) was assessed for its efficacy as a non- chemical method for degradation of pesticide (Deltamethrin). Up to 90% degradation of pesticidal activity was achieved with 5 kGy dose of *gamma* radiation *in vitro*. The recovery of deltamethrin on HPLC was as high as 95%. About 30% degradation was achieved with a low dose of 0.5 kGy.

5.3.6 Effect of Growing Temperatures on Photosynthetic Efficiency of four Cotton Varieties

Temperature tolerance of four cotton varieties, viz, H1117, P 56-4, P 1710 and RS 2013, was measured in terms of effect on photosynthetic efficiency. Temperature, in general, decreased the photosynthetic efficiency. However, the genotypic differences in thermal tolerance of photosynthetic apparatus was clearly apparent. The variety H1117 showed consistently higher photosynthetic rate and transpiration rate as compared to other cotton varieties.

5.3.7 Role of Phytosiderophore in Phytoremediation of Heavy Metals

The use of plant produced phytosiderophores was investigated as a possible phytoremediation strategy. It was observed that the metal chelation property of phytosiderophore went beyond Fe and Zn, to even mercury cadmium, chromium and lead. The interaction between phytosiderophore and mercury was concentration dependant. Phytosiderophore also mobilized cadmium, lead



Interaction of phytosiderophore and heavy metals at plant level measured as per cent HM-PS complex unavailable for plant uptake

and chromium in a descending order. The binding efficiency of phytosiderophore to zinc was the highest and depended on the species of phytosiderophore. The inhibitory effect of Cd on Zn-mobilization or Zn on Cd-mobilisation by phytosiderophore of wheat (Deoxymugineic acid) was much higher than the inhibition of phytosiderophore mediated Cd-mobilisation by Zn in barley (Mugineic acid). Cd-chelate appears to be a strategy of detoxification of metal. This is in contrast to Zn which not only binds with phytosiderophore but also the complex formed is readily transported into the roots and then to the shoot in a complex form. Similar to Cd, Ni concentrations in plants of bread and *durum* wheat declined, but for barley, in the presence of phytosiderophore. The translocation of Pb, as evident from shoot Pb level, was totally inhibited in cereal species. High performance liquid chromatography (HPLC) analysis confirmed the formation of heavy metal-phytosiderophore complex as evident from the appearance of a second peak in addition to the phytosiderophore peak for all the chelated metal forms. This investigation provides conclusive evidence of mobilization of heavy metals by phytosiderophore and preference for certain heavy metal complexes over others for plant uptake and regulation of metal chelation by phytosiderophore species.

5.3.8 Contribution of Leaves at Different Positions towards N-assimilation after Anthesis in New Wheat Plant Type (DL 1266-5)

Contribution of flag leaf towards N-assimilation was maximum at 27% followed by penultimate leaf (8th position, 18%) and lower leaf (7th position, 16%). This was due to higher leaf area duration, leaf dry weight and leaf nitrate reductase activity of flag leaf after anthesis in this promising wheat genotype (DL 1266-5). These traits can be exploited for genetic improvement of wheat.

5.3.9 Standardization of Forcing Technique for Early Flowering in Lilium

A significant reduction in time taken to flowering was recorded with prolonged storage of bulbs at 2 °C and 4 °C temperatures. Maximum reduction was recorded with the storage of bulbs at 4 °C for 8 weeks. However, flowering was not much affected by light regimes (18 hrs LD and 8 hrs SD + 4 hrs NI) when bulbs were stored for longer durations.

5.3.10 Post-harvest Physiology of Fruits, Vegetables and Flowers

5.3.10.1 Physiological and molecular bases of regulation of flower senescence

Regulation of banana fruit ripening by 1-methylcyclopropene (1-MCP). Experiments were conducted to study the effect of 1-methylcyclopropane (1-MCP) on fruit ripening in two varieties of banana.1-MCP treatment significantly delayed the ripening of banana fruits by extending their shelf life, reducing their pulp/peel ratio, respiration rate, ethylene evolution and total soluble solids (TSS). Non-significant differences were observed at different concentrations and durations of treatment employed. 1-MCP treatment delayed the degreening of banana fruit but had no effect on carotenoid content. 1-MCP treatment delayed the breakdown of starch into sugars. Pulp had higher sugar and starch content. 1-MCP treatment significantly reduced the activity of cell wall softening enzymes, viz., Polygalactouronase, Pectin methyl esterase, cellulase and pectate lyase, thus contributing to the delayed ripening. Pulp had higher level of activity of cell wall softening enzymes compared to that of peel. 1-MCP treatment led to increased ascorbate peroxidase and peroxidase activities but had no effect on catalase activity. Peel had higher antioxidant enzymatic activity as compared to that of pulp. Variety Basrai had longer shelf life compared to that of Bombay Green. Expression of cytochrome P450 and β-1,3 glucanase was closely related to fruit ripening and was ethylene inducible.

Cytochrome P450 expression was higher in peel than that in pulp, unlike β-1,3 glucanase, which was expressed equally in peel and pulp. Unlike cytochrome P450, β-1,3 glucanase was expressed early during ripening.

Characterization of proteases during flower senescence in gladiolus. The objective of this investigation was to understand the mechanism of protein degradation and its regulation during flower development and senescence in gladiolus and to identify the triggers that lead to senescence. Gladiolus is an ethylene insensitive flower system; therefore, ethylene is not involved in the process of senescence. To find out the role of proteases during the process of flower senescence, gladiolus flower spikes and florets of cultivar Snow Princess were chosen. Twelve endoprotease inhibitors were used to find out the impact on visible senescence of flowers and vase life and it was concluded that just before visible senescence more than half of total endoprotease activity was apparently due to cysteine proteases, and somewhat less to serine proteases, with a minor or no role of aspartic and metalloproteases. Treatment of isolated florets with the known cysteine protease inhibitors N-ethylmaleimide and E-64 prevented the increase in endoprotease activity and considerably delayed or prevented the normal senescence symptoms.

Regulation of petal senescence vis-à-vis cysteine proteases was studied by analyzing the expression programme of GgCyP in petals as affected by various antisenescent compounds. Results indicated that out of the three antisenescent compounds used (Inositol, SA and E-64), salicylic acid at 400 µM was most effective and led to a dramatic decrease in GgCyP transcript levels within four hours of exposure. This decrease in GgCyP transcripts levels occurred well before the appearance of visible symptoms of the onset of petal senescence.

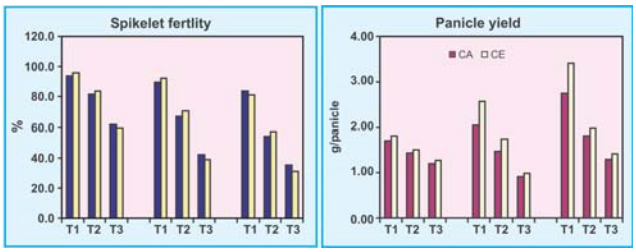
Regulation of ripening in climacteric fruits. The relationship between ripening behaviour and stem scar region of fruit in different tomato (*Solanum lycopersicon* L.) cultivars (stored at temperature of 30.0-30.5±1°C or 25.0±1°C) was studied by blocking the stem scar region either completely or to different degrees. It was demonstrated that the degree of blockage of the stem scar region determined the extent by which the rate of respiration, climacteric rise and ripening were suppressed. These suppressive effects were found to diminish with the advancement in the ripening of the tomato fruits being treated. The study pointed out the role, importance and significance of stem scar region in determining the rate of ripening. So, this may be exploited in improving the post -harvest storability of tomato fruits by delaying the process of ripening.

5.3.11 Characterization of Crop Responses to Global Climate Change

Interactive effects of high CO_2 and temperature on growth and yield of rice genotypes. Rising atmospheric carbon dioxide (CO_2) and temperature are two important factors of climate change scenario, and both may affect the growth and development of crop plants. Rising temperature may affect plant productivity as both duration and rate of grain filling are determined by change in temperature. However, high atmospheric CO_2 is expected to reduce the negative effect of temperature on yield by enhancing the rate of photosynthesis and supply of carbon assimilated to developing grains. The present study was conducted to analyse the interactive effects of high CO_2 and temperature on spikelet fertility, panicle yield and plant biomass for three rice genotypes.

Three rice genotypes, viz., N22, IR64 and IR75217H (Hybrid) were grown under controlled environment at optimum growth conditions. The plants were raised under normal and high CO_2 environment from germination onwards. At anthesis stage, two sets of plants of each genotype were transferred under high temperature conditions and exposed to 35 °C and 38 °C temperatures for a five-day period. One set of plants was kept under normal temperature.

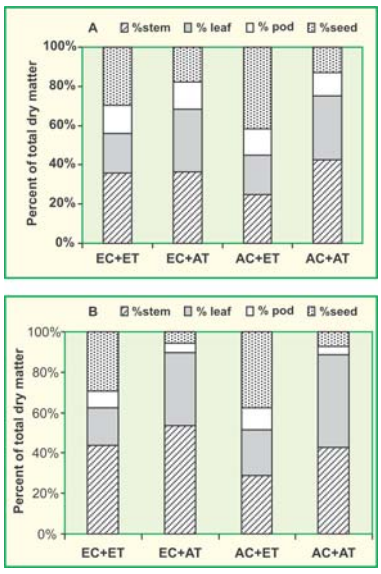
The study showed decreased spikelet fertility in all three rice genotypes due to exposure to high temperature. IR 64 and hybrid showed 58% and 62% reduction in fertility, respectively, at 38 °C. Reduction infertility in N22 was lower as compared to 1R64 & hybrid. Under high CO_2, spikelet fertility was more or less similar to that of control CO_2. Increased spikelet sterility in high temperature exposed plants caused significant reduction in panicle yield in all three rice genotypes. N22 showed only 15% and 17% reduction in panicle yield at 35 °C temperature, in control and elevated CO_2 grown plants but the reduction in panicle yield was up to 30% in 38 °C temperature



Effect of high temperature and CO_2 on spikelet fertility and panicle yield in rice genotypes. CA: ambient CO_2, 380µl l-1; CE: elevated CO_2, 600 µl l-1. T1: control temperature (29 °C); T2:35 °C; T3:38 °C

exposed plants. Similarly, large reductions in per panicle yield were observed in IR64 and hybrid rice. IR64 plants showed up to 32% and 55% reductions at 35 °C and 38 °C temperatures, respectively. On the other hand, in hybrid rice reductions in panicle yield were 42% and 58% at similar treatment. This study concludes that 5 °C increase in atmospheric temperature may cause large reduction in rice yield and higher CO_2 may be ineffective to negate the effect of temperature.

Dry matter partitioning in chickpea in response to elevated CO_2 and temperature. Dry matter partitioning in response to elevated CO_2 and temperature was studied in two genotypes of chickpea, viz., Pusa 256 and Pusa 212. High temperature along with or without elevated CO_2 concentration resulted in decreased dry matter partitioning in shoot and leaves, but increased dry matter partitioning in seeds. Seed growth rate and yield also increased with high temperature which also depended on genotype. Chickpea genotype with higher grain growth and size (Pusa 256) responded better to the future climate change scenario of higher temperature and elevated CO_2.



Effect of elevated CO_2 and temperature on dry matter production and partitioning in chickpea varieties. A: Pusa 256 and B: Pusa 212. (EC+ET: elevated CO_2 + elevated temperature, EC+AT: elevated CO_2 + ambient temperature, AC+ET: ambient CO_2 + elevated temperature, and AC+AT: ambient CO_2 + ambient temperature)

5.4 GENETICS

5.4.1 Wheat

5.4.1.1 Distribution of hybrid dwarfness genes

Distribution of hybrid dwarfness genes in more than one hundred genotypes of *Triticum aestivum* was investigated. Forty-nine genotypes were found to carry gene(s) for hybrid dwarfness, including prominent cultivars such as PBW 343, C 273, Raj 3765, UP 2338, Narmada 4, DBW 16, Ningmai, etc.

5.4.1.2 Genetics and linkage analysis for various traits in interspecific derivative

Genetic analysis was carried out in cytologically stable interspecific (*Triticum aestivum*/ *T.militinae*) derivative selection, Sel. T 2836-1 (2n=6x=42) to study the mode of inheritance of leaf rust resistance, leaf and node pubescence and glume hardness. The resistance analysed through test of allelism and molecular marker revealed that the resistance in Sel. T2836-1 was allelic to the gene *Lr24*. Pubescence of leaf and glume was controlled by duplicate dominant genes, one of which was linked to the node pubescence gene located at 36.84 Kosambi unit, whereas glume hardness was governed by a single dominant gene.

5.4.1.3 Pyramiding of rust resistance genes through molecular markers

Leaf rust resistance genes *Lr24*, *Lr28* and *Lr37* were pyramided in the genetic background of popular cultivar WH147 in various combinations using validated molecular markers for these genes. Near isogenic lines of WH 147 were produced with *Lr24/Sr24+Lr28*; *Lr24+ Lr37*, and *Lr28+Lr37/Sr38*. Initial agronomic data showed that these

pyramided lines were more or less on a par with WH 147 in yield and yield contributing traits.

One population carrying *Lr24/Sr24* in PBW 343 was homogenized by using marker assisted backcross breeding (MABB) with resistance to the native *Ug99* race. This would be an immediate stop gap arrangement for *Ug99* resistance preparedness in NWPZ till other genes are put together to overcome the variants of *Ug99*. This line is sufficient to resist the race which has reached Iran.

5.4.1.4 Genetics of angled spikelet arrangement in *durum* wheat

A different non-standard morphology of spikelet arrangement on the rachis of spike, in which spikelets are angled away from the axis of rachis was discovered in *Triticum durum*. Genetic analysis revealed that this unique morphology of spike was controlled by a single gene with incomplete dominant.

5.4.1.5 Genetic analysis for leaf rust resistance

Three *T. timopheevii* derivatives and two exotic lines were found highly resistant to12 pathotypes of leaf rust. The testing of F_1 and F_2 seedlings of crosses involving these lines with susceptible variety Agra Local against most virulent and prevalent pathotype *77-5* of leaf rust identified single dominant gene for leaf rust resistance in *T. timopheevii* derived line G7 and one recessive gene each in G8 and G12. Analysis of two exotic lines 1st SAMNYT 436 and 1st SAMNYT 439 by testing of F_1 and F_2 seedlings suggested that single recessive gene controlled leaf rust resistance in these lines.

5.4.1.6 Inter-relationships, stability and molecular diversity analysis for quality, yield and yield components in new plant type (NPT) wheat derivatives

Twenty-three new plant type (NPT) wheat derivatives along with three standard checks were investigated for stability, genetic variability and association analysis of yield and its components including quality traits. Farinograph and bread baking test of eighteen selected genotypes based on protein %, sedimentation value (ml) and dry gluten content (%), indicated existence of considerable variability for all the characters studied. Grain yield (t/ha), number of grains per spike, grain weight per spike (g), 1000- kernel weight (g) and sedimentation value (ml) exhibited high phenotypic coefficient of variation, genotypic coefficient of variation and high heritability coupled with high genetic advance as per cent of mean suggesting that these traits can be utilized as selection criteria in wheat breeding programmes. Correlation and path analysis revealed that the characters, viz., number of grains per spike, grain weight per spike (g), 1000-kernel weight (g), sedimentation value (ml) and dry gluten content (%) can be considered in selection programmes in the improvement of yield *per se* because of their positive direct effects and significant positive association with grain yield. DL 886, DL 901, DL 924, DL 927, DL 966 and DL 960 were found to be stable and suitable to a wide range of environments for grain yield. The genotypes DL 910, DL 919, DL 960 and DL 940 produced superior bread based on bread loaf volume and other textural characteristics. The location Delhi was found to be favourable for the expression of starch pasting properties and in realizing good bread making quality, whereas Pusa (Bihar) was suitable for the expression of traits related to biscuit. Molecular diversity analysis of forty genotypes by the use of a set of 40 STMS markers revealed a total of 113 alleles. Pair-wise similarity coefficients among the 40 genotypes based on 40 STMS markers ranged from 0.22 to 0.77 indicating greater extent of diversity among the genotypes which can be utilized in various breeding programmes.

5.4.1.7 Genetics of high temperature tolerance in wheat (*Triticum aestivum* L.)

High temperature at grain filling stage is an important production constraint of wheat (*Triticum aestivum* L.). Twenty-five promising wheat genotypes were evaluated under three environmental conditions. Sufficient genetic diversity was observed among different genotypes without aligning to their origin and adapted areas. Correlation studies showed the highly significant and positive association of grain yield with tillers per meter row, 1000-grain weight, membrane thermo-stability (MTS) index and canopy temperature depression (CTD) at anthesis in all the three environments suggesting that these can be used as selection criteria for high temperature tolerance. Genotypes HD 2808 and DL 711 were selected for generation mean analysis as they were found to be high

yielding under all three environments with tolerance to high temperature at grain filling stage. HUW 510 was taken as susceptible parent and two crosses, namely, HD 2808 × HUW 510 and DL 711 × HUW 510 were made to produce F_1, F_2 and F_3 populations and evaluated for various quantitative and physiological parameters under timely and late sown conditions. The significance of scaling tests indicated the presence of epistatic (non-allelic) interaction under timely sown condition in both the crosses. Genetic effects were different in both the crosses under late sown environment. Inheritance of MTS index was under epistatic interaction but higher magnitude of additive × additive effect is reported indicating reasonably higher heritability. Inheritance pattern of CTD varied from cross to cross and from environment to environment. Results demonstrated that high temperature tolerance of bread wheat was controlled mostly by epistatic alleles and suggested that selection must be employed at different locations and time during varietal development.

5.4.1.8 Genetic and molecular analysis of stem rust (*Puccinia graminis* f. sp. *tritici*) resistance gene in synthetic hexaploid wheat (SHW) lines

Three SHW lines, viz., Syn 4, Syn 55 and Syn 86 were studied and screened for rust resistance against most virulent stem rust pathotype 40A. All these synthetic hexaploid wheat lines were found to be resistant to stem rust pathotype 40A. In the Syn 4 × Agra Local and Syn 55 × Agra Local crosses, F_2 populations showed 3:1 ratio conferring single dominant resistance gene responsible for stem rust resistance. The gene for resistance in Syn 4 and Syn 55 was found to be the same, as confirmed by the test of allelism. In Syn 86, resistance to stem rust was governed by two genes (one dominant and one recessive) based on F_2 generation ratio of 13 resistant: 3 susceptible. The SSR marker *Xgwm533* located on chromosome 3B was found to be linked with resistance gene at a distance of 5cM and marker *Xgwm389* was co-segregating with resistance in the F_2 population of Syn 4 × Agra Local. This resistance gene was different from *Sr2* gene since there was no PBC (pseudo black chaff) and seedling chlorosis.

5.4.1.9 Molecular analysis for dwarfing genes

Reduced plant height has been achieved globally by exploiting *Rht-B1b* and *Rht-D1b*. Distribution of *Rht-B1b* and *Rht-D1b* genes in 250 released varieties and germplasm lines was studied. The genes were present in 39.1% and 25.3% of the genotypes. Alternative dwarfing genes like *Rht4, Rht5, Rht8* and *Rht12* are available in the germplasm. These genes were screened with the help of available molecular markers for their effect on plant heights and coleoptile lengths. Coleoptile length ranged from 3.8cm-10.41cm among individuals and varied with different gene combinations. *Rht*8c alone or in combination with *Rht-B1b* was more effective in maintaining longer coleoptile length and dwarf height. *Rht-D1b* masks or confounds the effect of *Rht8c* and, therefore, gain through marker based selection for *Rht8c* would not be much in its presence. The other genes like *Rht4*, *Rht5*, *Rht12* and *Rht13* though present in small frequency do not seem to offer any advantage.

5.4.1.10 Molecular studies for leaf rust resistance genes

The genotypes were studied for the desired leaf rust resistance traits such as *Lr9, Lr10, Lr19, Lr24, Lr26* and *Lr34* with the help of molecular markers so that they can be directly utilized in breeding programmes. Around 50 genotypes contained *Lr26/Yr9* segment. Four genotypes were positive for *Lr9* gene, and two each for *Lr19,* and *Lr10*. *Lr24*, and *Lr34* were present in eight genotypes.

5.4.1.11 Evaluation of MAS derived rust resistance populations

Fourteen population bulks carrying *Lr48+Lr24* and *Lr48+Lr28* in PBW 343 background were put together in the first approach for combining adult plant resistance with major gene seedling resistance in wheat for durable rust resistance approach by using MAS.

5.4.1.12 Wheat pyramiding of rust resistance genes in some popular indian bread wheat cultivars

Transfer of leaf rust resistance genes, *Lr24, Lr28, Lr35* and *Lr37* as well as yellow rust resistance genes, *Yr10* and *Yr15* into wheat genotypes HD 2733, HD 2687, PBW 343, HUW 234, Lok1 and WH 147 was carried out while transfer of *Lr24, Lr28, Lr35* and *Lr37* into all these cultivars was completed employing marker assisted selection (MAS).

5.4.2 Rice

5.4.2.1 Marker aided improvement of parental lines of Pusa RH 10 for resistance to bacterial blight (BB)

Parental lines of Pusa RH 10 (Pusa 6B and PRR78) were improved through marker assisted selection for transfer of two bacterial blight resistance genes *xa13* and *Xa21,* from Pusa 1460.

The extent of recurrent parent genome in the progenies in Pusa 6B backcross series, designated as Pusa 1605, ranged from 92.3% to 95.6%. While the progenies in PRR78 backcross series, designated as Pusa 1601, showed 89.5% to 91.5% recurrent parent genome recovery, the BC_2F_5 and BC_2F_4 families of Pusa 1605 and Pusa 1601 series, respectively, were highly resistant to the BB disease on artificial inoculation with the most virulent Kaul isolate of Xoo. Several

Data on quality traits of promising BB resistant lines of Pusa 6B and PRR 78

Designation	KLBC (mm)	KBBC (mm)	KLAC (mm)	KBAC (mm)	Aroma
Pusa6B	**7.60**	**1.67**	**11.53**	**2.07**	**2**
Pusa1605-05-38-32-31-4-1-1	7.13	1.60	12.07	2.07	1
Pusa1605-05-38-32-31-4-1-2	7.93	1.67	13.20	2.13	2
Pusa1605-05-38-32-31-4-2-2	6.93	1.60	11.73	2.13	1
Pusa1605-05-38-32-117-2-1-6	7.00	1.60	12.73	2.00	1
Pusa1605-05-38-32-117-3-1-1	7.80	1.67	11.73	2.07	1
SE±	0.18	0.02	0.27	0.02	0.21
PRR78	**7.47**	**1.67**	**13.13**	**2.07**	**2**
Pusa1601-05-46-22-25-5-1-3	7.93	1.67	13.20	2.07	1
Pusa1601-05-46-22-25-5-1-1	8.33	1.73	14.27	2.20	3
Pusa1601-05-46-22-25-88-5-3	7.60	1.67	13.87	2.13	3
Pusa1601-05-46-22-25-69-5-3	8.13	1.67	13.00	2.13	3
Pusa1601-05-46-22-2-88-5-2	7.60	1.67	13.47	2.00	2
SE±	0.14	0.01	0.20	0.03	0.33

KLBC: kernel length before cooking; KBBC: kernel breadth before cooking; KLAC: kernel length after cooking; KBAC: kernel breadth after cooking

Agronomic performance and disease reaction of selected improved progenies of Pusa 6B and PRR78

Designation	DFF	PH (cm)	NT	PL (cm)	TW (gms)	TNG	SF (%)	Yield (t/ha)	% Sup	SI (cm)
Pusa6B	**89**	**101**	**11.90**	**26.30**	**22.5**	**208**	**91.34**	**6.000**	**-**	**11.04**
Pusa1605-05-38-32-31-4-1-1	86	95	14.00	26.80	23.3	233	85.40	7.11	15.88	3.53
Pusa1605-05-38-32-31-4-1-2	86	100	10.00	28.50	23.8	206	96.11	6.96	13.44	3.98
Pusa1605-05-38-32-31-4-2-2	82	102	11.00	26.20	22.2	208	94.71	7.12	15.26	3.53
Pusa1605-05-38-32-117-2-1-6	85	98	11.00	27.30	20.1	201	93.03	7.20	19.20	3.55
Pusa1605-05-38-32-117-3-1-1	88	96	15.00	28.20	22.1	179	88.26	6.25	4.00	3.85
SE±	1.00	1.15	0.80	0.40	0.52	7.08	1.66	0.210	3.11	1.23
PRR78	**91**	**110**	**9.45**	**27.48**	**25.60**	**207**	**94.20**	**6.20**	**-**	**18.53**
Pusa1601-05-46-22-25-5-1-3	95	109	9.00	29.50	27.60	255	82.27	6.36	2.52	3.53
Pusa1601-05-46-22-25-5-1-1	87	115	10.00	27.50	30.80	175	85.71	6.41	3.25	3.40
Pusa1601-05-46-22-25-88-5-3	91	105	12.00	28.50	20.44	190	89.47	6.28	1.27	2.87
Pusa1601-05-46-22-25-69-5-3	97	103	12.00	28.33	26.8	225	89.77	6.76	8.28	3.53
Pusa1601-05-46-22-2-88-5-2	91	105	14.00	29.40	25.2	254	80.70	7.00	11.43	3.85
SE±	1.44	1.80	0.79	3.50	1.39	13.55	2.08	0.128	1.77	2.53

DFF: days to 50 % flowering; PH: plant height; NT: no. of tillers; PL: panicle length; TW: test weight; TNG: total no. of grain/ panicle; SF: spikelet fertility; SI: susceptibility index

selections showed improvement in spikelet fertility, kernel length after cooking (KLAC), aroma and yield superiority.

5.4.2.2 Marker aided improvement of parental lines of Pusa RH 10 for resistance to blast

A marker assisted back cross breeding programme was initiated for incorporating *Piz-5* and *Pi K*^{h} genes conferring resistance to blast disease in the parental lines of Pusa RH 10, viz., Pusa 6A and PRR 78. C101A51 and Tetep were used as donors for *Piz-5* and *Pi K*^{h}, respectively. Marker assisted foreground and background selection was used to compress the breeding cycle. A total of 329 BC_2F_2, BC_2F_3 and BC_1F_5 families involving cross Pusa 6B and PRR78 with Pusa 1460, C10151A and Tetep were evaluated for agronomic performance, disease reaction, and grain and cooking quality traits. The data on yield and components of improved PRR78 with Tetep and C101A51 are given in the following table.

5.4.2.3 Development of provitamin A rich *indica* rice lines through marker assisted backcross breeding (MABB)

The study aimed at introgressing provitamin A trait from transgenic Golden Rice (*GR1* and *GR2*) into widely grown Indian rice varieties, Swarna and Jaya. Stable transgene homozygous lines in BC_2F_4 generation introgressed with provitamin A gene form *GR1* are available for evaluation in the genetic background of Swarna and Jaya. These lines show total carotenoid level up to 12 µg /g of endosperm. Similarly, *GR 2* derived lines in the genetic background of Swarna are now in BC_2F_2 generation.

5.4.2.4 Mapping QTLs for yield and yield components by immortal mapping population in rice

Mapping of QTLs for grain yield and 11 yield related traits was carried out by using 310 F_7 RIL mapping population. A total of 127 QTLs were identified, of which 51 were novel.

5.4.3 Barley

5.4.3.1 Gene effects, combining ability and heterosis for fodder yield and other traits

Twenty-one genotypes of six-parent half diallel were analyzed for gene effects of variance, combining ability effects and standard heterosis for fodder yield and other traits in barley. Among the parents, BHS 352 and HBL 276 were identified as

Agronomic performance of improved lines of PRR 78 with resistance to blast disease

Designation	PH (cm)	NT	PL (cm)	TW (g)	Total no of grains / panicle			Yield (t/ha)
					F	UF	SF %	
PRR 78	**112.00**	**14**	**27.5**	**21.5**	**220**	**20**	**91.67**	**5.25**
PRR 78 × Tetep								
Pusa1603-05-89-39-20-1-67	111.40	10	26.46	26.8	285	23	92.53	6.20
Pusa1603-05-89-39-20-2-67	113.40	10.8	28.5	24.3	295	14	95.46	5.75
Pusa1603-05-89-74-21-1-80	92.20	14.2	25.96	19.5	195	11	94.66	6.45
Pusa1603-05-89-74-7-4-78	94.00	9.8	25.73	20.8	190	14	93.13	6.85
Pusa1603-05-89-74-23-1-81	94.20	10.2	27.03	21.3	165	12	93.22	6.75
SE±	4.24	0.84	0.42	1.10	21.88	1.95	0.57	0.252
PRR 78 × C101A51								
Pusa1602-05-25-20-5-1-48	101.2	12.80	28.80	25.3	183	24	88.40	7.88
Pusa1602-05-25-20-5-3-48	107.2	12.20	28.50	27.3	204	31	86.80	7.25
Pusa1602-05-25-23-6-1-59	98.8	8.60	28.39	27.5	183	36	83.56	7.25
Pusa1602-05-25-23-6-3-59	102.6	9.80	32.50	26.5	173	13	93.01	7.75
Pusa1602-05-25-23-4-1-57	84.6	9.6	27.28	24.2	131	11	92.25	7.25
SE±	3.83	0.87	0.78	0.93	12.45	4.04	1.51	0.389

PH: plant height; NT: no. of tillers; PL: panicle length; TW: test weight; F: filled; UF: unfilled; and SF: spikelet fertility

good general combiners for fodder yield, days to 50% heading and spikelets/ear, whereas the parent HBL 113 was found to be good general combiner for tillers/plant, ear length and biological yield. The predominance of non-additive components of genetic variance (H_1, H_2) along with positive values of additive component (D), high *per se* performance, significant *sca* effects and significant standard heterosis in top ranking hybrid, HBL 276 × HBL 113 suggested the scope of improvement for fodder yield, tillers/plant, ear length, biological yield and grain yield through bi-parental mating.

5.4.4 Maize

5.4.4.1 Molecular characterization of Indian maize landraces and allele mining for agronomically important traits

Under the ICAR National Fellow Project, a total of 43 accessions, including some unique maize landraces from the north-eastern Himalayan (NEH) region, especially from Sikkim, namely, Murli Makai (Sikkim Primitive), Kuchungtakmar, Paheli makai, Seti makai, Kaali makai, Raathi makai, Bancharey makai, Chaptey makai, Kuchungdari makai, Kukharey makai, Gadbade makai, etc., were collected and deposited with the NBPGR (IC 565865 to IC 565907).

Characterization of 133 accessions from NEH and other regions in India at both phenotypic and molecular levels, revealed significant genetic diversity in the NEH landraces and clear differentiation of 'Sikkim Primitives'. The analysis of population genetic structure and formulation of a 'minicore' set of accessions for allele mining were done using phenotypic and molecular datasets. A core set of NEH and non-NEH maize landraces found promising in the study were utilized for formulation of specialty corn pools (baby corn, sweet corn, pop corn & high carotenoid), and inbred lines are being derived from the same.

Allele mining was undertaken for two important genes, *Teosinte branched1* (*Tb1*) and *sugary1* (*su1*) in a diverse set of maize genotypes, including landraces. A distinct SNP in the *Tb1* promoter region was identified which differentiated the teosintes from the maize in general as well as Sikkim Primitives from other maize landraces.

5.4.4.2 Development, characterization and utilization of RILs

Two sets of 192 RILs, in $F_{7:8}$ stage, developed using CA00106 (BLSB resistant; drought susceptible) and CM140 (BLSB susceptible; drought tolerant) as parental lines, and ~100 RILs in F_8 stage (derived using CM139 and NAI116 as parental lines) were characterized at UAS-ZRS, Mandya under SDM artificial inoculation.

Graphical genotyping of 70 selected RILs was undertaken by the use of 42 microsatellite/SSR markers covering various bin locations in the maize genome.

5.4.4.3 Identification of maize lines with differential response to BLSB

Results of F_2 identified promising families such as DMB-9 × DMB-27 ($L_2 \times T_2$) with resistant reactions. Further, CM-151 × DMB-24 exhibited the lowest mean scores of 2.4 (in the scale of 1-5) while DMB-22 × DMB-27, CM-151 × DMB-27 and CM-150 × DMB-25 selections showed scores of 2.0 with promising potentiality for resistance exploitation against BLSB.

5.4.5 Pearl Millet

5.4.5.1 Screening of pearl millet inbreds and hybrids for micro nutrient (zinc and iron) contents

Among fifty-one elite inbred lines evaluated for their Zn content, the range of Zn was 15-79 mg/kg grain. The inbred lines, which exhibited Zn concentration above 40 mg/kg grain were PPMI 162, PPMI 190, PPMI 295, PPMI 484, PPMI 603, PPMI 862 (IARI), and lines 15041, 15067, 15105, 15774, 15791 and 22695 (ICRISAT). Iron (Fe) content in these inbreds varied from 64 to 97 mg/kg of grain. The Zn and Fe contents in five CMS lines and 15 restorer lines varied from 44 to 77 mg/kg and 108 to 176 mg/kg, respectively, while in the eleven available hybrids, the respective values were 45-76 mg/kg and 62-194 mg/kg.

5.4.6 Chickpea

5.4.6.1 Development of a molecular marker based linkage map of chickpea

An STMS linkage map was developed from *desi* × *Kabuli* cross which has 8 linkage groups covering, on an average, 14.2 cM distance.

5.4.6.2 Evaluation of candidate genes for drought tolerance in chickpea

The concentration of EMS and protocol for EMS treatment for the development of TILLING population were standardized. The parents of the population being developed were screened for RWC, MSI, and SLW, and screened with 750 primers sent by ICRISAT.

5.4.6.3 Genetics of flowering time and its effect on grain yield of chickpea in a semi-arid short season environment

Time of flowering is an important component of adaptation and productivity of chickpea in semi-arid short season environments of Peninsular India characterized by terminal drought and heat stress. Inheritance was studied in late × early, early × late and early × early crosses under field conditions to obtain additional information on the genetics of flowering time. The segregation analysis in an early × early cross has proved that flowering time in chickpea is governed by duplicate dominant gene with cumulative but unequal effect. The dominant genes at both loci resulted in lateness, and homozygous recessive alleles (absence of dominant alleles) at both loci produced extremely early flowering. Inheritance in late × early and its reciprocal (early × late) crosses revealed that BGD 132 carried a dominant gene (*Efl-3*) for time of flowering that is different from those in ICC 5810 (*Efl-1*) and ICCV 2 (*Efl-2*) and the maternal genetic factors were not involved in the inheritance of flowering time in chickpea. The early and late flowering plants produced more number of seeds of larger size, and therefore, produced higher seed yield than the super-early types, suggesting the possibility of breeding high yielding early, but not super-early, varieties in chickpea.

5.4.7 Lentil and Fieldpea

5.4.7.1 Genetic studies in lentil and fieldpea

To generate mapping population for wilt and rust resistance, seed size and maturity, crosses were made. F_1s will be raised in off-season for advancing the generation. For genetic differentiation of *Pisum* species by RAPD and SSR markers from leaf tissue, DNA was extracted and quantified. In lentil, polymorphism study was done using SSR and RAPD primers.

5.4.8 Pigeonpea

5.4.8.1 Identification of CMS lines (A and B) and search for restorers (R lines) maintenance of A lines

Cytoplasm of GT 288A was transferred to Pusa 33A, Pusa 2008A, GPL 100A, GPL 290A and maintained. In addition, other sources such as GT 288A, ICPA 2089A and ICPA 2039A and their 'B' lines and 'R' line ICPR 2438 were maintained.

Diversification of CMS cytoplasm. By the use of GT-288A cytoplasm, 2 lines each in BC_2 and BC_5 and 10 lines in BC_1 stage were generated, while with ICPA 2089A cytoplasm, 23 lines in BC_1 stage and with ICPA 2039A cytoplasm, 4 lines in BC_1 stage were developed.

Search for additional sources of CMS and restorer lines in progenies of inter-specific cross C. scarabaeoides x Pusa – 33. Six hundred thirty-nine F_6 progenies of male sterile (MS) and male fertile (MF) genotypes and crosses were evaluated for MS and MF along with fertility restoration. Progenies of 109 MF genotypes found in various MS lines were evaluated and scored for MS & MF for study of inheritance of male fertility restoration. Twenty-eight F_6 MF progenies identified were advanced, MS progenies maintained and progenies having both MS and MF plants were also identified. Progenies of 125 F_5 MF plants (identified in the MS progeny of male sterile F_4 genotypes) were grown as F_6 and advanced. MF and MS F_6 plants superior for yield components were identified. In addition 11 maintainers for GT 288A and 1 MF restorer genotype were selfed. Thirty F_6 progenies of F_5 superior genotypes, selected for seed yield components, were advanced.

5.4.8.2 Inheritance and development of mapping population for identification of QTLs

Eight F_2 mapping populations were evaluated for morphological traits and wilt resistance. Two F_2 and back cross generations from the cross H 2001-4 × ICP 7035 and SKNP 0205 × HDM 04-1 were evaluated for flower, pod and seed traits. Four *Fusarium* wilt resistant genotypes were crossed with several susceptible genotypes in order to develop mapping population and study the inheritance of *Fusarium* wilt resistance.

5.4.8.3 Wide hybridization in pigeonpea

Wide hybridization in pigeonpea has outlined 10 accessions of 6 wild species parents crossable with cultivated species *Cajanus cajan* to broaden the genetic base by introducing available genetic variations and to understand the species affinities. Correlation co-efficient analysis indicated various inter-character associations, viz, significant positive correlation between days to 50% flowering, plant height, number of primary branches, number of racemes, positive correlation between number of primary branches and number of secondary branches and negative correlation between 100-seed weight and seed protein content. Analysis of variance revealed significant variation in seven morphological and yield component traits in wild species parents, e.g., maximum pod bearing length was found in *C. goensis,* ICP 15633 (120.86 cm) and minimum was found in *C.platycarpus*, ICP 15670 (7.8cm). Two parental accessions of *C. scarabaeoides* (ICP 15692, and ICP 15707) were found *Fusarium* wilt resistant and ICP 15685 of *C. scarabaeoides* as susceptible with 25% PDI (percent disease incidence) on artificial screening.

The aim to outline species affinities among 6 wild species parents based on crossability and compatibility indicated maximum crossability success among secondary gene pool wild species (*C. acutifolius,* ICP 15607 × *C. scarabaeoides,* ICP 15707) as 20% with bilateral compatibility, tertiary gene pool wild species (*C. goensis,* ICP 15633 × *C. mollis,* ICP 15653) as 26.66% with unilateral compatibility and among tertiary gene pool and secondary gene pool wild species (*C. goensis,* ICP 15633 × *C. acutifolius,* ICP 15607) as 50% with bilateral compatibility. This study further extended to synthesize a phylogenic tree indicating relationship among compatible genotypes (based on total tris-soluble proteins in seeds by the use of SDS-PAGE) placed ICP 15607 and ICP 15707 distantly with similarity co-efficient of 0.091, ICP 15633 and ICP 15653 very close with similarity co-efficient of 0.833, and ICP 15633 and ICP 15607 distantly with similarity co-efficient of 0.091, based on similarity in seed proteins polypeptides. This study also identified three accessions of cultivated species (ICP 11965, ICP 13206 and ICP 13211) with pod fly resistance and moderate pod borer resistance to be incorporated in interspecific/intraspecific hybridization for insect pest resistance.

5.4.9 *Brassicas*

5.4.9.1 Development of mapping populations

Development of mapping populations for mapping white rust resistance gene. Eight mapping populations including backcrosses and F_2s were developed by using Varuna and Bio-902 as susceptible parents and BEC 144, BEC 286, Bio YSR and JM 1 for mapping white rust resistance. One hundred seventy four SSR primers were used for studying the parental polymorphism. Forty six markers were polymorphic between parented lines and were screened on the bulked DNA of F_2 plants of the crosses Varuna × BIO-YSR and Bio-902 × Bio-YSR, of which two markers were found to be putatively linked to resistance.

Mapping populations for Alternaria blight resistance gene(s). Two *B. juncea* (Varuna and NPJ 93), susceptible to *Alternaria* blight and a *B. carinata* (NPC 12) strain, and an *Alternaria* blight resistant genotype, were used for developing mapping population for *Alternaria* blight resistant gene(s). These populations are in F_2 now, and individual plants have been selfed for generation advancement. RILs are also being developed from the cross NPJ 102 × BEC 144 (F_3) for mapping genes/QTLs for traits like plant type, maturity, disease resistance, etc.

Mapping population developed from cross the Varuna × BEC 144 consisting of 192 RILs is in the F_{14} stage and has been found very stable and phenotyped for various morphological traits for the last five years at Delhi location.

5.4.10 *Drosophila melanogaster*

5.4.10.1 Molecular genetic analysis of *stambhA*

A detailed functional genomic analysis of a 725kb genomic region on chromosome 2L housing 76 genes and four Wnt genes was carried out. Mutations were discovered in 19 of the 76 genes, and importantly 8 new mutations in DWnt4 were discovered. The functional relation and interactions between the members of the wnt gene family were studied.

The $DWnt4^{AL7}$ allele had a missense substitution at nucleotide 341 of exon 2 of DWnt4 resulting in serine to glycine in the protein. All the other DWnt4 alleles had a normal coding sequence.

Homozygotes of all the DWnt4 alleles (RF1,RF2,RF3, RF4,RF7,AL7,HL11,HL34) died as late embryos with denticles that were smaller as compared to those of the wild type (+) embryos.

DWnt 4, DWnt 6 and DWnt 10 genes were overexpressed ubiquitously in five members of this gp, AL7, RF2,RF3, HL11 and HL34. Ectopic overexpression of DWnt 4 could rescue the defects in DWnt4 mutations as expected. However, DWnt6 and DWnt10 could also rescue DWnt 4 mutations.

Similarly, overexpression of DWnt2 in DWnt4 mutational backgrounds ubiquitously in *DWnt4* ^{AL7} embryos could rescue the cuticular defect in AL7 and create segment duplications. Segment duplications were also seen in wild type controls. This demonstrates that DWnt2 mimics DWnt4 in function.

UAS SUMO when overexpressed in smt3 AL1 homozygotes is able to rescue the dorsal mouth parts defect. In addition, the overexpression leads to duplication of denticle belts. This has brought out a novel function for smt3 (SUMO). DORSAL protein was not localized to nuclei in smt3 SUMO mutants, validating that SUMO is needed for DORSAL function.

5.4.11 Diversity Analysis in Soybean and Mungbean

About 408 germplasm lines of soybean were screened for specific leaf weight (SLW). Wide variation for SLW was observed (range: 0.185 to 0.66). Germplasm line G 2225 showed minimum SLW (0.185) while the highest SLW was observed for the germplasm line EC 472073 (0.66). Diverse lines were selected on the basis of SLW for further studies on stable isotope variation in water use efficiency and transpiration rate.

Mungbean germplasm data comprising 895 accessions with 9 descriptors (primary branches, plant height, days to 50% maturity, days to maturity, pods/plant, pod length, seeds/pod, seed yield and grain weight were studied for capturing the variability with minimum set of accessions. Eighty-eight accessions were selected (50 from the top inertia scorer, 32 from the middle score and 6 from the bottom scorer). This procedure led to very high diversity in terms of evenness and richness as it represented variability from all sections of the population.

5.5 AGRICULTURAL PHYSICS, REMOTE SENSING AND GIS

5.5.1 Soil Physics

5.5.1.1 Studies on hydrothermal regimes under different soil management practices

The influence of manure, management practices and mulch on soil hydrothermal regime was studied in the field. Conventional planting system had significantly lower soil temperature (ST; 1-2 °C) and higher soil water content (SWC; 1.5 to 2% w/w) compared to those of bed planting system. Application of transparent polythene (TP-175 ìm thickness) as mulch increased the maximum surface ST by 4.5-6.5 °C over no polythene (NP). Similarly, the average ST of 0-20 cm depth under no manure treatment was significantly higher and SWC lower (0.9% and 1.6%) than those under green manure treatment. Monitoring of ST at hourly interval during day time showed that peak ST at surface had higher magnitude and was achieved earlier than peak ST at 15-20 cm soil depth. All thermal properties were higher under conventional system than under bed system, green manure and no manure and TP and NP. Higher magnitude of ST was in bed system as compared to that in flat system, in no manure than in green manure and in TP than in NP.

5.5.1.2 Soil physical and canopy hydro-thermal environment in long-term fertilization

A field experiment with the treatments: 50% NPK (T1),100% NPK (T2), 150% NPK (T3), 100% NPK+FYM @15 t ha^{-1} y^{-1} (T4) and control (T5) was conducted under long-term fertilizer experiment in sandy loam soil at IARI, New Delhi during *rabi* season with the objective of characterizing the soil physical and canopy hydro-thermal environment of wheat (cv. HD 2329). Relatively lower bulk densities were found (at sowing : 1.49 Mg m^{-3} and harvest:1.52 Mg m^{-3}) with the application of recommended NPK along with FYM compared to those of other treatments reflecting the favourable influence of organics. However, these effects narrowed down appreciably among the treatments at harvest. The highest root weight density (0.093 g cm^{-3}) was recorded in T4 followed by that inT3, T2, T1, and T5. Considerably higher transpiration rate was recorded in T4 compared to

that of control, which increased with the advancement of crop growth. It increased from 4.5 to 13.6 µg cm^{-2} sec^{-1} in T4 and 2.6 to 8.6 µg cm^{-2} sec^{-1} in control during the growing season, leading to significantly higher grain (5.48 Mg ha^{-1}) and straw (4.79 Mg ha^{-1}) yields and harvest index (0.534) in T4. Higher values of vegetation index (VI) (9.3) and normalized difference vegetation index (NDVI) (0.78) were recorded in T4 followed by those in T3, T2, T1, and T5. A reverse trend was observed in stress degree day (SDD), which was minimum in T4 (-135.5 °C) and maximum in T5 (-78.5 °C). Significantly higher positive correlation was found among VI, NDVI and grain yield (r=0.86 and r=0.83). On the other hand, an inverse relationship was found between SDD and yield (r=-0.81). Application of FYM @ 15 t $ha^{-1}y^{-1}$ along with recommended NPK resulted in better growth indices and favourable bulk density and canopy environment leading to optimum yields in wheat under long-term fertilization.

5.5.1.3 Nitrogen dynamics under conventional and bed planted tillage systems in wheat

A comparative study of nitrogen dynamics under conventional tillage (CT) and bed planting (BP) tillage systems in wheat crop was conducted under two nitrogen application rates: 120 kg N ha^{-1}(N1) and 180 kg N ha^{-1} (N2). The available nitrogen in soil was determined after 10-15 days of irrigation during the crop life. The root zone nitrate profiles were determined up to 120 cm depth at regular intervals. The effects of bed formation on nitrate concentration in the top 30 cm soil depths were examined at 41, 60, 82, 99 and 116 DAS. In the upper 30 cm soil layer, the beds retained higher nitrate concentration as compared to that under conventional tillage throughout the cropping season. This difference in nitrate concentration was 51% higher under normal dose and 40% under higher dose during the initial vegetative period of the crop (41DAS). It is beneficial for a good crop stand as maximum roots at this stage reside in this upper soil layer, and higher nitrate concentration in this layer ensured higher nitrate availability for uptake. The study also indicated that the nitrate availability under normal dose (N1) in beds was better than that under higher dose (N2) in conventional practice throughout the crop season.

As the crop progressed, the bed height decreased and the beds started disintegrating. Because of this, the effect of BP on nitrate retention also decreased. At 99 DAS, the nitrate concentration was only 20 per cent higher in beds than in conventional system under normal dose (NI), whereas it was 11 per cent higher in beds as compared to that in conventional system under higher dose application (N2).

5.5.1.4 New cropping sequence for a watershed based on simulation technique

Simulation and GIS techniques take into consideration the crop-weather interactions and spatial variability of the area in terms of soil hydro-physical properties and provide the expected yield of a crop at a location under given meteorological variables. DSSAT35 model was calibrated for the existing crops, viz., chickpea, pearl millet and wheat in the study area of Shikohpur watershed, which was divided into grids by using farmer's field data. The calibrated model for each crop was run to simulate yield in each grid using the soil hydro-physical properties of that grid and common weather at the watershed. Two new crops, soybean and sorghum, were evaluated for this watershed on the basis of their agro-climatic requirements and soil hydro-physical characteristics. On these parameters, an experiment file was created in DSSAT35, which included all the details of cultivation, weather and management practices. The simulations of growth and yield of soybean and sorghum were carried out by the use of DSSAT35-with the same soil and weather files as were used for pearl millet. The yield maps of all the crops were prepared for the entire watershed on the basis of which the watershed was divided into low, medium and high producing areas for each crop. Various combinations of *kharif* and *rabi* crops were evaluated and compared, based on their profitability. The best options among all possible cropping sequences were identified as soybean-wheat-fallow and sorghum-chickpea-fallow and their long term performances in the watershed were evaluated. Performances of the recommended cropping sequences showed an increasing trend under variable conditions of 20 years of historic weather data. This further strengthens the suitability of the recommended cropping sequences for sustainable production in this watershed.

5.5.1.5 Delineation of contaminated zones in the soil-water system of Gohana Block, Haryana

An analysis of groundwater samples collected from sixty

locations of Gohana Block showed wide variation with respect to EC: 0.8 dS m^{-1} at point No.55 (Puthi-B) to 12.4 dS m^{-1} at point No.31 (Anwali-B), with an average value of 5.1 dS m^{-1}. Based on the EC value of groundwater, the study area was delineated by using Arc GIS® 9.1 software and it revealed that the study area comes under three salinity classes: Medium to high (C_3, EC: 0.75-2.25 dS m^{-1}), high (C_4, EC: 2.25-5.00 dS m^{-1}) and very high (C_5, EC: >5.00 dS m^{-1}). The maximum percentage of area is covered under class C_5 and is 49.27. Percentage-wise the areas covered under class C_4 and class C_3 are 46.54 and 4.19, respectively. Hence, about 49.27% of the study area is unfit for irrigation purpose and is suspected to be polluted. Areas near the canal showed a lower value of EC. Probably the seepage of good quality water from the canal improved the EC value of groundwater adjoining it. The lower elevated part of the study area showed high value of EC which may be because of the accumulation of water and poor drainage.

5.5.1.6 Wheat crop growth as influenced by saline irrigation water in farmers' fields

The wheat yield and growth parameters such as leaf area index (LAI) and biomass showed no significant variation at 5% level up to the EC_{iw} of 4 dS/m. But, there was a significant decrease in yield, LAI and biomass beyond this EC_{iw} value. The relation between wheat yield and EC_{iw} has been worked out. The decrease in yield, LAI and biomass could be because of the increased osmotic pressure limiting water uptake (physiological drought), abnormally high pH, ionic competition limiting nutrient uptake (especially K), specific ion toxicity (Na in particular), adverse soil physical condition (in case of saline water with high SAR) and excess boron generally found in semiarid regions with irrigated agriculture of moderate to high salinity.

5.5.2 Remote Sensing and GIS

5.5.2.1 Mapping trends in crop phenological events in IG plains of India

In order to the study the climatic, ecological and socio-economic drivers for the changes in Indo- Gangetic plains (IGP), it is essential to derive the spatial patterns of temporal trends in phenology and productivity at the disaggregated level of the crops grown. In this study, an attempt was made to use satellite observed NDVI time series to derive the spatial patterns of trends in crop phenology and growth in the IGP of India in the last 20 years (1982-2001). During *kharif*, dominated with rice, maximum vegetative growth stage happened early, across most of Punjab, north Haryana, parts of central and east Uttar Pradesh and some parts of Bihar and West Bengal. Only the central parts of Haryana recorded a delay in achieving maximum vegetative stage. During *rabi*, south Punjab and north Haryana showed early occurrence of maximum vegetative stage, whereas, most parts of central and eastern Uttar Pradesh, north Bihar and West Bengal showed delayed occurrence of maximum vegetative stage. In general, the rice dominating system showed an increased duration of crop season in Punjab, Haryana, western Uttar Pradesh, central Uttar Pradesh and south Bihar, whereas in some parts of north Bihar and West Bengal, a decrease in the duration was observed. During *rabi* season, except Punjab, the crop duration declined.

5.5.2.2 Retrieval of crop biophysical parameters from satellite data through radiative transfer modeling

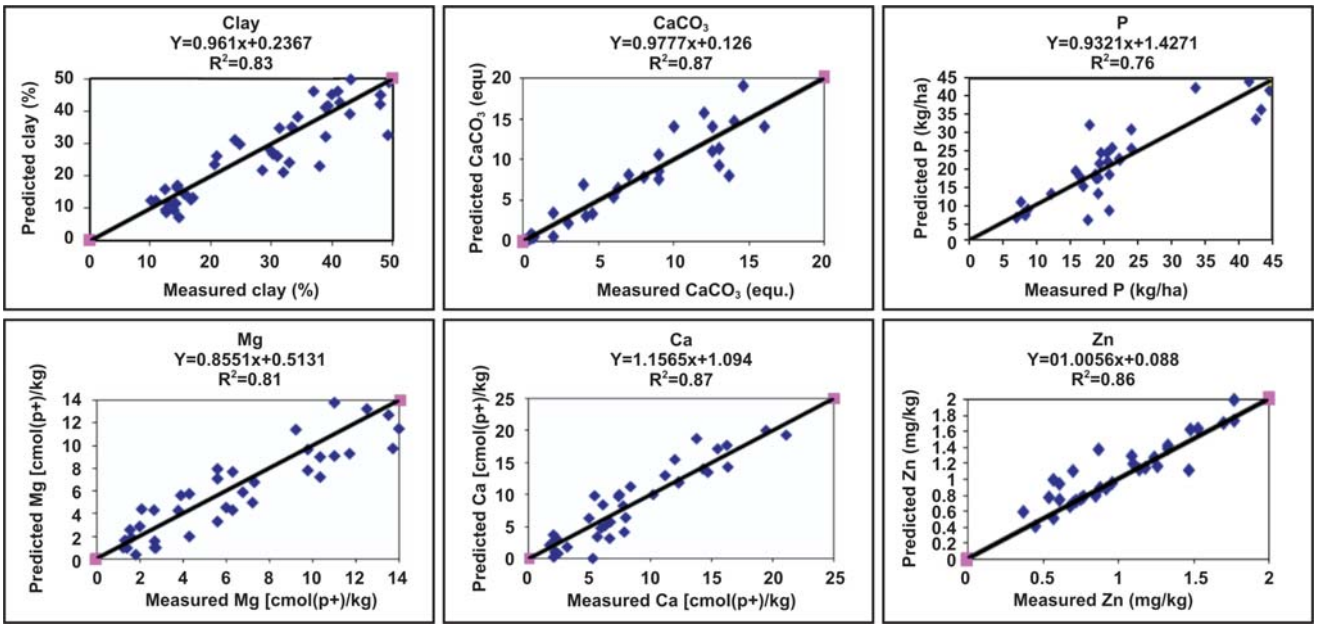
Retrieval of crop biophysical parameters in spatio-temporal scale is crucial for better monitoring of crop growth system. Keeping in view the limitation of statistical approach and advantages of physical process based model for parameters' retrieval, research was carried out to retrieve leaf area index (LAI), chlorophyll (Cab) and moisture content (Cw) of wheat crop grown in trans Gangetic plain of India from TERRA MODIS products by the use of radiative transfer model. The trans Gangetic plain of India comprising Punjab, Haryana, Delhi, Chandigarh and part of Rajasthan has spatial extent between 72°38'54.44"E and 77°36'11.74"E longitude and between 27°39'19.38"N and 32°30'26.85"N latitude. A field survey was conducted in the study area during February 10 to 20, 2008 with the help of GPS and spectral data (by using Spectrordiometer, ASDI FS3). *In-situ* LAI and leaf samples of wheat crop were collected from 190 locations for further analysis and estimation of the required parameters in laboratory condition. MODIS Surface-Reflectance 8-day composite product (MOD 09) with a spatial resolution of 500m and LAI 8-day composite L4 MODIS Product (MOD15A2, 1km) were acquired from the EOS Data Gateway

(*https://wist.echo.nasa.gov/api/*) for the period of February 10 to 17, 2008. IRS-P6, LISS-III data (23.5 meters resolution, path-094, row-050, February, 2008) were also used.

The radiative transfer model PROSAIL was used for retrieval of LAI, Cab and Cw through its inversion. The model was calibrated for major parameters such as LAI, Cab, Cw and biomass (Cm) and sensitivity analysis was performed. Inversion of PROSAIL model was carried out for LAI, Cab and Cw by using Look Up Table (LUT) approach and merit function. Results revealed that LAI, Cab and Cw, were very well retrieved with RMSE 0.3892, 4.307 and 0.0063, respectively, when compared with measured values. The retrieved products were evaluated with its corresponding regressed products through different vegetation indices. RMSE between these regressed estimation and measured parameter values were 0.553, 5.204 and 0.01 for LAI, Cab and Cw, respectively. The parameters generated through physical approach were found to be more reliable and can be used for crop growth monitoring and yield prediction.

5.5.2.3 Quantitative assessment of soil parameters from hyperspectral reflectance data

Different soil physico-chemical properties of various soils were quantified by the use of hyperspectral reflectance data. Eighty-seven surface soil samples (0-15cm) representing 23 soil series were collected from 23 sites of four different places of India covering four soil taxonomic orders (Vertisols from Nagpur, Alfisols from Ranchi , Inceptisols from Delhi and Mollisols from Pantnagar) having varying soil physico-chemical parameters. Spectral reflectances of these soils were collected in the range of 350-2500 nm range by using a ground held spectroradiometer (Fieldspec^3, ASDI, USA) both in laboratory and field conditions. Soils samples were analyzed for 16 physico-chemical parameters such as texture, moisture, colour, organic matter, soil reaction, available N, P and K, exchangeable Ca, Mg, Fe, Mn, Cu and Zn, calcium carbonate and oxide contents**.** Absorbance spectra were retrieved from reflectance spectra and first and second derivatives of both reflectance and absorbance spectra were computed for finding their best correlation with different soil properties. Best correlated bands and spectral parameters (i.e., reflectance, absorbance, first and second derivative of reflectance and first and second derivative of absorbance) were identified for different soil parameters through statistical analysis. A few best correlated bands of different spectral parameters were chosen through multiple regression analysis (MRA), and prediction equations were developed by taking 50 soil sample data. These were validated with the rest of 37



Comparison of predicted soil parameters from reflectance data with measured values

soil sample data. The r^2 values obtained for prediction equations of different soil constituents were: 0.87 for organic matter, 0.84 for sand; 0.83 for clay; 0.82 for silt; 0.76 for available N & P and 0.71 for K, 0.87 for exchangeable Ca, 0.81 for Mg, 0.87 for $CaCO_3$, 0.83 for iron oxides, 0.88 for micronutrients like Fe, 0.53for Cu, 0.86 for Zn, and 0.78 for Mn, 0.91 for Kaolinite, 0.87 for smectite, 0.85 for mica and 0.59 for soil moisture. Standard error of prediction (SEP) was nearly the same as that of standard error of calibration (SEC). The best fitted equations were developed for predicted and measured parameter values and found best fitted with 1: 1 line.

5.5.3 Agricultural Meteorology

5.5.3.1 Effect of weather variability on growth characteristics of *Brassica* crop

In continuation of the previous season's experiments, field experiments were conducted during 2007-08 *rabi* season at IARI, New Delhi to study the effect of weather variability on crop growth and seed yield in three varieties of *Brassica juncea*, viz., Pusa Gold, Pusa Jaikisan (most popularly grown in north western parts of India) and BIO 169-96, which were sown on October 16 & 30, 2007and November 13, 2007, to have the same variety's phenological events exposed to different variable weather conditions .

The weekly mean maximum temperatures at sowing and crop establishment periods were higher than the normal temperature, while during the active vegetative, flowering and reproductive stages of the crop, the temperatures were marginally lower than the normal temperature. The minimum temperatures during the season were considerably lower than the normal values of temperature. From 4th standard week till 8th week, the minimum temperature was lower than the normal temperature. During this period, the temperature even reached -0.8 °C on January 2 and remained more or less near zero for over 9 days. The low temperature proved to be beneficial to mustard crop as it suppressed the aphid population to a great extent, reducing the yield losses. The rainfall during this season was negligible.

It was observed that the LAI was higher in BIO 169-96 by 38% and 18% as compared to those of Pusa Jaikisan and Pusa Gold, respectively. The first sown crop showed 40% and 24% higher LAI in Pusa Gold and BIO 169-96 respectively, compared to that of the late sown crop. However, there was no change in LAI in Pusa Jaikisan irrespective of date of sowing. The variety BIO 169-96 produced higher biomass as compared to those of Pusa Jaikisan and Pusa Gold irrespective of sowing dates which might be due to higher LAI. The biomass production was higher in early sown crop than in late sown crop by 60% in BIO 169-96, 46% in Pusa Jaikisan and 58% in Pusa Gold.

The seed yield in the early sown crop was 60% higher in Pusa Jaikisan, 15% in Pusa Gold and 22% in BIO169-96, respectively, compared to that of the late sown crop. In Pusa Jaikisan, the seed yield was 17% more than that of BIO 169-96. One probable reason for the lower seed yields in Pusa Gold could be more aphid infestation in this variety as compared to the other two varieties.

5.5.3.2 Variation in temperatures during different phenological stages of *Brassica* sown at different dates

The weekly maximum and minimum temperatures during germination for 1st sowing were 31.7 °C and 14.8 °C, those for 2nd sowing were 30.2 °C and 11.8 °C and those for 3rd sowing were 28.2 °C and 10.6 °C. Owing to the lower maximum, minimum and average temperatures, the germination rate was less in 3rd sowing as compared to those of 1st and 2nd sowings. During flowering, the weekly maximum and minimum temperatures for 1st sowing were 26.3 °C and 9.7 °C, while during the 2nd and 3rd sowings, the corresponding temperatures were lower (2nd sowing: 20.2 °C and 7.0 °C and for 3rd sowing: 20.0 °C and 3.4 °C). During pod formation, the weekly maximum and minimum temperatures for 1st sowing were 22.2 °C and 6.0 °C, those for 2nd sowing were 21.9 °C and 4.9 °C and those for 3rd sowing were 20.6 °C and 3.5 °C. During maturity, the weekly maximum and minimum temperatures for 1st sowings were 26.3 °C and 9.1°C, those for 2nd sowing were 32.8 °C and 14.0 °C and those for 3rd sowing were 32.3 °C and 16.5 °C. Owing to higher maximum, minimum and average temperatures during flowering and pod formation and lower maximum, minimum and average temperatures during

maturity, the yield was higher in 1st sowing as compared to those of 2nd and 3rd sowings.

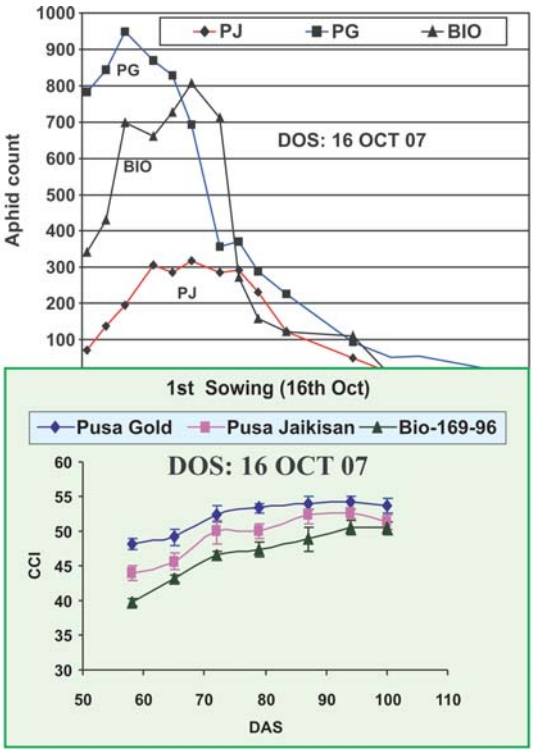
5.5.3.3 Validation of forewarning hypothesis for mustard aphid, its limitations

Based on the forewarning hypothesis (if the rate of accumulation of the degree days from 1st to 25th is lower, the peak aphid population in mustard crop would be higher and *vice versa),* the rate of degree day accumulation from January 1 to 25, 2008 was relatively higher. However, during the previous season, the corresponding rate was lower indicating higher aphid infestation. But, during the 2006-07, about 30.6 mm of rainfall was received on February 11, which dislodged the entire active aphids. During 2007-08, there was no rainfall (except 1.8 mm received on January 10, 2008), and hence the peak aphid population was found to be 300/10 cm main shoot. This indicates that the physical damage due to rainfall during the active aphid multiplication stage is purely physical and has nothing to do with their increasing or decreasing multiplication.

5.5.3.4 Can Pusa Gold be grown as a catch crop for aphid? - A case study

It has been observed that the mustard variety Pusa Gold attracts more aphids as compared to other varieties, although there is no scientific evidence in the literature. Hence an attempt was made to establish the scientific evidence. The cumulative stress degree days, leaf chlorophyll content index (CCI) and other biophysical parameters were studied during the year 2007-08 and the experiments are being continued during 2008-09 *rabi* season also. It was observed that the peak aphid population in Pusa Gold was far higher than that in the popularly grown Pusa Jaikisan and another variety Bio169-96. The CCI was also found to be higher in Pusa Gold than in the other two varieties.

The cumulative stress degree days were found to be more in this variety as compared to those of other two varieties in the three sowings. These results point to the possibility that higher leaf chlorophyll content in Pusa Gold might be attracting the aphids for their sustenance and rapid multiplication leading to increased stress in the plant.



CCI is higher in Pusa Gold

Variation in aphid population of mustard as determined by different parameters

6. SOCIAL SCIENCES AND TECHNOLOGY TRANSFER

6.1 AGRICULTURAL ECONOMICS

6.1.1 Labour Migration and its Implications on Rural Economy of Indo-Gangetic Plains of India

A study was undertaken to examine the magnitude and determinants of migration, and their implication on structural and socio-economic condition of agriculture as a whole and rural household in particular. A primary survey was conducted earlier to collect household level data from out-migrants, non-migrants and in-migrants from the states of Bihar, Uttar Pradesh (U.P.) and Punjab.

The study identified low wages, lack of adequate employment and seasonal nature of work available locally as the push factors for migration in the study area. The migrant households benefited from the remittances they received from the migrant members of the family as they helped significantly to improve the health, nutrition and educational status of the migrant households. A 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 home, most of which was spent for food and farm investment.

The income inequality was found lower in migrant households as compared to that in non-migrants in the selected states of the Indo-Gangetic plains.

The factors influencing male out–migration were identified using logistic regression model. The land per capita, income other than remittances and caste had a negative impact on male out-migration while literacy and number of members in the family had a positive influence on male out–migration. The drudgery indices computed showed that migration increased the drudgery of the female members of the migrant families as it led to increase in work load of the members of the family. This was reported by 81 per cent of the family members of migrants from Bihar and 54 per cent from U.P. However, migration also empowered the female members of the migrant households in terms of enhancing their decision making role in various activities.

Problems in supervising labour due to migration of male members were reported by 47 per cent respondents, and inadequacy of remittance for farm purposes was reported by 69 per cent respondents from Bihar. Nearly 88 per cent respondents from Bihar, and 73 per cent from Uttar Pradesh expressed difficulty in obtaining loan in times of need.

6.1.2 Impact of Trade Liberalization on Indian Agriculture

This study attempts to examine agricultural trade policy in India in the wake of economic liberalization and ascertain the trade dynamics as well as competitiveness of major agricultural commodities. It focuses on major agricultural commodities and their trade.

Traditionally coffee has been one of the important export commodities of India. An analysis of India's coffee trade showed that coffee export from India increased at a high annual growth rate of 24.60 per cent during 1985-86 to 1994-95. However, the magnitude of the rate of growth declined to 12.74 per cent during 1995-96 to 2006-07. This shows that there is potential for Indian coffee exports during liberalization even after stiff competition from the traditional competitor, Brazil and non-traditional competitor, Vietnam. The maximum unit value of coffee was realized from the Russian Federation in all the years in pre-and post-liberalization period. The unit value realized from Germany, Italy and USA increased substantially (190%, 158%, and 65%, respectively) during the period 1995-96 to 2006-07 over that of the period 1984-85 to 1994-95. The remaining markets showed reasonable increase of 95% in unit value for Indian coffee during this period. An examination of the direction of Indian coffee trade

showed that Germany was the most loyal importer of Indian coffee followed by Russian Federation. Italy, Spain and USA failed to retain their previous market share.

Indian coffee export competitiveness was judged through measures like NPC,DRC and EPC. The average values of NPC, DRC and EPC were positive and less than one, indicating the global competitiveness of Indian coffee. Thus, India has a comparative advantage and it can specialize in the production and export of coffee to earn valuable foreign exchange. Efforts should be made to maintain this competitiveness. In order to ensure that producers benefit from trade liberalization, there is a need to create an enabling environment and generate marketing intelligence so that farmers have an understanding of and information about the dynamics of global coffee trade.

6.1.3 Peri-Urban Agriculture

Producers in peri-urban areas are moving towards intensive production of high value commodities such as vegetables. Around two-third of the peri-urban Delhi area is occupied by vegetables because of the areas proximity and easy access to markets. Small and marginal farmers utilized their scarce resources more intensively and efficiently. However, there are mixed implications from peri-urban agriculture with regard to efficiency of vegetable production. Savings in cost could be achieved through selling the produce to consumers and markets in proximity.

Potato is an important vegetable grown by all the categories of farmers irrespective of the size of holding. This was followed by cucumber in both *kharif* and *rabi* seasons. Cauliflower, brinjal and spinach are not grown by large farmers because of their high labour requirement.

The average cost of cultivation, yield, gross and net returns per hectare and benefit-cost ratios were computed, the technical and marketing efficiency of all the categories of farmers of Delhi NCR was examined. In the case of *rabi* crops, the cost of cultivation per hectare was the highest for potato (Rs. 28409 to Rs.33994) followed by that for gherkins and wheat. Among *kharif* crops, the cost of production per hectare was found to be the highest for gherkins (Rs.23706 to Rs.24947). Maximum net returns were observed for potato crop (Rs.33567 to Rs.33994). Farmers were found to be commercial minded in their attitude and outlook as they grew off-season crops in both the seasons.

All the farmers were found efficient in allocating their resources. Benefit-cost ratio also supported the fact that all the farmers are receiving higher net profits through efficient allocation of resources, especially in horticultural crops.

6.1.4 Economic Analysis and Prospects of Non-edible Oilseeds in India

Non-edible oilseeds, especially tree-borne minor oilseeds, have been accorded very high priority as a source material for bio-energy in the country. India is endowed with a vast potential for oilseeds of tree origin, important among them being *jatropha,* pongamia, *mahua*, *neem*, *kusum*, *undi*, *nahor*, simrouba, tung, etc. In the absence of organized sources of data and documentation on area and production of these tree-borne oilseeds, data were collected from various government departments and private sector agencies involved in plantation and oil extraction. These oilseed-bearing trees are found widely distributed throughout the country in wastelands, forests and homesteads. Rural households across the regions extract a wide variety of products, known as non-timber forest products (NTFPs) from nearby forests. *Neem*, *mahua*, *karanj*, and *kusum* trees have a very important place in the socio-economic and cultural life of tribals in the states like Bihar, Orissa, Jharkhand, Madhya Pradesh, Chattisgarh and Rajasthan as they have a variety of uses including timber and food. The present availability of these oilseeds is estimated to be more than 1 million tonnes annually. However, only limited quantity of the total availability is utilized for commercial applications mainly due to lack of policy and adequate infrastructure. There is considerable scope to enhance the collection of seeds from the existing trees by developing infrastructure facilities such as seed/produce procurement centres equipped with facilities for drying, decorticating, cleaning/grading, de-pulping, storing and oil extraction near the areas of collection. Establishment of bio-diesel processing units near procurement centres will also help in reducing the cost of production of oil.

Apart from the natural plantations of different oil bearing tree species in the country, there is a recent central government

drive to produce bio-energy from *Jatropha curcus* and *Pongamia pinnata*. Many state governments have given high priority to plantations of *Jatropha and Pongamia* for bio-diesel production. States like Chattisgarh, Uttaranchal, Rajasthan, Andhra Pradesh, Orissa, Tamil Nadu, Madhya Pradesh, etc., have already established nodal agencies for bio-diesel development, announced draft bio-diesel policies, and initiated plantation programmes mainly on wastelands, degraded forest areas and other lands not used for crop cultivation. Plantations established during 2003-2007 through various agencies reveal that, at present, the total planted area under *Jatropha* is approximately 3,82,487 hectares in the country. State-wise, the actual reported area under *Jatropha* plantation is maximum in Chhattisgarh, (44%) followed by that in north-east states (22%), Rajasthan (6%), and Maharashtra (5%).

A primary survey was done on 55 *Jatropha* cultivators in Erode and Coimbatore districts of Tamil Nadu where *Jatropha* was planted under irrigated conditions with buyback arrangement with private firms. The cost of cultivation/production based on various concepts of the cost was worked out. The cost of *Jatropha* cultivation per hectare ranged from Rs. 14219 to Rs. 23503, while the cost of production of *Jatropha* seeds varied between Rs. 4.11 per kg to Rs. 6.79 per kg under different cost regimes in the study area.

6.2 AGRICULTURAL EXTENSION

6.2.1 Enhancing the Efficiency of Extension Organizations

6.2.1.1 Evaluation of programmed text on selected management skills

A study was conducted on the development of programmed text on management skills such as leadership, motivation, team development and stress management. The programmed text materials on the above skills were evaluated with the help of twenty-five extension professionals drawn from various KVKs and SAUs. An assessment of the effectiveness of the programmed text was done as detailed below:

Evaluation of contents. The study revealed that the extension professionals perceived the overall contents of the programmed text as having a higher level of effectiveness with an overall average score level of 4.06 (out of the maximum possible score level of 5).

Evaluation of contents of programmed text **(N= 25)**

Sl. No.	Item	Leader-ship	Motiva-tion	Team develop-ment	Stress manage-ment	Over-all aver-age	Rank
1.	Adequacy and appropriateness of sequencing of contents of the text	4.3	4.34	3.95	4.07	4.17	1
2.	Simplicity of language used	4.35	3.69	3.79	4.05	3.97	4
3.	Interesting way of presentation	4.15	4.11	3.68	3.90	3.96	5
4.	Integration of text with case-lets to help in understanding the subject	4.40	4.19	3.84	3.85	4.07	3
5.	Self learning without the help of an instructor	4.15	4.42	4.05	3.75	4.09	2
6.	Average score	4.27	4.15	3.88	3.95	4.06	

Maximum possible score: 5, minimum possible score: 1

An overall average score level of 4.17 was recorded for adequacy and appropriateness of sequencing of contents of the text followed by self learning without the help of an instructor (4.09), 'integration of 'text with case-lets to help in understanding the subject'(4.07), 'simplicity of language used'(3.97) and 'interesting way of presentation' (3.96). It is clear from the data that the extension professionals rated the contents of programmed text on different management skills as appropriate, simple to understand, interesting and helpful in self learning. Among the different programmed text materials, 'leadership' received the highest average score on effectiveness (4.27 score) followed by 'motivation' (4.15 score), stress management (3.95 score) and 'team development' (3.88 score).

Perceived utility. The overall utility of programmed text developed on management skills such as leadership, motivation, team development and stress management was rated to be high with a score of 3.83 (out of the maximum possible score of 5). The 'usefulness to improve professional competency' received the highest overall average score (3.92) followed by 'likely improvements in work productivity' (3.90), 'learning new concepts in management skills' (3.86), 'increased motivation for learning' (3.85), 'realization of one's strengths and weaknesses' (3.77) and 'helping in self introspection' (3.73).

Among different programmed text materials, 'motivation' received the highest score on perceived utility (4.03 score) followed by 'stress management' (3.94), 'leadership' (3.93) and 'team development' (3.44).

Usefulness of programmed text in comparison to conventional text. An assessment of the perceived usefulness of programmed text prepared in four management skill areas (leadership, motivation, team development and stress management) revealed that the extension professionals perceived the programmed text more useful than conventional text in all dimensions with an overall average score level of 3.91 (the maximum score obtainable was 5). The greatest advantage of the programmed text was the 'interest created by it' (4.14 score) followed by 'improved learning' (3.99 score), 'studying at one's own pace' (3.96 score), 'studying at one's own time' (3.95 score), 'cost advantage' (3.85 score) and 'ease in understanding' (3.84 score).

Among the different programmed text parameters, 'motivation' had the highest level of perceived usefulness score (4.14) followed by 'leadership' (4.06 score), 'stress management' (3.86 score) and 'team development' (3.58 score).

Perceived utility of programmed text (N= 25)

Sl. No.	Item	Leadership	Motivation	Team development	Stress management	Overall average	Rank
1.	Usefulness to improve professional competency	4.20	3.99	3.63	3.85	3.92	1
2.	Learning new concepts in management skills	4.05	4.26	3.21	3.90	3.86	3
3.	Realization of one's strengths and weaknesses	3.75	3.84	3.47	4.00	3.77	5
4.	Helping in self introspection	3.95	3.76	3.42	3.80	3.73	6
5.	Increased motivation for learning	3.75	4.30	3.42	3.95	3.85	4
6.	Likely improvements in work productivity	3.90	4.05	3.50	4.15	3.90	2
7.	Overall utility of programmed text (Average)	3.93	4.03	3.44	3.94	3.83	

Maximum possible score: 5; minimum possible score: 1

Perceived usefulness of 'programmed text' in comparison to 'conventional text' (N= 25)

Sl. No.	Item	Leadership	Motivation	Team development	Stress management	Overall average	Rank
1	Learning taken place	3.90	4.07	3.79	4.20	3.99	2
2	Interest created	4.20	4.42	3.63	4.30	4.14	1
3	Ease in understanding	4.15	4.19	3.53	3.50	3.84	6
4	Cost	3.95	3.84	3.84	3.75	3.85	5
5	Accessibility	3.85	3.96	3.16	3.65	3.66	7
6	Studying at one's own pace	4.0	4.26	3.58	4.00	3.96	3
7	Studying at one's own time	4.35	4.30	3.53	3.65	3.95	4
8	Average	4.06	4.14	3.58	3.86	3.91	

Maximum possible score: 5; minimum possible score: 1

6.2.2 Assessing Socio-economic and Environmental Impact of Agricultural Technologies

6.2.2.1 Socio-economic and ecological implications of transgenic agriculture

A survey in the villages of Akola, Yawatmal and Wardha districts of Maharashtra and Khandwa and Khargone districts of Madhya Pradesh revealed that Bt cotton hybrids had pre-dominance over others owing to agronomic, socio-economic and ecological benefits like higher yield and income, opportunity for double cropping, decreased use of pesticidal sprays, decreased incidences of pesticide-led health hazards, increased employment days for women during cotton picking, etc. By adopting Bt cotton hybrids, the farmers secured increased yield of 1-1.5 t/acre under irrigated condition and 0.6-0.8 t/acre under rainfed condition as against the respective yields of 0.4-0.6 and 0.2-0.4 t/acre from non-Bt cotton hybrids. The farmers reported that due to cultivation of Bt cotton hybrids, the number of pesticide sprays reduced from 4-8 to 2-4 sprays, though last year due to higher incidence of sucking pests and mealy bug they had to go in for 1-2 extra sprays. The incidence of health hazards due to pesticide application had reduced from 4-6 cases per season per village to 0-1 due to adoption of Bt cotton hybrids. Progressive farmers could harvest a yield up to 2.7-3.0 t/acre by extending the crop life with assured irrigation up to April-May. The increase in yield led to increase in on-farm employment days for women during cotton picking. The success of Bt cotton instilled conviction among all categories of farmers. Even landless people in villages derived benefits of Bt cotton through its cultivation on leased-in lands. Also a shift in the perception and attitudinal orientation among the farmers was observed as out of one hundred and fifty sample number of farmers, more than one-third expressed willingness to adopt genetically modified crops, while three-fourth of them said they would go in for genetically modified crops only if proven and declared safe by the scientists.

6.2.2.2 Influence of changing agricultural and socio-economic environment on household food security

Data collected from rural households in Samastipur district of Bihar, the project area revealed that a majority of the households were marginal and small land holders. About 90 per cent family units were aware of food processing/value addition practices. Above two-third of the households adopted crop diversification practices during the last five years. These households grew improved varieties of wheat, paddy and hybrid maize. The area under *oal (*elephant foot) and flower (marigold and roses) increased owing to more profit but the area under sugarcane decreased owing to non-availability of sugar mill. Also the majority of farmers discontinued sweet potato cultivation owing to heavy loss on account of low market prices. Social participation was more among educated and people with good economic background. However, poor women's participation in SHGs was really encouraging. More than 85 per cent of households had mass media exposure. Still radio is the primary source of information and communication followed by TV and newspapers.

A majority of the households had occasional extension contact with SAUs/research institutes and private agencies but very rare extension contact with State Agriculture Department. Most of the households had moderate accessibility to resources like farm inputs (seeds/fertilizers/pesticides), farm implements and credit, but very low accessibility to labour and market. The nature of participation of rural households in government developmental schemes was very encouraging, and the households under BPL derived the maximum benefit. Most of the households adopted seasons-wise pattern of food stock keeping for meeting the future needs, and there was no change in the food habits of poor people during the last five years.

About 90 per cent of the households reported inadequate accessibility to safe drinking water because of the only source of drinking water being shallow tube well with high iron content. More than 50 per cent households adopted dairy practice as self employment and subsidiary occupation but earned low profit because of the high cost of animal feed. Seasonal migration of men was common in the area (i.e, rural-urban and inter-district as well as inter-state). The main reasons for migration of men were non-availability of sufficient work in local area and prospects of more income and better employment in distant places/states like Delhi, Mumbai, Punjab, etc. However, migration was restricted over the year because of the effective functioning of NAREGA in Bihar.

Most of the households were aware of the household food security, i.e, physical, social and economic access to sufficient and nutritious food throughout the year. More than 90 per cent of them were aware of the fact that balanced nutrition was a pre-condition for a healthy and productive life. They were also aware that inadequate access to safe and hygienic water increased the incidence of malnutrition. Women and children continued to face greater risk of malnutrition due to discriminatory allocation of food within the household. Food security of the household depended upon its ability to generate sufficient income to meet the needs of nutritious food. Special nutritional programmes like Balwadi nutrition programme, Anganwadi programme and Mid-day meal programme (for school children) were found to be beneficial for BPL households.

6.2.3 Farming Systems Research and Extension for Sustainable Development

6.2.3.1 Analysis of farming systems of selected locations

A survey conducted in Muzaffarpur district of Bihar under the project on "Farming Systems Research and Extension for Sustainable Development" found that a majority of the farmers in the area were small and marginal landholders but their major strength was their positive attitude towards agricultural diversification and entrepreneurship development in agriculture. The households having small and marginal farms with dairy as subsidiary occupation were economically better. The household engaged in entrepreneurship or having a member in service had good socio-economic status in the village. Such households were fully dependent on mechanized farming. The households having multiple sources of income were found to be in a better position. Farmers secured low yield due to the predominance of rice-wheat cropping system, infestation of weed (*Phalaris minor*) in wheat and micronutrient deficiency in the area because of the imbalance in the use of fertilizers and very less or no use of compost or organic manure or FYM.

The major farming systems were categorized as rice-wheat farming system, irrigated farming system, rainfed farming system, and mixed farming system. The predominant units in the farming systems in Samastipur and Muzaffarpur districts of Bihar were rice, wheat, mustard, pigeonpea, mungbean, tobacco, vegetables, fruits (mango, litchi, *aonla*) and animal husbandry. A majority of the farmers were aware of the diversified farming, and had initiated the adoption of beekeeping, vermicomposting, mushroom cultivation, dairy, vegetable cultivation, etc.

6.2.3.2 Sustainable interventions for improving production and productivity of farming systems

An assessment of training needs was done in the area of animal husbandry. The needs were scored on a scale of 1 to 5 with 5 being a 'very high need' and 1 being characterized as 'not needed'.

Training needs assessment of farmers in animal husbandry

N=50

Sl. No.	Training needs	Score	Av. score
A	**Feeding**		
1	Enrichment of straws to enhance nutritive value for feeding dairy animals	3.57	3.27
2	Feeding of mineral mixture	3.40	
3	Feeding of newly born calves	2.97	
4	Preparation of balance feed at home	3.07	
5	Balanced feeding to dairy animals on the basis of milk production	**3.73**	
6	Feeding of heifers and dry animals	2.90	
B	**Breeding**		
1	Appropriate age, body weight and time of insemination	3.50	3.54
2	Measures to have the dairy animals served within 60-90 days of calving	3.57	
3	Management of repeat breeders and anoestrus cases	**3.67**	
4	Important characteristics of proven breeding bulls	3.57	
5	Pregnancy diagnosis	3.37	
C	**Healthcare/disease control practices**		
1	Precautions to be taken regarding outbreak of contagious diseases and vaccination	**4.00**	3.50
2	Diagnosis of common diseases of dairy animals	3.53	

Contd....

Sl. No.	Training needs	Score	Av. score
3	First aid treatment of dairy animals	3.27	
4	Control of ecto-and endo-parasites in diary animals	3.27	
5	Deworming of dairy animals	3.43	
D	**Management practices**		3.71
1	Care of pregnant advanced dairy animals	**4.13**	
2	Clean milk production	3.77	
3	Care of newly born calves and heifers	3.50	
4	Selection of milch animals	3.70	
E	**Fodder production**		
1	Suitable fodder crops for the area and their high yielding varieties	3.23	2.75
2	Green fodder production throughout the year	2.90	
3	Hay and silage making	2.13	

The important areas where the farmers needed training in animal husbandry were:

- Balanced feeding to dairy animals on the basis of milk production
- Management of repeat breeders and anoestrus cases
- Precautions to be taken regarding outbreak of contagious diseases and vaccination
- Diagnosis of common diseases of dairy animals
- Care of pregnant advanced dairy animals
- Suitable fodder crops for the area and their high yielding varieties

6.2.3.3 Empowerment of farmmen and farm-women to enhance their skills

Participatory Rural Appraisal (PRA) and focused group discussions were held to assess the entrepreneurial ventures being taken up by the farmers in the study locales, viz., Tigipur village, Delhi and Saidpur village, Gurgaon. Further, SWOT analysis and matrix ranking identified the potential enterprises, which could be taken up by the farmers in these villages. Vegetable cultivation and flower cultivation on a commercial basis were the most preferred entrepreneurial ventures of Tigipur. Nursery raising and fisheries were the other agri-preneurship areas which could be promoted. Dairy enterprise, individual or group, was found to be the most feasible potential enterprise in Saidpur village. Fruits like *aonla* and *ber* could also be taken up for commercial cultivation in Saidpur. Twenty-eight farmers in Tigipur village had already taken up agri-enterprises like vegetable cultivation, mushroom cultivation, baby corn production, etc. Sixteen farmers in Saidpur village, Gurgaon, were found to be earning profits from selling milk. Simulation exercises and thematic apperception test (TAT) were done, and data on risk taking behaviour were collected from youth. They were given motivational inputs regarding human behaviour. The issues which emerged from these exercises were as follows:

Goal setting behaviour. Most of the farmers were found to put higher targets of income from vegetable cultivation in their fields. They were aware of the market demands and price fluctuations in vegetable markets.

Risk taking behaviour. Risk taking behavior was found to range from moderate to higher levels. Some were taking unduly higher risks like sowing earlier than the recommended time of sowing. For example, sowing of cucumber was recommended for mid February but farmers advanced it to January, in spite of risks of frost at that time. Higher risks were taken to get higher returns, to avoid low prices and glut in the markets in the subsequent months.

Low risk taking behaviour. Being cautious in times of ambiguities was noticed. Farmers in Tigipur village were found to adjust to uncertainties prevailing in the market such as fluctuating prices, heavy demands sometimes and glut at other times. Uncertainties sometimes made them reduce their targets in order to reduce the losses at times of crises.

Perception of obstacles. Sometimes, the farmers perceived a few obstacles as real even when they were not real; for instance, uncertainties and ambiguities in the market, which vary from season to season. Motivational levels of youth before and after the training were assessed by using the standardized instrument thematic apperception test. The motivational level of youth was found to be low on an average. The youth in Tigipur village had a higher entrepreneurial motivational level than those of the Saidpur village. The

overwhelming adverse conditions like salinity and non-availability of water in Saidpur were the demotivating reasons for low interest of the youth to take up farm related agri-enterprises. Available organizational support for rural entrepreneurial ventures was documented, and awareness generation exercise regarding these was conducted.

6.2.3.4 Development of communication materials for transfer of technology

Communication materials (brochures) on the following topics were tested for their effectiveness as perceived by the farmers: "Commercial Cultivation of Flowers", "Seed Production of Tomato", "Food Processing", "Entrepreneurship Development for Farmwomen", and "Self Help Groups". The effectiveness was tested for the following components: physical design, simplicity of language, contents, integration of text with pictures and utility in terms of relevance, learning new knowledge and help in improving productivity.

6.2.4 Development of Participatory Extension Methodology and Intersectoral Micro-plans

6.2.4.1 A model of sustainable extension system through rural institutions

The study was 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 participation of farmers. A methodology for organizing the farmers for rural institution (Rural Social Centre) was developed. Sustainability attributes were reviewed.

The investigations showed that the major problems faced by the farmers were related to the availability of quality input in time and at reasonable rates in the villages, marketing, value addition, credit, irrigation water, wild animals, electricity, time taking land litigation cases, storage, post-harvest technology, and availability of labour. Despite all these problems, they are not organizing themselves to solve them. There were so many socio-economic, personal and political reasons, and, above all, ignorance of the steps to be followed in organizing their own institutions. They had assumed that these problems were bound to happen and there was no remedy for them. An effort was, therefore, made to intervene in this process and three Rural Social Centres (in the form of Cooperative Society) were organized in three study areas (Delhi, Haryana and U.P.) and legal linkage was established with the line departments.

The rural social centres had helped the farmers in the supply of inputs in time in the villages itself. It was the observation of the farmers that owing to supply of quality seed and agro-chemicals, their yield had increased by about 25 per cent during the year.

6.2.4.2 Development of micro-plan for empowering the youth

The major objectives of the study were as follows: to assess the level of food security with respect to rural youth; to examine the time-use pattern of the rural youth and introduce intervention for better time utilization and to analyze

Rural social centres established

State	Block	Village clusters	Name of the society	Members
Delhi	Alipur	Palla, Jhingola, Kulakpur, Tigipur, Bakhtawarpur, Sungerpur, Tazpur, Hiranki and Bakoli	Integrated Agriculture and Marketing Cooperative Society (Ltd.)	120
Haryana	Rai	Atterna, Jakhauli, Pubsara, Dahisra, Manauli, Jati Khurd, Khurampur, Khadkad, Bhaira, and Jati Kala	Atterna Baby Corn Production and Marketing Cooperative Society (Ltd.)	60
U.P.	Khurja & Jawa	Nekpur, Jahangeerpur, Kalakhuri, Jawa, Kanpur, Milak Karimabad, Bhoyra, Rakhera, Udaipur and Chak	Samagra Krishi Vikas Sahakari Samiti (Ltd.), Nekpur	60

the problems of rural youth. Farm youth from Kamona and Phasu villages of Bulandshahar district (U.P.), Atterna village of Sonepat district and Saidpur village of Gurgaon district (Haryana) formed the study sample.

Data collected from three-study locales revealed inadequate dietary intake by youths. The major reasons attributed to this are ignorance regarding appropriate balanced diets, nutritive values of individual food items and personal food habits of youth. Vegetables and fruits were found missing from the majority's diet intake. Though milk and milk products were available in plenty in each household, the youth were not consuming even these in recommended portions. Time use patterns of the youth were as follows: agricultural operations, household chores, TV viewing, listening to radio, sports/cricket, card playing, *Akhara*/ gymnastics, reading (newspaper, magazines) and hanging out with friends/gossiping.

The perceived problems of rural youth were ranked as follows:

Perceived problems		Rank
1)	Lack of information/guidance	I
2)	Unemployment/under employment	II
3)	Lack of infrastructure facilities in village to pursue hobbies/ interests/career	III
4)	Lack of training facilities for learning new skills (grading, processing, and packaging, etc.)	IV
5)	Lack of training/awareness regarding health, hygiene and nutrition issues	V
6)	Financial constraints	VI
7)	Lack of effective linkages with hi-end market retailers	VII

For effectively utilizing the energies of youth for development, an appropriate strategy in terms of proper guidance/counseling, provision of career/training opportunities for taking up agri/non-farm enterprises was needed. The findings corroborated other research studies highlighting the hidden hunger phenomenon among rural people. Awareness generation regarding nutritional aspects/ balanced diet would have to be taken up by different government/non governmental agencies.

6.2.4.3 Assessment of performance of development administration in achieving human development

A set of parameters of human development index and variables were identified and necessary measurement procedure was constructed. Various indices of agricultural and human development were reviewed and a prototype index for assessing agricultural and human development was developed and tested. The index consists of parameters like education, health, infrastructure, and development indicators. It was found that the blocks varied greatly in their agricultural and rural development indices, and the performance of development administration also varied greatly. Planning process in various sectors at block and district levels was studied. Linkages and modes of coordination among various development departments were also studied.

6.2.5 Impact Analysis of Training Programmes Conducted under CAS in Agricultural Extension

A study aimed at assessing the impact of training programmes conducted at IARI under the Centre of Advanced Studies in Agricultural Extension revealed that most of the trainees (42.3%) had organized various activities in their respective institutes on the basis of learning acquired in the IARI-CAS training programmes. These activities included: 'proposing/organising new projects', 'introducing new courses for students', 'organising seminars, workshops, lectures' and 'writing articles related to the areas covered in the training programmes'. It was found that many of the participants (29.1%) were in contact with other participants for the purpose of exchanging knowledge and developing new programmes. Thirty-seven per cent of the participants reported that the training had helped them in acquiring a higher job position. A majority of the participants (76.9%) considered the training manual provided to them as 'very useful' and were regularly referring to it. Lack of cooperation from their institutions (89.2%) was reported as the major constraint in utilizing the learnings from the IARI-CAS training in work situation. Time constraints and lack of funds were the other major reasons for not utilizing the learnings in work place.

6.2.6 Evaluation Capacity Building in Rural Resource Management: An Action Project

The demand for programme evaluation information is growing. Because the need to support local developmental programmes is increasing and the resources are limited, there is an increased competition among agencies. This has resulted in greater expectations for efficiencies and accountability reports of performance for organizations. Despite the recognition that evaluation is an important programming function, there has been no systematic effort for capacity building in this area. Increased emphasis on result orientation as well as the growing need for improved management of development and research programmes has resulted in more priority for evaluation capacity building (ECB) in India. This project was designed to address the educational need among programme managers and educators to conduct programme evaluations.

The Institute collaborated with the Center for Evaluative Studies at the Department of Community, Agriculture, Recreation and Resources Studies (CARRS), Michigan State University (MSU) to take up an action research project on evaluation capacity building. The main objective of this project study was to develop evaluation capacity among rural resource management programme staff in South Asia Region (India, Nepal, Bhutan and Bangladesh) through development of a cadre of evaluators, who would be willing and able to conduct evaluation of educational and/or developmental programmes through "train the trainer" approach. However, owing to limited fund availability, the project was restricted to the participants from India. The project also aimed at developing a manual on evaluation. In order to achieve the objectives of the project, three workshops were designed and conducted during March, April, and August 2006. Each phase of the workshop was held for a period of five days and attended by twenty participants who were given both theoretical and practical trainings on programme evaluation related to rural resource management. Each participant also completed a field project on evaluation and submitted a final report of his/her evaluation study. The impacts of the workshops were assessed through pre- and post-tests. The study revealed that as a result of the workshops, the knowledge level of participants in evaluation increased by 36.18%. The investigation also revealed that the extent of change due to workshop was perceived to be at a very high level in all the areas of evaluation. The study showed that all the participants had acquired several new skills due to evaluation workshops. The project achieved two major outputs, namely, the development of a cadre of twenty programme evaluators and development of a training module as well as twenty cases on evaluation, which can be used as resource materials on evaluation by the trainers. At individual level, the project contributed to the enhancement of evaluation capacity of twenty extension scientists and professionals resulting in gaining of additional knowledge and skill and improved capability as well as boosting of their confidence to undertake evaluation functions.

A manual on evaluation capacity building was edited and published which would serve as a reference book for the trainers and the students of evaluation. Fourteen cases prepared on evaluation and included in this manual would be an effective tool in training the future professionals.

6.2.7 Taking Wheat Cultivation Technology to Unreached and Tribal Areas

A total of 149 frontline demonstrations of 12 bread wheat varieties were conducted during 2007-08 in western tribal district of Jhabua, eastern districts of Rewa, Satna and Sidhi in M.P. and Bharatpur, Dausa and Dhaulpur districts in Rajasthan to popularize "Dry Sowing Limited Irrigation Wheat Cultivation Technology" and newly evolved wheat varieties. Despite severe drought in M.P., yield increase was 53% in irrigated and 96% in limited irrigated demonstrations.

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

Use of fungus (Fusarium sp.) for Orobanchae control. The fungus *Fusarium* sp. was identified and isolated from

some infected plants of Orobanchae in the operational areas. The fungus multiplied by the Division of Plant Pathology was used as seed treatment and broadcasted in the affected fields of mustard crop in four demonstrations, which resulted in the reduction of the incidence of Orobanchae infestation in the demonstration plots up to 50% and increase in the grain yield by 53.3- 87.5%.

Assessment and promotion of improved varieties. A total of 139 varietal demonstrations during *rabi* 2007-08 and 55 demonstrations during *kharif* 2008 were conducted.

Among three IARI mustard varieties demonstrated, Pusa Bold gave the highest yield of 1.19 t/ha against the local check which yielded 0.80 t/ha. In wheat demonstrations of 5 IARI varieties, HD 2733 having profuse tillering gave the highest average yield of 4.19 t/ha followed by HD 2824 (3.57 t/ha) as against the local check which gave a yield of 2.80 t/ha. However, the variety Kundan was preferred by farmers because of its reasonably good yield of 3.38 t/ha with limited irrigations and better *chapati* making quality. The performance of gram variety BGD 72 owing to its bold grains was very good in terms of yield, i.e. 60% increase as against the yield of local check variety but its local market price was comparatively less than that of the varieties grown in the area. Sixteen demonstrations of *methi* variety PEB recorded an average yield of 1.88 t/ha in comparison to 1.35 t/ha of the local check variety.

Thirty-five demonstrations on mungbean variety Pusa Vishal gave an average yield increase of 38.33% as compared to that of the local check variety (0.60 t/ha). Among 3 *bajra* varieties assessed, Pusa 383 gave an average yield of 2.02 tonnes/ha followed by variety Pusa 23 (1.86 t/ha).

Yield performance of crop demonstrations during *rabi* 2007-08 (Jhunjhunu)

Crop	Variety	No. of demons-trations	Av. yield (tonnes/ha)	Yield of local check variety (t/ha)	Per cent increase
Mustard	P. Bold	29	1.19	0.80	48.75
	P. Jagannath	19	1.07		33.75
	P. Jaikisan	26	1.07		34.50
Wheat	HD 2733	7	4.19	2.80	49.64
	HD 2824	8	3.57		27.50
	Kundan	7	3.38		20.71
	WR 544	4	3.12		11.43
	HD 2851	4	3.36		20.00
Methi	PEB	16	1.88	1.35	39.26
Gram	BGD 72	12	1.12	0.70	60.00
	BG 1088	7	0.86		22.85

Yield performance of crop demonstrations during *kharif* 2008 (Jhunjhunu)

Crop	Variety	No. of demons-trations	Yield t/ha		Per cent increase over local
			Average	Local check variety	
Mungbean	Pusa Vishal	35	0.83	0.60	38.33
Bajra	Pusa 334	4	1.62	1.45	11.72
	Pusa 383	13	2.02		39.31
	Pusa 23	3	1.86		28.28

Capacity building. Three field training programmes on production technologies of *zaid, kharif* and *rabi* crops were organized during the year.

6.3.1.2 Agri-horti system in peri-urban area of Ghaziabad and Baghpat districts

Improved/hybrid varieties of *rabi* and *kharif* crops were introduced in the area.

In Ghaziabad district, 55 demonstrations on wheat varieties HD 2733, HD 2851, HD 2643, HD 2824, HD 2329, HD 2687 and PBW 502 were conducted. Among these varieties, HD 2329 gave the highest yield followed by HD 2851. Farmers reported that the grains of varieties, HD 2851 and HD 2643, were good for *chapati* making. Among mustard varieties, Pusa Bold, owing to its bold grain, gave the highest average yield of 2.44 t/ha and was reported to have high oil content. Cauliflower variety PSB K 25 gave an average yield of 28.17 t/ha as compared to PSB K1 (26.56 t/ha). In Baghpat district 32 demonstrations of five wheat varieties (10 of HD 2733, 6 of HD 2851, 7 of HD 2643, 8 of HD 2824, 1 of HD 2329) were laid. HD 2329 gave the highest yield of 6.24 t/ha in comparison to 3.98

Yield performance of different crops in Ghaziabad and Baghpat districts (U.P.) during *rabi* 2007-08

Crops	Variety	Ghaziabad				Baghpat			
		No. of demons-trations	Yield (t/ha) Average	Local	Per cent increase	No. of demons-trations	Yield (t/ha) Average	Local	Per cent increase
Wheat	HD 2733	8	5.35	4.13	29.54	10	5.78	3.98	45.23
	HD 2851	13	5.91	(PBW 373)	43.10	6	5.91	(PBW 373)	48.49
	HD 2643	19	4.75		15.01	7	4.75		19.35
	HD 2824	8	5.33		29.06	8	5.68		42.7
	HD 2329	3	6.01		45.52	1	6.24		56.78
	HD 2687	1	5.57		34.87	—	—		—
	PBW 502	3	5.74		38.98	—	—		—
Mustard	Pusa Bold	19	2.44	1.64 (Varuna)	48.78	8	2.23	1.56 (Varuna)	42.95
	Pusa Jagannath	16	2.14		30.49	8	2.18		39.74
	JD 6	6	2.02		23.17	—	—		—
	Pusa Agrani	5	2.42		47.56	—	—		—
Cauliflower	PSB K 1	5	26.56	20.55 (Poosi)	29.25	—	—		—
	PSB K 25	3	28.17		37.08	—	—		—

t/ha of the local check variety PBW 373. In mustard, the varieties, Pusa Bold and Pusa Jagannath yielded 42.95% and 39.74% higher, respectively than the local check variety Varuna.

Yield performance of different crops in Ghaziabad and Baghpat districts (U.P.) during *kharif* 2008

Crop	Variety	No. of demons-trations	Yield (t/ha) Average	Local	Per cent increase
Ghaziabad district (U.P.)					
Paddy	PRH 10	45	6.28	3.17	98.11
	PB 1	10	4.61		45.43
	PS 4	15	3.96		24.92
Moong	Pusa Vishal	25	0.83	0.51	62.75
Arhar	P 992	28	1.87	1.22	53.28
Bottle Gourd	Pusa Naveen	5	30.11	-	-
Jowar	PC 23	2	77.27	-	-
Maize	MAH2049	3	4.04	2.46	64.23
Baghpat district (U.P.)					
Paddy	PB 1	16	4.15	3.01	28.55
	PS 4	13	4.56		42.12

Among 70 paddy demonstrations, the rice hybrid PRH 10 gave the highest average yield of 6.28 t/ha. in Ghaziabad district which was higher than that of local check variety (Sarbati). The variety PRH 10 became popular among the farmers due to its high yield, good quality grains and less disease infestation. The *moong* variety Pusa Vishal and *arhar* variety P 992 also recorded an increase in yield to the extent of 62.75% and 53.28%, respectively, as compared to their local check varieties. The bottle gourd variety Pusa Naveen was reported to be market friendly owing to its cylindrical round small fruit in addition to high yield.

A one-acre orchard of 100 plants of guava (25 each of Hisar Surkha, Lalit, Sardar L 49 and Allahabad Safeda) and 20 plants of *aonla* (NA 7) was established.

Under farmers' participatory seed production, paddy seed 1.6 tonnes of var. Pusa 1121, 0.6 tonne of PRH 10 and pigeonpea seed 3 tonnes of vars. Pusa 992, Pusa 2001 and Pusa 2002 were produced.

6.3.1.3 Sustainable rice-wheat based production system in irrigated areas (Patiala district, Punjab, Gautam Budh Nagar and Bulandshahr districts, U.P.)

Introduction and promotion of improved varieties of rabi and kharif crops. (Gautam Budh Nagar district). Improved varieties of *rabi* and *kharif* crops were introduced in the area. Of the 42 demonstrations of 4 wheat varieties (HD 2733, HD2824, HD 2851 and WR 544), HD 2733 gave the highest average yield of 5.38 t/ha followed by HD 2851 (5.25 tonnes/ha) which were 14.47% and 11.70% higher, respectively than that of the local check variety. Fifty-five demonstrations of mustard varieties, JD 6, Pusa Bold and Pusa Jaikisan gave an average yield of 1.87 tonnes, 1.81 tonnes and 1.82 tonnes/ha, respectively, as against 1.60 tonnes/ha of the local check variety (Rohini). The demonstration plots of *palak* variety Allgreen, cauliflower variety PSBK 25 and marigold variety Pusa Narangi also recorded 14.29%, 17.64% and 16.0% higher yields, respectively, than that of their local check varieties.

Yield performance of different crops in Gautam Budh Nagar : *Rabi* 2007-08

Crop	Variety	No. of demonstrations	Yield (t/ha)		Per cent increase
			Average	Local	
Wheat	HD 2733	10	5.38	4.70 (PBW 343)	14.47
	HD 2824	12	4.94		5.11
	HD 2851	5	5.25		11.70
	WR 544	15	4.94		5.11
Mustard	JD 6	13	1.87	1.60	16.88
	Pusa Bold	22	1.81		13.13
	Pusa Jaikisan	20	1.82		13.75
Palak	Allgreen	1	8.00	7.00	14.29
Cauliflower	PSBK 25	1	20.00	17.00	17.64
Marigold	Pusa Narangi	1	29.00	25.00	16.00

Yield performance of different crops in Gautam Budh Nagar : *Kharif* 2008

Crop	Variety	No. of demonstrations	Yield (t/ha)		Per cent increase
			Average	Local	
Paddy	P 1121	26	3.91	4.00 (Sarbati)	2.25
	PRH 10	16	5.87		46.75
	P 44	9	6.50		62.50
Fodder *Jowar*	PC 9	13	79.58	62.5 (Kanpuri)	27.33
Arhar	P 992	10	1.50	1.25 (Manak)	20.00
	P 2001	12	1.60		28.00
Bottle gourd	Pusa Naveen	04	17.80	16.0 (PSPL)	11.25
Marigold	Pusa Narangi	02	30.0	25.0 (Span Gold)	20.00

During *kharif* 2008, fifty-one demonstrations on paddy varieties (P 1121, PRH 10 and P 44) gave an average yield of 3.91 tonnes, 5.87 tonnes and 6.5 tonnes /ha, respectively, in comparison to 4.0 tonnes/ha of the local check variety (Sarbati). Thirteen demonstrations on fodder *jowar* (PC 9) gave an average fodder yield of 79.58 t/ha in comparison to 62.5 t/ha of the local check variety (Kanpuri). The fodder quality of PC 9 *jowar* was reported to be better than that of the local variety. *Arhar* (Pusa 992) gave an average yield of 1.50 t/ha in comparison to 1.25 t/ha of the local check variety (Manak). Four demonstrations of bottle gourd (Pusa Naveen) gave an average yield of 17.8 t/ha in comparison to 16.0 t/ha of the local check variety (Pusa Summer Prolific Long). Two demonstrations of marigold variety Pusa Narangi gave an average yield of 30.0 t/ha against 25 t/ha of the local check variety Span Gold.

Seed production of improved IARI varieties of paddy and wheat (Rakhra-Patiala, Punjab). The major emphasis of the Institute's collaboration with Young Farmer Association, Rakhra (Patiala) was on seed production of paddy and wheat for ensuring the availability of quality seed of high yielding IARI varieties to farmers of different districts of Punjab. During *rabi* 2007-08, a total of 31.1 tonnes of seeds of wheat varieties HD 2733 (10.0 tonnes), HD 2851 (15.4 tonnes), HD 2894 (2.1 tonnes), WR 544 (3.6 tonnes) were produced. During *kharif* 2008, a

total of 46.5 tonnes seed of paddy varieties Pusa 1121 (18.0 tonnes) and Pusa 44 (28.0 tonnes) at Rakhra (Patiala) and PRH 10 (0.5 tonne) at Badshahpur (Faridabad) were produced.

6.3.1.4 Assessment and promotion of improved animal husbandry technologies for small household dairy farming units

The following technological interventions/animal healthcare/training programmes were implemented/organized.

1) Implemented three technological interventions for enhanced productive and reproductive performance of household dairy animals: a) deworming in buffalo calves to reduce mortality - 60 buffalo calves, b) deworming and ectoparasite control in milch buffaloes for improved productive and reproductive performances - 36 buffaloes, and c) minerals and vitamin supplements for improved reproductive performance - 45 buffaloes/heifers.

2) Organised four animal health care camps in operational areas of the project in addition to attending a total of 385 animals for treatment/advice against various ailments.

3) Organised three training programmes on improved dairy farming practices for farmers/farm women (140).

Deworming interventions gave better response in semi-arid areas whereas interventions on ecto-parasite control and vitamin-mineral supplements received better response in irrigated areas.

6.3.2 Water Management Technologies for Sustainable Crop Production - An Action Research

With the objective to assess and transfer five water management technologies to the end users for enhanced water and nutrient use efficiency and improved soil health for sustainable agricultural productivity, the followings field demonstrations on five water management technologies were conducted.

The demonstrations on the use of biogas slurry in paddy crop in farmers field showed 17% saving in the number of irrigations and a saving of 52.46% per hectare on cost of chemical fertilizers. The overall increase in total income per hectare was higher by 6.34%.

Field demonstrations conducted

Technologies	Demonstrations	
	Kharif 2008	*Rabi* 2008-09
Enhancing water holding capacity and organic carbon content of the soil through biogas slurry	8 ha	20 ha
Aqua - ferti seed drill	-	6 ha
Laser leveling for efficient irrigation	3 ha	10 ha
Raised bed technology to achieve higher yield with less water	-	2 ha
System of rice intensification (SRI)	9 ha	-

Paddy crop demonstrations on laser levelled farmers' fields demonstrated 43.4% saving in irrigation cost which resulted in 24.4% higher net return per hectare.

SRI demonstration plots in farmers' fields yielded 5% higher than the control plots. The seed cost reduced by 36% resulting in 12.6% higher net return per hectare.

Installation of 50 biogas plants at three locations of the programme was completed. Six field days and 6 *kisan goshthies* were organised.

6.3.3 Livelihood and Nutritional Security of Tribal Dominated Areas through Integrated Farming System and Technology Models

The major objectives were to promote high yielding IARI varieties of various crops, varietal diversification through seed production programme of wheat, vegetables, paddy, etc., to create seed processing facilities, to develop skills through extension activities and training programmes, content development (cassettes/CD preparation) and to publish need based farm literature on crops and seed production technology. The study covered 4 districts of Rajasthan, namely, Udaipur, Banswara, Dungarpur and Sirohi. Demonstrations on rice, wheat, gram and mustard were conducted. Seed production of field crops (wheat, gram, mustard and rice) and seed production of vegetables - bottle gourd (Pusa Naveen), brinjal (Pusa Uttam) and pumpkin (Pusa Vishwas) were undertaken. Orchards of mango, kinnow, papaya and *aonla* were established in Udaipur district. Two books – one on vegetable production and the other on horticultural crops– were published. One training at IARI for

seven days for the farmers of study area and 3 one –day off-campus trainings in study areas were conducted. Seed processing facilities were developed at ARS Banswara.

6.3.4 Front Line Demonstrations on Wheat, Barley and Maize

Sixty FLDs on wheat covering an area of 30 hectares were conducted in selected villages of Bulandshahr, Aligarh and Gautam Budh Nagar districts in U.P. and Sonepat and Gurgaon districts in Haryana. Twenty-nine demonstrations were conducted on newly released varieties of wheat (PBW 502 and HD 2851). Ten demonstrations on zero tillage and 21 demonstrations on use of bio-fertilizer (*Azotobacter* + *PSB*) were also conducted. The average yield of PBW 502 (5.33 t/ha) was higher than those of the local check varieties. The demonstrations on the use of bio-fertilizers resulted in 7.32% increase in the yield. The zero tillage practice resulted in 5.06% increase in the yield over that of the control plot.

Ten frontline demonstrations were laid out in Samastipur and Muzaffarpur districts. The demonstrations conducted were on the use of bio-fertilizers—*Azatobactor* and PSB (2), zero-tillage technology (2) and new improved wheat variety (6). The size of each FLD was one hectare. The performance of different demonstrations was very encouraging.

IARI Regional Station, Wellington conducted 20 ha FLD in north Tamil Nadu and southern Karnataka to popularize the cultivation of wheat in non-traditional areas by introducing wheat varieties, COW(W) 1 and HD 2833.

Two soil test based frontline demonstrations on wheat were conducted in the farmers' fields in Sadalkalan village, Sonepat (Haryana) during *rabi* 2007-2008. Higher grain yield, yield response (kg grain kg^{-1} nutrient applied) and net profit were obtained where fertilizer application was done on the basis of soil test for a specified yield target compared to those obtained with general recommended dose and farmer's practice.

Front line demonstrations on wheat and barley were conducted by IARI Regional Station, Tutikandi, Shimla in 4 villages under Shimla, Bilaspur and Kinnaur districts of Himachal Pradesh. The performance of 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 showed an average yield of 2.0 t/ha with an increase of 17% - 25% over that of the local checks.

During *kharif* 2008, in all 100 FLDs including 62 for grains and 38 for green cobs covering an area of 25 hectares were conduced on maize in Bulandshahr, Gautam Budh Nagar, Ghaziabad and Aligarh districts in U.P. The demonstrations were conducted on latest varieties of maize, 32T- 25, 30V- 92, 30B- 07 and K 26. Among the varieties, 32T-25gave the highest grain yield of 4.70 t/ha. Farmers in NCR region found maize

Soil-test based fertilizer recommendations for specific yield targets vis-à-vis other recommendations

Treatment	Fertilizer dose (kg ha^{-1})			Yield (t ha^{-1})	Extra yield (t ha^{-1})	Cost of extra yield (Rs.)	Cost of fert. (Rs.)	Res. ratio (kg kg^{-1})	Net profit (Rs. ha^{-1})
	N	P_2O_5	K_2O						
Farmer: Shri Devi Singh, Sadalkalan village, Sonepat, Haryana. Crop/variety: Wheat (HD 2824) Year: 2007-08									
Target 5.0 t	145	50	70	5.13	3.21	32100	3335	12.11	28765
Gen. dose	120	60	40	4.44	2.52	25200	2860	11.45	22340
Farmers practice	100	57	0	3.75	1.83	18300	2155	11.66	16145
Control	0	0	0	1.92	-	-	-	-	-
Farmer: Shri Satender, Sadalkalan village, Sonepat, Haryana. Crop/variety: Wheat (HD 2733) Year: 2007-08									
Target 5.0 t	160	25	50	5.20	3. 03	30300	2955	12.89	27345
Gen. dose	120	60	40	4.72	2. 55	25500	2860	11.59	22640
Farmers practice	100	57	0	4.07	1. 90	19000	2155	12.10	16845
Control	0	0	0	2.17	-	-	-	-	-

highly remunerative if they sold the cobs. For cob, variety 30V-92 gave the highest cobs yield of 14.55 t/ha.

6.3.5 Collaborative Extension Programme with SAUs/ICAR Institutes

National Extension Programme (NEP) was taken up by the CATAT of the Institute from *kharif* 2007 in collaboration with selected SAUs/ICAR institutes such as Marathwara Agricultural University, Parbhani and Mahatma Phule Krishi Vidyapeeth, Rahuri in Maharashtra; BHU, Varanasi and IIVR, Varanasi in Uttar Pradesh; MPUAT, Udaipur in Rajasthan; University of Agricultural Sciences, Bangalore and Dharwad in Karnataka; and BAU Ranchi in Jharkhand. Under this programme, IARI has provided its improved varieties of different crops, to the collaborative SAUs/ICAR institutes.

6.3.5.1 NEP in collaboration with SAUs / ICAR institutes (Distance range > 500 km from IARI, New Delhi)

During 2007-08, in all, 425 demonstrations were conducted on varieties of wheat, gram, mustard, paddy, *arhar*, pearl millet, *moong*, *jowar* and vegetables in collaboration with partner institutes. In UAS Bangalore, 12 demonstrations on *palak* (All Green), Peas (Pusa Panna), bottle gourd (Pusa Samriddhi), onion (Pusa Red) and brinjal (Pusa Shyamala) were conducted. In MPUAT, Udaipur, 25 demonstrations on gram (BG 1088 and BGD 72), 75 on mustard (Pusa Agrani, JD 6, Pusa Bold and Pusa Jaikisan), 3 on paddy, 2 on *bajra* (PC 383, and Pusa Hybrid 605), 2 on *arhar* (Pusa 992), 2 on *moong* (Pusa Vishal), 4 on *jowar* (PC 9) and 3 on bottle gourd (Pusa Samriddhi) were conducted**.** In MPKV, Rahuri and MAU, Parbhani, 30 demonstrations on mustard varieties (Pusa Jagannath, Pusa Jaikisan and Pusa Bold), 2 on *moong* (P 9351 and Pusa Ratna), 1 on paddy (Pusa 1121), 15 on wheat (NIAW 301, HI 8498 and HI 8663), and 6 on gram (BG 1088) were conducted. At IIVR, Varanasi and BHU, Varanasi (UP), 50 demonstrations on wheat (HD 2824, HD 2643, HD 2733 and Kundan), 50 on mustard (Pusa Bold, Pusa Jaikisan, Pusa Tarak and Pusa Jagannath) and 12 on gram (BGD 72 and BG 1088), 19 on paddy (P 1121, PRH 10, Pusa 1401 and Pusa 44) and 8 on pigeon pea (Pusa 992) were conducted. At BAU, Ranchi, 25 demonstrations on wheat (HI 1500, HI1531, HI 1418, HI 1454 and HI 1539) 10 on gram (BGD 72 and BGD 1088) and 10 on mustard varieties (Pusa Bold, Pusa Jaikisan and Pusa Jagannath) were conducted.

IARI varieties of different crops gave encouraging results at most of the collaborating locations.

6.3.5.2 Integrated agricultural development (Distance range of 75 - 500 km from IARI, New Delhi)

National Extension Programme for integrated agricultural development was taken up in selected villages by IARI in Bulandshahr district (UP), and Jhunjhunu district (Rajasthan). The programme was taken up in collaboration with YFAP Rakhra in Patiala district (Punjab) and in collaboration with NRC on rapeseed and mustard, Bharatpur in Bharatpur district (Rajasthan).

During 2007-08, a total of 278 demonstrations on wheat (HD 2733, HD 2824, HD 2851, Kundan and WR 544), mustard (Pusa Agarni, JD 6, Pusa Jaikisan, Pusa Bold, Pusa Jagannath and Pusa Sarson Sag 1), *methi* (PEB), gram (BGD 72 and BD 1088), pea (DDR 55, DDR 23 and DMR 7), lentil (L 4076), tomato (Nandi and Vaibhav), paddy (Pusa 1121, Pusa 44 and PRH 10), *jowar* (PC 9), *arhar* (Pusa 992), *bhindi* (V.Uphar and A. Anamika), *moong* (Pusa Vishal) and *bajra* (Pusa 334, Pusa 383 and Pusa 23) were conducted.

6.3.5.3 Peri-urban agriculture (Distance range of < 75 km from IARI, New Delhi)

A total of 846 demonstrations on wheat (HD 2733, HD 2824, HD 2851, HD 2932, HD 2687 and WR 544), mustard (Pusa Jaikisan, Pusa Bold, Pusa Jagannath and Pusa Sarson Sag), cauliflower (Pusa snowball and PSBK 25), tomato (Nandi and Vaibhav), paddy (Pusa 1460, PB 1, Pusa 1121, Pusa 44 and PRH 10), *arhar* (Pusa 992 and Pusa 2001), bottlegourd (Pusa Naveen) and sorghum (PC 9) were conducted in the operational areas of Sonepat, Faridabad, Gautam Budh Nagar, Ghaziabad, Baghpat and Jhajjar districts.

6.3.6 Field day/Field trial

A field day was organized on December 27, 2008 at Lohtaki village, Gurgaon district. In this event, more than 150 farmers were taken to the on-farm experiments in order to show them the outstanding crop performance under SSNM,

A farmer is surprised to see 103 siliquae per branch in mustard under SSNM at Lohtaki village

and to apprise them of the advantages of soil test-based fertilizer use. The field visits were followed by a detailed interaction of the farmers with the scientists.

Trials were conducted in farmers' fields at Jhundpur village, Sonepat in rice against *M. graminicola* and bottle gourd against *M. incognita*. The farmers of Nathawala, Jaipur and Barielly (UP) were educated about the nematode problems in wheat (against *H. avenae*), and vegetables (against root-knot nematodes).

6.3.7 *Pusa Krishi Vigyan Mela*

A three-day *Pusa Krishi Vigyan Mela* was held at IARI, New Delhi, from February 21 to 23, 2008 on the theme "IARI – Marches Towards Higher Productivity and Commercialization". The *mela* was inaugurated by Dr. Mangala Rai, Secretary, Department of Agricultural Research and Education (DARE) and Director-General, Indian Council of Agricultural Research (ICAR) on February 21, 2008. Dr. S.A. Patil, Director, IARI presided over the function and gave the welcome address. On this occasion, Dr. Mangala Rai released four publications: a thematic souvenir of the *mela; Prasar Doot (Mela Visheshank); phal phul avem sabji utpadan takniki;* and *krishi aur gramin vikas yojnae avem suvidhaye*, and nineteen extension bulletins on different topics of farmers' interests.

Dr. Mangala Rai, Secretary, DARE & Director-General, ICAR lighting a lamp at the inaugural function of *Pusa Krishi Vigyan Mela* on February 21, 2008 at IARI

Technologies developed by IARI for higher agricultural productivity and commercialization were displayed in a thematic *pandal*, where some progressive farmers shared their experiences of IARI technologies with other visiting farmers. Different project directorates, divisions, centres and units of the Institute demonstrated their technologies in their respective separate stalls. Seven state agricultural universities, twenty-five ICAR institutes including some livestock based research institutes, thirty-five private companies, fourteen public sector undertakings, twenty-one NGOs/societies and twenty progressive farmers from extension operational areas of the Institute participated in the *mela*. A total of 175 stalls besides thematic pavilion displayed the latest agricultural technologies/ products of different organizations.

A very large number of visitors from different parts of the country covering farmmen, farmwomen, students, extension workers, entrepreneurs and others visited the *mela*.

In the first technical session of the *mela* on February 21, 2008, Shri A.K. Upadhyay, Additional Secretary, DARE & Secretary, ICAR was the chief guest, and Dr. K. Chugh, Chairperson, Associated Chambers of Commerce & Industry of India, and Shri Brahm Yadav, Chairman, Delhi Agriculture Marketing Board were the guests of honour.

A workshop on "Women Empowerment" was inaugurated by Mrs. Krishna Tirath, Hon'ble Member of Parliament on February 22, 2008. More than 5000 farmwomen and farmmen from different parts of the country participated. The second technical session of the *mela* on "Public-Private Partnership — Organizational Support and Schemes" on

February 22, 2008 was sponsored by the Directorate of Marketing and Inspection, Ministry of Agriculture, Government of India. Dr. C.D. Mayee, Chairman, Agricultural Scientists Recruitment Board (ASRB) was the chief guest. Shri Har Prasad, Joint Agriculture Marketing Advisor, Directorate of Marketing and Inspection; Dr. P.N. Mathur, former Joint Director (Extension), IARI; and Dr. B.S. Hansra, Director, School of Agriculture, Indira Gandhi National Open University (IGNOU) were the guests of honour.

The third technical session of the *mela* on "Agrobiodiversity Resource Conservation and Farmers' Rights" on February 23, 2008 was sponsored by the Protection of Plant Varieties and Farmers' Rights Authority, Ministry of Agriculture, Government of India. Prof. R.B. Singh, former Member of the National Farmers' Commission was the chief guest. Dr. A.K. Singh, Deputy Director-General (NRM), ICAR and Dr. Kartar Singh, former Head, Centre for Agricultural Technology Assessment and Transfer (CATAT) were the guests of honour.

High yielding seeds of different crops worth rupees 20 lakhs were sold through Pusa Seed Sale Counter in the *mela*. Many farmers from extension operational areas of the Institute also sold seeds of high yielding varieties produced on their fields through 'Farmer Participatory Seed Production' programme of IARI. Revenue worth Rs. 7.40 lakhs (Rupees seven lakhs forty thousand) was generated from the *mela* through stall bookings, advertisements in *mela* souvenir and sponsorship for technical sessions/farmers honours.

Shri Mangat Ram Singhal, Hon'ble Minister of Industries, Labour and Building, Government of Delhi was the chief guest of the valedictory function on February 23, 2008, and Dr. P.L. Gautam, Deputy Director-General (Crop Science), ICAR was the guest of honour. The chief guest honoured 25 progressive farmers from different states of the country. He also addressed the farmers, and gave away the prizes and certificates to various participating organizations and farmers.

6.3.8 Training Programmes Organised for Farmers and Extension Workers

Several training programmes were organized by the CATAT/ATIC of the Institute on different topics during the period under report.

Training programmes organised

S.No	Date (s)	Topic	State	Participants
1.	June 16, 2008	Soil Conservation and Soil Testing	Delhi State	23 progressive farmers
2.	June29-30, 2008	Pre-seasonal Training on *Kharif* Crops	Delhi State	24 progressive farmers
3.	June 20, 2008	Water Harvesting and Water Management	Delhi State	21 progressive farmers
4.	July22-31, 2008	Modern Agricultural Technologies (Under ATMA)	Saharanpur (UP)	11 acheiver farmers
5.	July23-29, 2008	Organic Farming	Gulberga (Karnataka)	13 progressive farmers
6.	July 25, 2008	Training on Organic Farming and Vermi-compost	Delhi	Agricultural officials and progressive farmers
7.	September1-6, 2008	Seed Production Technology of *Rabi* Crops (Under NAIP)	Banswara, Dungarpur, Sirohi and Udaipur Districts (Rajasthan)	21 progressive farmers
8.	September 11-20, 2008	Modern Agricultural Technologies (under ATMA)	Bijnaur, U.P	10 achiever farmers
9.	September 18 -19, 2008	Pre-seasonal Training Programme on *Rabi* Crops	Delhi	Agricultural officials and progressive farmers
10.	September 20-29, 2008	Cultivation Technologies of *Basmati* Rice and Allied Subjects of Agriculture (under ATMA)	Madhya Pradesh	38 achiever farmers
11.	October 10, 2008	Dry Land Farming	Delhi	Agricultural officials and progressive farmers

Contd....

S. No	Date (s)	Topic	State	Participants
12.	October 13-22, 2008	Training of Achiever Farmers (Under ATMA)	Ghaziabad, (UP)	8 acheiver farmers
13.	October 16-20, 2008	Training of Achiever Farmers on Crop Production (Under ATMA)	Bijnaur	11 acheiver farmers
14.	October 20-29, 2008	*Basmati*/Paddy and Its Cultivation Techniques & Allied Subject of Agriculture	Madhya Pradesh	38 progressive farmers
15.	November 21, 2008	Integrated Nutrient Management	Delhi	16 farmers and field staff
16.	November 29 - December 5, 2008	Production of *Rabi* and Horticultural Crops and Post Harvest Technology	Gopal Ganj, West Champaran and Nalanda districts, Bihar	25 progressive farmers
17.	December 30, 2008	Post Harvest Technologies	Delhi	18 farmers and field staff

6.3.9 Off-campus Exhibitions

The CATAT and ATIC of the Institute participated in several agricultural exhibitions for display /sale of IARI technologies, products, services and publications.

Events participated

S. No	Name of the event	Venue	Period
1.	Exhibition during the International Conference on Science-based Agricultural Transformation towards Alleviation of Hunger and Poverty in SAARC Countries (Jointly organised by Ministry of Agriculture, Govt. of India, ICAR, IFFCO and IFFCO Foundation)	NASC complex, New Delhi	March 5-7, 2008
2.	YFA *Krishi Vigyan Mela*	Rakhra, Patiala	March 15, 2008
3.	KVK *kisan mela*	KVK, Shikohpur, Gurgaon	February 12, 2008
4.	"e-India 2008" Delhi (Organised by the Department of Information and Technology, Government of India).	Pragati Maidan, New Delhi	July 29-31, 2008
5.	Science, Technology and Planet Earth	Central Board of Secondary Education (CBSE), Delhi	August 25-26, 2008
6.	Eastern Rajasthan Agricultural Science Fair and Agricultural Industries Exhibition-2008	Bharatpur Gramin Haat, Bharatpur (Rajasthan)	September 27-29, 2008
7.	Rakhra Kisan Mela (Organised by YFA, Punjab	Patiala (Punjab)	October 3, 2008
8.	Regional *Kisan Mela* (organised by Marketing Committee)	Kosikalan, Mathura district (UP).	October 13, 2008
9.	India International Trade Fair, 2008	Pragati Maidan, New Delhi	November 14-27, 2008
10.	KISAN 2008- Agricultural Trade Fair (Organised by Kisan Forum Pvt. Ltd.)	Pune	December 17-21, 2008
11.	Agricultural Exhibition on *Sabji Uttpadan, Katai Uprant Prabandhan Evam Vipannan* (Organised by Krishi Vigyan Kendra, Ujwa, New Delhi.)	NCUI, 3 Sri Institutional Area, August Kranti Marg, New Delhi	December 8-9, 2008
12.	Exhibition and poster display during National Seminar in Hindi on " *Behtar Paryavaran ke liye Bhartiya Krishi*" (Organised by IARI)	IARI	December 16-17, 2008

6.3.10 Agricultural Technology Information Centre (ATIC)

Major activities of the ATIC are to provide products, services, technologies and information to different

stakeholders through a 'Single Window Delivery System'. Farmers are given farm advice through personal interaction at the ATIC, Pusa Helpline, IInd level of Kisan Call Centre, exhibitions, farm literature, NCDEX Price Ticker and letters. A IInd Level of Kisan Call Centre (1551) established at the ATIC provide remedial measures for the problems/queries of farmers of Delhi state. The ATIC, is also a nodal agency for Kisan Call Centre of Delhi state. Live demonstration of the latest high yielding varieties of wheat like HD 2687, HD 2851, HD 2932, HD 2824 and HD 2643 in *rabi* 2008-2009 were conducted in crop cafeteria to educate the visiting farmers. High density fruit tree orchards planted with lemon (Kagzi Kalan), mango (Amrapali), guava (Allahabadi Safed), *ber* (Banarasi Karaka) and plantation of *aonla* (varieties NA 7, NA 10, Krishna, Lakshmi 52, Chakaiya) and *Jatropha*, *aloevera*, *ashwgandha*, satavar, etc., related to the growing information needs of farmers for fruits and medicinal plants. Information and advisory needs of the visitors are also being catered through information museum, plant clinic, farm library, and exhibits.

About 14000 farmers/entrepreneurs, development department officials, students, NGO representatives, etc., from almost all parts of the country visited the ATIC during the year for farm advisory, diagnostic services, purchase of technological inputs/products and trainings. Purpose-wise, maximum number of farmers (9934) visited the ATIC to purchase or enquire about seeds/varieties, followed by those visiting for information related to horticultural and medicinal plants (4895), plant protection (1358), agro-based enterprises (956), farm literature (3045), dairy (525), agricultural implements (732) and others (965). In terms of visits to the ATIC by farmers, U.P. (30%) ranked first followed by Haryana (22%), Rajasthan (18%), and Delhi (14%).

About 2500 farmers/entrepreneurs from 17 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 made by the farmers related to seed availability (1135) followed by production technology (763), plant protection (621), agro-based enterprises (324), and literature (418), biofertilizer (156) and others (538). Seeds and publications worth about Rs. 10.30 lakh were sold by the ATIC during the period.

Two bulletins on "Government Support and Facilities for Farmers and Rural Development" and "*Rabi Fasalon Ki Sasya Vidhiyan*", and two issues of the six-monthly magazine "Prasar Doot" were published by the Centre during the year. Besides, two books, namely, "*Rajasthan ke Jan Jatiya Kshetron Me Sabji Utpadan*" and "*Rajasthan ke Jan Jatiya Kshetron Me Falotpadan Evam Narsaree Prabandhan*" were also published for tribal areas of Rajasthan. More than 20 pamphlets on cereals, pulses, vegetables and fruit crops were printed and distributed free of cost to the visiting farmers. A large number of farmers got farm advisory services through letters during the period. Around 19 training courses (on-campus 7 and off-campus 12) were organized for different clients including farmers, extension officers and development department officers of state departments. The ATIC also participated in 8 exhibitions and 5 farmers' days where IARI products, services and technologies were displayed and sold. Visitors took a lot of interest in IARI products and technologies.

On the basis of the qualitative advisory services providing by the ATIC, many farmers and NGOs developed their own agro- based enterprises and enhanced their income. Some of these champion farmers were honoured by the national institutes like IARI, and IVRI, and other agricultural universities. Besides, the ATIC is providing a mechanism for getting direct feed-back from the technology users to the technology generators. The feed - back strengthened the ATIC activities and provided a ground for need based technologies.

6.3.11 Krishi Vigyan Kendra (KVK), Shikohpur, Gurgaon

The Institute's Krishi Vigyan Kendra at Shikohpur, Gurgaon is playing a catalytic role in combating the

Dr. Anjani Kumar, Programme Coordinator, KVK, Shikohpur, Gurgaon (right) receiving the Best KVK National Award from Shri Sharad Pawar, Hon'ble Union Minister of Agriculture

unemployment of rural youth through technological empowerment, and improving the farmers' awareness and farm productivity through various TOT programmes.

6.3.11.1 Front line demonstration (FLD) programme

FLDs on oilseeds, pulses and cereal crops are playing a key role in transferring and disseminating location specific crop technologies in the demonstration area. During the year 2007-08, 74 demonstrations (*kharif* and *rabi*) covering 33 ha on oilseeds, pulses and cereal crops were organized in farmers' fields in 8 villages of 4 blocks of Gurgaon district.

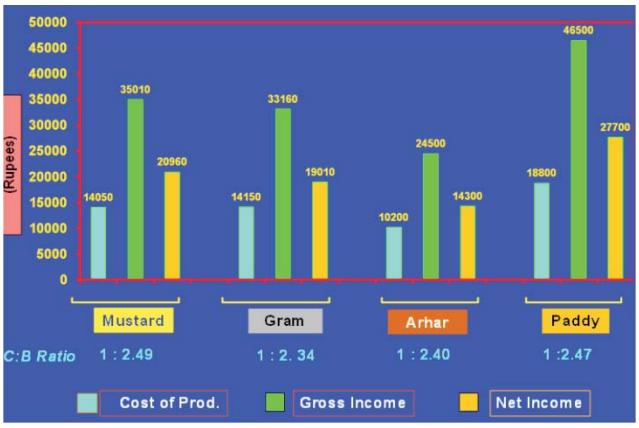
Frontline demonstrations

Season	Crop	Varieties	No. of demonst-rations	Area (ha)
***Rabi*: 2007-08**	Mustard	Pusa Jagannath	29	15.00
	Gram	Pusa 1103	03	1.00
	Lentil	L 4076	05	1.00
		Total	**37**	**17.00**
***Kharif*:2008**	*Arhar*	Pusa 2001	07	4.00
	Moong	Pusa Vishal	07	2.00
	Bajra	9944 (Proagro)	10	4.00
	Paddy	Pusa 1121 and PB 1	07	4.00
	Onion	AFD Red	04	1.60
	Okra (*Bhindi*)	A 4	02	0.40
		Total	**37**	**16.00**

A bumper crop of mustard variety Pusa Jagannath in a farmer's field under FLD on oilseeds

The average yields of mustard, gram, lentil, *arhar*, *moong*, *bajra* and paddy obtained were 1889 kg, 1939 kg, 1216 kg, 1820 kg, 1050 kg, 3114 kg and 4921 kg/ hectare, respectively. Comparative results revealed that the average yield of mustard, gram, *arhar*, *moong*, *bajra* and paddy increased by 7.94%, 19.69%, 19.10%, 20.10%, 17.50% and 6.55%, respectively, over farmers' existing practices. The average yields of FLDs on vegetable crops, viz., onion and okra (*bhindi*) were 12000 kg and 9500 kg /hectare, respectively, which were higher by 15.40% and 25%, respectively, over that of the farmers' practices.

The data showed that most of the FLD crops were economically viable and gave comparatively more net profit per unit area. The average cost of cultivation, gross income, net return and cost: benefit ratio of important crops under FLD programme are given in the following figure.



Economics of important FLD crops

Dr. H.P. Singh, Deputy-Director General (Horticulture), ICAR (third from left) visiting the wheat trials at KVK farm, Shikohpur along with scientists and farmers

During *rabi* 2007-2008, the KVK organized 21 demonstrations on wheat (covering 10 ha) sponsored by the Directorate of Wheat Research (DWR), Karnal. Comparative results of these FLDs are given below:

Frontline demonstrations sponsored by DWR

Season/ year	Theme of FLDs	Name of varieties	No. of demons-trations	Area (ha)	Av. yield (kg/ha)	Increase over control (in kg)	Increase over control (%)
Rabi	**New varieties**						
2007-08	(i) Variety under test	PBW 502	17	8.00	5153	320	6.62
	(ii) Varieties under control (Farmers' practice)	PBW 343	17	8.00	4833	—	
	Use of biofertilizers*						
	(i) Technology under test	PBW 502	04	2.00	5180	114	2.18
	(ii) Control (Farmers' practice)	PBW 343	04	2.00	4852	—	

***Bio-fertilizers used – Azotobactor & PSB**

6.3.11.2 Trainings for different target groups - Achievements

The major objectives of on-campus and off-campus trainings are to generate opportunities for income and employment, to provide technical know–how to the practising farmers and farmwomen and to update the knowledge of in-service personnel.

Vocational trainings for rural youth and girls. During the period under report, 11 vocational training courses on various subjects, viz., beekeeping (1), dairy farming (2), dress designing & tailoring (2), nursery management (1), motor winding (1), protective cultivation of vegetable crops (1), vermi compost technology (2), and preservation of seasonal fruits and vegetables (1) were organized . Through these trainings 251 youth (117 male and 134 female) were benefited.

Trainings organized for different target groups during 2008

Sl. No.	Type of training with target groups	No. of training	No. of beneficiaries		
			Male	Female	Total
1.	Vocational trainings for rural youth and girls	11	117	134	251
2.	Day-long on-off-campus trainings for practising farmmen and farm women	82	1318	276	1594
3.	In-service (refresher course) trainings for field extension functionaries	03	45	—	45
	Total	**96**	**1480**	**410**	**1890**

Day-long on and off-campus trainings for practising farmers and farmwomen. During the period, 82 day-long training programmes for the practising farmmen 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, 1594 farmers (1318 male and 276 female) were benefited.

Discipline-wise on- and off- campus trainings organized during the year 2008

Training areas	No. of trainings	No. of beneficiaries		
		Male	Female	Total
Crop production	20	271	—	271
Plant protection	22	402	23	425
Dairy farming	16	383	149	532
Horticulture	20	203	76	279
Agril. engineering	02	34	—	34
Beekeeping	01	25	—	25
Vermicompost	01	—	28	28
Total	82	1318	276	1594

In-service (refresher course) trainings. During the year 2008, three (3) in-service trainings (Refresher course) – one each on integrated pest management (IPM), integrated plant

nutrient management (IPNM), and live stock production and management were organized for 47 Agriculture Development Officers (ADOs) and field worker of Haryana agriculture department, Gurgaon.

6.3.11.3 On-farm testing

On-farm testing is mainly intended to test developed technologies which might be helpful to solve the most important and wide spread problems of a group of farmers in a defined area with their farming system perspective, active participation and management. The major objective of the programme is to provide tailor-made recommendations to the farmers by testing location specific technologies to solve their field problems.

Major OFTs, number of trials, treatments and comparative yield performance during *rabi* 2007-08 and *kharif*: 2007

Sl. No.	Field problem/ title of OFT	Technology tested			Control (Farmer's practice)			Increase in yield over the farmers' practice (%)
		No. of trials	Treatments	Av. yield (kg /ha)	No. of trials	Treatments	Av. yield (kg /ha)	
***Rabi* 2007-08**								
1.	Evaluation of new herbicide molecule for weed control in wheat	04	Metsulfuran@ 20 g /ha	5072	04	Hand weeding /non use of any chemical	3350	51.40%
2.	Management of nematode in wheat crops	04	Soil treatment with carbofuran (3G) @ 33 kg /ha & neem cake @ 500 kg /ha	5135	04	non use of any chemical	4956	3.61%
3.	Management of pod borer in gram	04	i) Pheromone trap ii) Use of NPV@ 1ml/l of water iii) Neem seed extract@ 5 ml/lt. of water iv) Use of wooden T sticks for the predatory birds	2151	04	One spray of endosulphan @ 2 ml/l of water One spray of Dichlorovas @ 1ml/l of water	1944	10.64%
***Kharif*: 2008**								
4.	Management of pod borer in *arhar*	04	i)Use of Pheromone trap ii) One spray of endosulphan and one spray of quinolphos@ 2 ml/l of water	1718	04	One spray of endosulphan @ 2 ml/l of water	1562	9.98%

Animal problem based OFT-1

Objectives	Treatment/ dewo-rming drugs	No. of calf under treatment	Mortality	Per cent mortality
To test the efficiency of different deworming drugs on calf mortality	Albendazole	10	01	10
	Morental citrate	10	0	0
	Piperazine	10	03	30
	Control group	10	03	30

Animal problem based OFT-2

Objectives	Treatment	No. of animals under treatment	No. of animals coming to heat	Per cent success
To test the deficiency of mineral mixture + natural reproductive hormones (Aurvedic) and mineral mixture + vitaminAD3 E on reproductive performance of buffalo	Mineral mixture	05	02	40
	Mineral mixture + genoro	05	03	60
	Mineral mixture + vitamin AD3E	05	04	80
	Control group	05	02	40

During the period under report, 22 on-farm trials were conducted on different field/farm based problems besides 2 trials on animal problems.

6.3.11.4 Agricultural extension activities and farm advisory services

For speedy dissemination of technologies among the farming community, the KVK organized various extension activities in different villages and at KVK campus. During the period under report, 514 activities were organized. These related to *kisan mela*, field days on different crops, women in agriculture day, animal health day cum clinical camp, honey day, method demonstrations, group meetings/discussions, camps /campaigns, lectures delivered by the subject matter specialist (SMS) of KVK in the meetings/trainings organized by the line departments, programmes on TV/radio, press releases on KVK activities, field visits of scientists/SMS in the farmers' fields. The KVK organized 560 visits of farmers to the KVK campus for farm advice. Farm advisory services were provided to 783 farmmen and farmwomen on telephone. Nineteen popular articles were prepared for different magazines, besides 33 extension service literatures. The KVK also organized 7 exhibitions, 3 diagnostic surveys and 1 seminar. One hundred twenty six farm animals and 72 dogs were vaccinated and treated during animal health camps.

Krishi Vigyan Patrika, a quarterly newsletter of KVK in Hindi continued to provide information on the latest technologies related to field crops, fruits, vegetables, home and dairy management to the farmers at proper time at their doorsteps. During the period, 5175 (4482 male and 693 female) members of different farming communities were benefited through these programmes. Among the beneficiaries 71% belonged to OBC, 12% to SC and 17% to other categories.

7. EMPOWERMENT OF WOMEN AND MAINSTREAMING OF GENDER ISSUES

7.1 EMPOWERMENT OF WOMEN IN AGRICULTURE

Rural women are playing a significant role not only in homestead activities but also in agricultural development and allied fields. Women have proven that they can be good entrepreneurs and development managers in any kind of activities. The KVK, Shikohpur is playing a vital role in empowering rural women of Gurgaon district by organizing various need-based self employment and income generating activities, and other extension programmes for creating awareness about scientific farming and technologies.

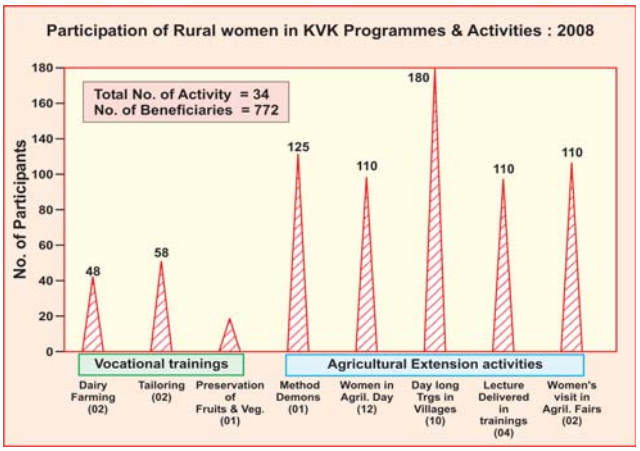
The important programmes and activities organized for rural women during 2008 are as follows:

- Capacity building (vocational) training courses for self employment and income generation
- Trainings in villages for updating farm knowledge /skills
- Lectures in trainings organized by line department/NGOs
- Method demonstrations for skill development and visit of rural women to agriculture fairs and exhibitions
- Celebration of women on agriculture day

Dr. H.P. Singh, Deputy Director-General (Horticulture), ICAR (Second from right) giving the best entrepreneur award to a farmwoman at KVK, Shikohpur, Gurgaon

7.1.1 Activity-wise Participation of Rural Women

A total of 34 activities were organized for rural women during the year 2008, through which 772 rural women were benefited. Out of 772 participants, 118 (15.28%) belonged to SC, 512 (66.32%) to OBC and 142 (18.40%) to other castes.



Participation of rural women in KVK programmes and activities: 2008

7.1.2 Impact of Capacity Building and Agricultural Extension Activities

- After getting vocational trainings, the rural women were able to save/earn Rs. 3000-3500/- per annum by stitching the garments of their family members and other needy neighbours.
- Some rural women started their own training centres and provided training to needy girls/women on tailoring in their own villages.
- Through active participation in village trainings and in extension activities, the farmwomen were getting comparatively more profit by applying improved farm technologies.

- Some SHGs of rural women, trained in preservation of fruits and vegetables were doing value addition activities as well as marketing of different types of pickles, *murabba,* sqashes, etc.
- The most distinct impact of women empowerment activities in the area was the creation of a sense of security and self reliance among rural women.

7.2 GENDER EMPOWERMENT AND FARMING SYSTEM DEVELOPMENT: AN ACTION RESEARCH

7.2.1 Farming System Development

Introduction of improved crop varieties/hybrids and practices for higher productivity. With group meetings, trainings and demonstrations held in the project villages, namely, Mumtajpur, Banspadamka, Safedarnagar and Lokra of Pataudi block and Sampka and Johari of Farookhnagar block of Gurgaon district of Haryana during *kharif* and *rabi* seasons, the farmers were educated about improved varieties/hybrids of different crops as well as improved practices for higher productivity with adequate integration of resource conserving technologies like mulching, system of rice intensification (SRI) for rice cultivation, use of bioferlizers and plant based formulations for pest management, etc. Demonstrations with a unit area of one acre were conducted for improved varieties/hybrids of paddy, viz., Pusa 1121 (32 units) and PRH 10 (20 units), PB 1 (10 units) and Pusa 44 (4 units); pigeonpea, viz., Pusa 992 (40 units); and fodder sorghum, viz., Pusa Chari (PC 9) (15 units). In contrast to the previous year (2007) when owing to low market return, the farmers had shown unwillingness to adopt Pusa 1121, during the year 2008, the farmer showed greater acceptance of the variety Pusa 1121 owing to its higher yield (1.6-2.0 t/acre) and better market return (Rs 22000-31000 per tonne). The farmers also appreciated PRH 10 as they got higher yield (2.4-2.8 t/acre) from it as against the traditionally cultivated variety PB 1. They also appreciated PRH 10 because they could go in for cultivation of vegetable crops as the rice crop was harvested early. However, the comparatively lower market return (Rs 1100 - 1165) was reported as a constraint in its increased adoption.

During *rabi* season, demonstrations were held for wheat (HD 2851 in 10 units), mustard (Pusa Jagannath in 12 units), gram (BG1108 in 5 units) and pea (Azad pea 1 in 14 units). Learning from the demonstrations on SRI system of paddy cultivation, two farmers adopted it and obtained an average yield of 1.85 t/acre with Pusa 1121 variety besides obtaining benefits of savings in seed and irrigation cost.

Crop diversification. In order to promote crop diversification, six demonstrations on fruits orchard establishment (guava and kinnow) were taken up. The farmers were trained in orchard plantation and management.

Nursery raising. Eight units (60-100 m^2 area) of net house were raised in farmers' field for demonstration.

Capacity building for seed production. As a result of the interventions in capacity building for seed production and with the success achieved by Mr. Bhura Singh last year, a group of farmers in Mumtajpur and Banspadamka villages took up the initiatives in seed production. Trainings were organized on seed production of PRH 10 paddy and cucurbits (bottle gourd). Three farmers took up seed production of PRH 10 and secured about 0.4 t of seed and 0.4 t of produce from male plants. Group meetings were held to promote farmer-to-farmer seed exchange programme. However, with the success of Pusa 1121, the farmers wanted to take up its seed production. As a result, the farmers gained knowledge and skills in various areas of seed production such as reasons and methods of maintaining isolation distance, managing synchronization of flowering and facilitating pollination either through mechanical measure (rope pulling) or chemical measure (application of GA_3), harvesting with great caution to avoid mixing of seeds, and maintenance of purity and viability of seeds.

Capacity building for application of biofertilizers and IPM. Training programmes were held in Banspadamka village on vermicomposting and use of biofertilizers and integrated pest management practices. Demonstrations were conducted to educate the farmers about the use of NPV and pheromone traps for effective management of pod borer in gram. Farmers learnt about the integrated package of cultural, biological and chemical practices of pest management.

7.2.2 Gender Empowerment

Mobilization of women self help groups (SHGs). Women were educated about effective functioning and development of their SHGs. With group meetings, they were educated about conflict resolution among group members and transparency in record keeping, loan disbursement and recovery. A majority of women felt secured by becoming members of SHGs.

They were sensitized to take up entrepreneurial activities in groups for additional income generation in the family. They were motivated, and technical guidance was provided to take up activities of processing and value addition like preparation of *dal, badi,* pickle, lemon juice, squash, *papad,* etc., besides work of making carpet, show pieces, dress items, and foot mats with waste materials. The women trained in stitching and tailoring (as a source of non-farm employment) reported saving the expense on stiching of household clothes in the range of Rs 1200/-1800 per annum. Women groups which were assisted in taking up goatary reported that an income of Rs 1200-1500/- per annum could be secured by the sale of progenies and milk.

8. POST-GRADUATE EDUCATION AND INFORMATION SYSTEM

8.1 POST-GRADUATE EDUCATION

8.1.1 Admission during the Academic Session 2008-2009

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 at a national level entrance examination conducted in different parts of the country as well as 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 department of agricultural research and education (DARE), Ministry of Agriculture, Govt. of India. Foreign students are exempted from appearing in the written test and interview.

During the academic year 2008-2009, a total of 234 students were selected for admission to various M.Sc. and Ph.D. courses.

Category	M.Sc	Ph.D.	Total
Open competition	96	120	216
Foreign students*	8	10	18
Total	104	130	234

***Foreign students admitted were from Bangladesh, Nepal, Ethiopia, Iran, Iraq and Libya.**

The total number of students on roll were 581 (183 M.Sc. and 398 Ph.D.) which include 30 students from foreign countries, namely, Egypt, Ethiopia, Iran, Libya, Sri Lanka and Vietnam.

8.1.2 Golden Jubilee Year Convocation 2008

The Golden Jubilee Year Convocation 2008 of the Post Graduate School of IARI was held on February 8, 2008. Dr. S. Banerjee, Director, Bhabha Atomic Research Centre, Mumbai, who was the chief guest, delivered the convocation address. In his address, the chief guest emphasized that education could transform our youth into a huge 'human capital' and make India one of the most powerful nations of the world.

Dr. S.A. Patil, Director, IARI, in his report presented the significant research achievements of the Institute during the year 2007. 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. The chief guest released eight IARI publications, namely, Volume 2 of Agricultural Transformation in India (a compilation of Lal Bahadur Shastri Memorial Lectures delivered during 1995-2008), Pusa Agri Science 2007, Empowering Rural Youth, and Disha – a PGSSU magazine besides four laboratory manuals. Four IARI crop varieties, namely, HD 2932 (Pusa

A Ph.D. student receiving her degree certificate from Dr. S. Banerjee, Director, Bhabha Atomic Research Centre, Mumbai at the convocation. Also seen in the picture are: Dr. Mangala Rai, Secretary, DARE and Director-General, ICAR (right) and Dr. S.A. Patil, Director, IARI (left)

Wheat 111), Improved Pusa Basmati 1, Pusa Mustard 21 (LES 1-27), and Cotton PSS 2 (Arvinda) were also released.

At this convocation, 75 M.Sc. and 84 Ph.D. students were awarded degrees. Ms. Reeta Bhatia (Horticulture) and Ms. Nisha M. (Genetics) were awarded the Best Student of the Year 2007 Award for Ph.D. and M.Sc., respectively. Five recipients of Ph.D. degrees, namely, Mr. N. Nanda Kumar (Genetics), Ms. Sangita Yadav (Biochemistry), Ms. Kapila Sekhawat (Agronomy), Mr. Abbas Salahi Ardakani (Nematology) and Mr. Susanta Banik (Plant Pathology); and 5 recipients of M.Sc. degrees, namely, Ms. Prabha K. (Plant Pathology), Ms. Dhanya M.S. (Environmental Sciences), Mr. Koushik Chakraborty (Plant Physiology), Ms. Ramya P. (Plant Genetic Resources) and Mr. Shivendra Kumar Srivastava (Agricultural Economics) were awarded the 'IARI Merit Medals' for their outstanding academic performance.

Three distinguished scientists in the area of Agricultural Sciences, namely, Dr. M.V. Rao, former Special Director-General, ICAR; Dr. R.S. Paroda, former Secretary, DARE and Director-General, ICAR; and Dr. Mangala Rai, Secretary, DARE and Director-General, ICAR were awarded the Doctor of Science (*Honoris Causa)* degree.

Five faculty members, namely, Dr. (Mrs.) Chitra Srivastava (Entomology), Dr.Madhuban Gopal (Agricultural Chemicals), Dr. Subhash Chander (Entomology), Dr. Sunil Pabbi (Microbiology) and Dr. (Mrs.) Shally Parveen (Biochemistry) were awarded 'Best Teacher Awards' for their outstanding contribution to teaching.

The 15th Sukumar Basu Memorial Award for the biennium 2005-06 consisting of a cash prize of Rs.10,000/- and a commendation certificate was awarded to Dr. (Mrs.) P.R. Sinha, Principal Scientist, Division of Animal Biochemistry, National Dairy Research Institute, Karnal for her outstanding research contributions on 'Development and Study of Properties of Probiotic Dahi'.

The 12th Dr. B.P. Pal Memorial Award for the year 2007 consisting of a cash prize of Rs.10,000/-, a gold medal and a commendation certificate was awarded to Dr. A.K. Singh, Senior Scientist, Division of Genetics, IARI for his outstanding research contribution to 'Development of Basmati Rice through marker aided selection.

The 8th Hari Krishna Shastri Memorial Award for the year 2007 consisting of a cash prize of Rs.25,000/- and a commendation certificate was awarded to Dr. Mathura Rai, Director, Institute of Vegetable Research, Varanasi, (U.P.) for his outstanding research contribution to plant breeding with special reference to vegetable breeding.

The 38th Lal Bahadur Shastri Memorial Lecture was delivered on February 7, 2008 by Dr. S. Nagarajan, Chairperson, Protection of Plant Varieties and Farmers' Rights Authority, Govt. of India on the topic 'Intellectual Property Rights as an Option to Promote Excellence in Agriculture'. The function was presided over by Dr. V.L. Chopra, Member, Planning Commission, Govt.of India.

Dr. A.V. Moharir, former Professor and Head, Division of Agricultural Physics, IARI gave an impressive presentation on February 7, 2008 on the life and achievements of Dr. A.B. Joshi, the first Dean of the Post Graduate School, IARI. Dr. Joshi's contribution to the post graduate education at IARI was highly appreciated.

8.1.3 Training Programmes

Several training programmes were organized by the Institute during the year 2008.

Training programmes organized during 2008

Training programme	Period
Division of Agricultural Economics	
• Advances in food and agricultural marketing	October 3 – 23, 2008
Division of Agricultural Engineering	
• Motor winding	October 29, 2008

Contd.....

Training programme	Period
Division of Agricultural Extension	
• Gender issues and empowerment in agriculture	August 28 – September 17, 2008
• Monitoring and evaluation technology for extension programme including e-monitoring tools and mechanism	October 14 – 21, 2008
Division of Agricultural Physics	
• Remote sensing, geographical information system and global positioning system	August 25 – November 20, 2008
Division of Agronomy	
• Rhizosphere strategies for augmenting soil fertility and productivity	November 3 – 24, 2008
Division of Biochemistry	
• Basic techniques in plant molecular biology	February 19 – March 10, 2008
• Recombinant DNA techniques	August 16 – September 5, 2008
• Biochemical and molecular biology advanced techniques	November 18 – December 8, 2008
Division of Environmental Sciences	
• Climate change, crop yield and sustainability	February 15 – March 3, 2008
Division of Floriculture & Landscaping	
• Commercial cultivation of flowers	March 14 – 20, 2008
• Advances in floriculture research and development	April 19 – 25, 2008
• Advances in research and development in floriculture crops – gladiolus, marigold, tuberose, gerbera and rose	July 15 – 21, 2008
• Recent production technology and development for floriculture crops – gladiolus, marigold, tuberose, gerbera and rose	October 18 – 24, 2008
• Improved production technology for gladiolus, marigold, tuberose, gerbera and rose	November 4 – 10, 2009
Division of Microbiology	
• Blue green algae and *azolla* biofertilizers	February 23 – 29, 2008
• Production and use of BGA and *azolla* biofertilizers	July 5 – 7, 2008
Division of Nematology	
• Basic techniques for isolation and identification of plant parasitic nematodes, and their management	June 30 – July 11, 2008
Division of Plant Pathology	
• Mushroom cultivation technology	September 15 – 20, 2008
Division of Post Harvest Technology	
• Integrated post-harvest management of horticultural produce	April 21 – 26, 2008
• Quality assurance and application of food safety systems in the supply chain and agri-business development	September 30 – October 20, 2008
• Synergistic impact of pre- and post-harvest practices on quality and shelf life of horticultural produce	November 25 – December 4, 2008
Division of Seed Science & Technology	
• Winter school on PPV and FR Act and 2008 its implementation	December 18,2007 – January 7,
• Varietal development and evaluation	February 18 – March 25, 2008
• Farmers' training on hybrid vegetable seed production	February 22 – 23, 2008
• DUS testing for plant variety protection: principles and procedures under DAC (PVP Legislation)	February 26 – March 3, 2008

Contd.....

Training programme	Period
• Farmers' training on vegetable seed production	March 5 – 6, 2008
• Testing of plant varieties for DUS testing-principles and procedures	March 5 – 9, 2008
• Plant variety protection and related issues	August 11 – October 18, 2008
• Seed technology	October 21 – November 4, 2008
Division of Soil Science & Agricultural Chemistry	
• Advanced level training in soil testing, plant analysis and water quality assessment	September 9 – 29, 2008
Water Technology Centre	
• Scaling of water productivity for livelihood	June 10 – 23, 2008 July 7 – 13, 2008 July 15 – 28, 2008 November 11 – 24, 2008
Centre for Agricultural Technology Assessment and Transfer	
• *Basmati*/paddy cultivation techniques and allied subject of agriculture	September 20 – 29, 2008
Centre for Protected Cultivation Technology	
• Integrated nutrient management in horticultural crops	September 27, 2008

8.1.4 Accreditation of IARI

Upon the recommendations of the ICAR Peer Review Team and Education Division, the Accreditation Board has granted accreditation to IARI up to August 5, 2013.

8.1.5 Post-Graduate School Golden Jubilee Lecture

On August 22, 1958, the Indian Agricultural Research Institute at New Delhi was declared a deemed-to-be-university under the UGC act of 1956 and was authorised to award post-graduate degrees of Master of Science and Doctor of Philosophy in agricultural sciences and its related basic disciplines. On the successful completion of 50 years of its establishment, the IARI Post Graduate School celebrated its Golden Jubilee on August 22, 2008. On this occasion, Dr. M.S. Swaminathan, Member of Parliament (Rajya Sabha) and Chairman, M.S. Swaminathan Research Foundation, Chennai delivered the Golden Jubilee Lecture on 'Higher Education in Agricultural Sciences in India: 50 Years and Beyond'. Dr. Mangala Rai, Secretary, DARE & Director-General, ICAR presided over the function. Dr. S.A. Patil, Director, IARI introduced the chairman and speaker and highlighted the significant contributions of IARI during the last 50 years. Dr. H.S. Gaur, Dean and Joint Director (Education), IARI warmly welcomed the chairman, speaker and other dignitaries and highlighted the contributions of PG School in the service of the nation during the last 50 years.

8.1.6 Post-Graduate Faculty

During the year, 17 new scientists were inducted in the PG faculty and 35 faculty members were inducted as research guides. The out-sourced faculty was also invited to take part in the teaching programmes of their respective divisions, where sufficient faculty is not available for teaching the courses.

8.1.7 Students' Extra Curricular Activities

IARI students participated in the '9th All India Inter Agri-Universities Youth Festival' held at Maharana Pratap University of Agriculture and Technology, Udaipur and won many prizes; A large number of students participated in the 'IARI Annual Sports Meet 2007' and won prizes in various events. The PGSSU arranged free yoga classes both for boys and girls. Several IARI students attended a lecture on 'Rural America' organized by SPAN Magazine at the American Center on December 19, 2007. PGSSU successfully organized a blood donation camp. The students also actively participated in several international and national scientific meetings and a 'Cultural Evening' organized by ICAR Cultural Committee at IARI Auditorium.

8.2 INFORMATION AND DATABASE

8.2.1 Bioinformatics

8.2.1.1 *In-silico* tRNA prediction and comparative analysis of *Populus trichocarpa*

Transfer ribonucleic acids (tRNA) are small molecules of length ~73-90 nucleotides. These play a key role in translation of genetic information from mRNA into proteins. In genome tRNA database (GtRDB), the number of tRNA genes that have been predicted are 639 in *Arabidopsis*, 764 in *Oryza* and till date 858 in *Populus trichocarpa*. In this study, the unit of Simulation and Informatics (USI) has predicted the tRNAs of *Populus trichocarpa* and then compared it with the tRNA sequences of *Arabidopsis thaliana* and *Oryza sativa*. A total number of 765 tRNAs of *Populus trichocarpa* were predicted by computational approaches. The present study showed that 68 tRNAs in *Populus trichocarpa* were absent in both *Arabidopsis* and rice, and the tRNAs which were present in *Populus* but absent in *Arabidopsis* were 16 and in *Oryza* they were 11. It was also observed that 21st amino acid named Selenocysteine (Sec) was present in *Populus* but absent in both the annual plants, i.e. *Arabidopsis thaliana* and rice. The suppressor tRNA was found in *Populus* but absent in *Arabidopsis* and rice. The results suggest that there are some tRNAs which are present only in *Populus* and they may have a specific role for the development of plants. The presence of Sec tRNA suggests that there is some role of this tRNA in plants also. It was reported earlier that Sec tRNA was present only in animals and algae but our study showed that Sec tRNA was also present in *Populus trichocarpa.*

8.2.1.2 Structure and function prediction of six hypothetical nuclear proteins of *Oryza sativa* by *in-silico* approach

Determination of protein structure and function is one of the challenging problems in the post genomic era. Moreover, if the protein is hypothetical in nature, it becomes too difficult to predict its structure and function. In short, hypothetical proteins are theoretically predicted unknown proteins and there is no experimental evidence that it is expressed *in vivo*. In contrast to the other proteins whose templates are available in public domain (PDB), the structural and functional annotation of hypothetical protein becomes a tedious job due to the low similarity with other known proteins. The scientists of USI downloaded all the 35 hypothetical proteins present in the nuclear membrane of rice (*Oryza sativa*) from the NCBI site. In the present study, the USI predicted the 3D structure of six hypothetical nuclear proteins of *Oryza sativa*. Blast2 Sequence of all these proteins was done with our previously annotated protein BAC-78599, which was also hypothetical in nature. The offline blast done to validate our Blast2 sequence results also found the same results. The Blast2 as well as offline Blast results showed that our protein (BAC-78599) has 100% similarity with two proteins, viz., EAZ-33603 and NP-001055 and 48.55% similarity with three other proteins viz., EAZ-11359, NP-001042 and BAD-81138. These three proteins which have less proximity with BAC-78599 (48.55% only) have cent per cent similarity among each other. For the structure prediction of these sequences, the softwares, Modellar (linux env.), I-TASSER, etc., were used. Through various approaches, it was found that all these proteins which have different accession numbers and submitted by different group of researchers have similar protein structure.

8.2.1.3 *In-silico* analysis of Hevein-like protein (*Arabidopsis*)

Carbohydrate-binding proteins are known to be important in a variety of biological processes, mediated through their carbohydrate specificities. Some of the well-characterized roles of carbohydrate-binding proteins are in cell–cell communication, host–pathogen interactions, cancer metastasis, and embryogenesis and tissue development. Detailed knowledge of the molecular mechanisms of carbohydrate recognition by these proteins is therefore required not only to understand the prime events in various biological processes but also to translate them into applications in medicine and biotechnology. *Arabidopsis thaliana* contains a small chitin-binding protein that strongly resembles hevein from the rubber tree and the hevein domains of the win proteins and tobacco CBP20 with respect to its primary structure and physicochemical properties. It is known to act as an antimicrobial compound and its transcript level increases on pest attack. Therefore it has been categorized as a defense-related protein. An analysis

of the deduced amino acid sequence of the hevein-like protein revealed the presence of an N-terminal domain with striking sequence similarity to previously reported chitin-binding domains whereas the C-terminal domain showed extensive similarity to the catalytic domain of chitinases. The Institute scientists carried out a systematic database analysis extending to several hevein-like molecules to derive common minimum principles characterizing the features generating carbohydrate recognition capability as well as the determinants of specificity. The vast numbers of sequences, a significant amount of biochemical data, as well as a few crystal structures reported enable a simultaneous analysis of all known members of the family to develop a broader perspective of the functionalities as well as potential uses of these proteins.

8.2.2 Agri-Informatics

8.2.2.1 Consortium for e-Resources in Agriculture (CeRA)

Agricultural research, the backbone of agricultural growth in the country, demands timely dissemination of knowledge being generated and updated across the globe from time to time. The ICAR has network connectivity across the institutes and state agricultural universities. It is the need of the time to disseminate knowledge through research papers which can be made available over the network for the use of scientific community. Keeping this broad objective in mind, the National Agricultural Innovation Project (NAIP) has funded the establishment of the Consortium for e-Resources in Agriculture (CeRA) at the Indian Agricultural Research Institute. Firstly, it aims to develop the existing R & D information resource base of ICAR institutes/ universities, etc., comparable to that existing in world's leading institutions/ organizations. Secondly, it aim to create an e-access culture among scientists/teachers in ICAR institutes/agricultural universities. Thirdly, it aims to develop a Science Citation Index (SCI) Facility at IARI for evaluation of scientific publications which will help to assess the impact of CeRA on the level of research publications measured through SCI. The expected outcomes of the project are: online accessibility of most of the important journals related to agriculture and biotechnology to researchers and students of the Consortium members, quick access to world R & D information, and permanent archive of the subscribed e-databases. The project has improved the quality of scientific publications, teaching and research guidance, by providing one print version of each title subscribed for ready reference at IARI free of cost.

8.2.2.2 AGROWEB digital dissemination system for Indian Agricultural Research (ADDSIAR)

Website is one of the communication and dissemination tools between the organization and the end user. A user friendly, well designed website is a great asset today for any research organization to disseminate and communicate the latest development. The great advantage of website is that it will be available 24 hours a day, 7 days a week and can be viewed from anywhere in the world. So anyone can collect suitable information from the website at any time. Keeping this in view, the NAIP has funded a network sub-project, Agroweb - digital dissemination system for Indian Agricultural Research (ADDSIAR) with the lead centre at NBPGR, New Delhi and IARI as one of the eight consortium partners. The ADDSIAR project is handled by the USI at IARI, New Delhi. In this subproject, attempts were made to tackle the website related issues like visual and domain name uniformity, content quality, web application for e-publication, technologies dissemination etc. The new web portal works under new generation technologies for content management and data exchange over different platforms. For identification of standards, development of uniform guidelines, and content management strategies for websites of ICAR institutes, a model website template was developed. One of the objectives is to disseminate the agricultural technologies developed at IARI to the end users. The project will lead to identification of suitable off the shelf content management, and better user interface with the organization through online activities.

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 8000 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 846 publications, which included 195 in Hindi and 651 in English, costing Rs. 33,76,911. The Library also acquired 97 gift publications, and 149 IARI theses.

8.3.1.2 Serials

The Library procured 806 journals/serials through subscription, gifts and exchanges. It subscribed to 263 foreign journals (out of which 45 had online access) and 252 Indian journals and 84 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 twelve (112) annual/scientific/technical reports of different institutions and 182 bulletins were received in the Library. The expenditure on Serial Acquisition Programme from Plan was Rs. 1,01,81,154 (Rs. One crore one lakh eighty one thousand one hundred fifty four only).

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, 838 articles were scanned, processed and sent to DIPA, ICAR for inclusion in AGRIS Index.

8.3.2.2 Development news in agriculture

Four thousand seven hundred and six (4706) news papers were scanned and 22 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, 1231 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, 2600 volumes consisting of 20,800 loose issues of journals, reports and bulletins were bound and 1677 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, 18,130 publications were issued to its members. In all, 35 documents were issued under Inter Library Loan System to various institutions including NISCAIR. Two hundred and eighty-two No Due Certificates were issued to staff, including scientists, after checking the relevant record. Stock verification of the holding of the Library was done on a random sampling basis and report submitted to audit party.

8.3.3.3 Reprography services

During the period, the total no. of reproductions of all the photocopy machines were 12,64,480. Out of these, 42,460 pages of photocopies were provided to the scientific and technical staff officially from the holding of the Library.

8.3.3.4 CD-ROM workstation

In all, 74,023 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 30,721, which generated revenues amounting to Rs. 52,441. The scientists of IARI accessed through the Intranet (Local Area Network).

8.3.3.5 Consortium for e-Resources in Agriculture

A sub-project under NAIP titled 'Consortium for e-Resources in Agriculture' was launched on April 30, 2008 at

IARI, New Delhi. The main objective of the project is to provide on-line access of journals from Springer Verlag SIRO, and annual reviews to researchers in 123 institutions (including 40 agricultural universities) under the National Agricultural Research System (NARS) for enhancing research capabilities and output. The duration of the project is five years.

In addition to the above on-line access, the Library is providing document delivery services to 123 institutions (including SAU's) under NARS. During the period, the Library provided 4091 photocopies against 998 requisitions from the holding of the Library.

8.3.4 Training Activities

The following training activities were arranged/ organized by the Training Cell of the IARI library during the period under report:

- CAS training on Management Development for Extension Professionals from the Division of Agricultural Extension, IARI on March 13, 2008.
- Seminar-cum-discussion adjacent to Network Centre (USI) Library about UTM Cybercom on April 19, 2008.
- Launch workshop on Consortium for e-Resources in Agriculture (CeRA), USI from April 30, 2008 to May 1, 2008.
- Demonstration of Agricultural Database Relating to Statistical Methods conducted by CMIE on May 23, 2008.
- Hindi Competition test on August 17, 2008.
- AIS course practical classes.
- Advances in Agricultural and Food Marketing for professionals from Division of Agricultural Economics, IARI on October 22, 2008.
- Training on Financial Management System under NAIP from November 6 to 7, 2008.
- Three hundred and nineteen Faculty Members used the Training Centre and accessed their required information through computers.

8.3.5 *Krishi Prabha* : Indian Agricultural Doctoral Dissertations Repository

The project was submitted by Chaudhary Charan Singh Haryana Agricultural University and was approved by NAIP in the year 2007. Under this project, theses submitted to all the agricultural universities/deemed universities will be digitized and made available to all the stakeholders through internet. Metadata and abstract will be made available over internet all over the world through IP address.

The IARI Library has a collection of 1157 theses for the period of 2000 to 2007. The creation of soft copies of the theses collection was started in the Library premises through private agencies on a contract basis. Half of the collection was digitized.

8.3.6 National Agricultural Library Activities under National Agricultural Knowledge Initiative (AKI) Programme

The Government of India and the US Department of Agriculture (USDA) agreed to work together for a new India-US Knowledge Initiative on Agriculture Education, Research Services and Commercial Linkages.

The IARI Library was identified as the lead and coordinating centre under this programme.

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 2007-2008 (ISSN: 0972-6136)
- IARI News (Quarterly) (ISSN: 0972-6144) - 4 issues
- IARI Current Events (Monthly) - 12 issues

Ad hoc Publications (English)

- Dryland Agronomy – A Practical Manual (ISBN 978-81-88708-24-6)
- Agricultural Transformation in India – Lal Bahadur Shastri Memorial Lectures (ISBN 978-81-88708-25-3)
- Tools and Techniques in Microbiology (ISBN 978-81-88708-26-0)
- Catalogue of Fungal Cultures 1936-2007 (ISBN 978-81-88708-27-7)
- Elementary Agronomy – A Practical Manual (ISBN 978-81-88708-28-4)
- Evaluation Capacity Building in Rural Resources Management – A Manual (ISBN 978-81-88708-29-1)
- Post-graduate Students' Research: Significant Achievements (1996-2007) (ISBN 978-81-88708-30-7)
- Innovating MultiHyper- Spectral Remote Sensing Techniques for Improved Natural Resource Characterization (ISBN 978-81-88708-31-3)
- Rhizophore: Strategies for Augmenting Soil Fertility and Productivity (ISBN 978-81-88708-32-1)
- Integrated Plant Nutrient Supply and Management System for Enhancing Soil Quality, Input Use Efficiency and Crop Productivity (ISBN 978-81-88708-33-8)
- Microbiotech – A Manual for Agricultural Microbiologists (ISBN 978-81-88708-34-5)
- Bacterial Blight of Pomegranate (TB-ICN:48/2008)
- Rice Hybrid Seed Production Technology: A Compendium of Lectures (ICN:49/2008)
- Training Module (Vocational, In-service & Day long) (TB-ICN:50/2008)
- Site Specific Nutrient Management for Breaking Yield Barrier in Gurgaon District of Haryana (TB-ICN:51/2008)
- Developing a System of Temperate and Tropical Aerobic Rice in Asia(TB-ICN:52/2008)
- Nursery Management in Paddy (TB-ICN:53/2008)
- Success Story: Seed Processing and Storage (1997-2007) (TB-ICN:54/2008)

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)

- *Dhaan Beej Utpadan ka Sasya Parbandh* (ICN : H-55/2008)
- *Sankar Dhaan Beejotpaadan Takniki* (ICN : H-56/2008)
- *Gehoon kee Labhdaayak Kheti - Kam Lagat Adhik Utpadan*(ICN : H-57/2008)
- *Kisanon kee Samridhi hetu Krishi avam Pashupaalan ki Unnat Takniki* (ICN : H- 58/2008)
- *Khadya Padarthon ke Mulya Sanvardhan Hetu Pariraksha*n *Takniki*(ICN : H-59/2008)
- *Vyavsayik Madhumakkhi Paalan*(ICN : H-60/2008)
- *Baagwani Phaslon mein Gunvatta Beej avam Paudh kee Utpadan Prodyogiki*(ICN : H-61/2008)
- *Sankar Tamatar Beej Utpadan Krishkon ke Liye Labhdaayak Vyavsaye* (ICN : H-62/2008)
- *Sabzi Phaslon mein Sankar Beej Utpadan* (ICN : H-63/2008)
- *Basmati Dhaan kee Unnat Taknik va Sambadhh Krishi Vishye* (ICN : H-64/2008)

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

- *Bacillus licheniformis* MTCC 7445 for control of soil borne pathogenic fungi
- Synthetic gene encoding Cry 2 Aal δ-endotoxin of *Bacillus thuringiensis*
- Pusa Chickpea Thresher
- Pusa 5 SD-a bio-formulation of *Trichoderma harzianum* (IARI P-4) for seed treatment
- Pusa Bio-Pellet – a bio-formulation of *Trichoderma harzianum* (IARI P-4) for soil application
- Methodology and composition of artificial diet for mass rearing of Lepidopteran pests (in particular *Halicoverpa armigera, Spodoptera litura* and *Earias vittella*)

Patents Granted/Renewed

- A multi/hyper-spectral data analyzing process for complete quantification, characterization and compression of natural resource specific information
- Process for the preparation of pesticidal oxime esters
- Process for the preparation of mono/di/polyol ester pesticides
- A process for the preparation of mosquito larvicidal formulations based on *Rabdosia melissoides* ingredients

MoUs Signed

- A Memorandum of Understanding (MoU) between IARI and Mechanical Engineering Research and Development Organization (MERADO), Ludhiana signed on undertaking joint design and development work on precision seeder for vegetable crops
- Fourteen MoUs signed on commercialization of superfine grain aromatic rice hybrid Pusa RH-10 between IARI and Advanta India India Ltd., Secunderabad; Zuari seeds Limited, Bangalore; Devgan Seeds and Crop Technology Pvt. Ltd., Hyderabad; J.K. Agri Genetics Ltd., Secunderabad and Nath Biogene (I) Ltd., Aurangabad; Nuziveedu Seeds Ltd., New Delhi; Bhawani Seeds & Bio Tech, Mathura; Namdhari Seeds Pvt. Ltd., Bangalore; Amareswara Agri – Tech Ltd., Hyderabad; Yashoda Hybrid Seeds Ltd., Wardha; Atash Seeds Pvt. Ltd., Bangalore and Krishidhan Seeds Ltd., Jalna; Rasi Seeds (P) Ltd., Attur; and Andhra Pradesh State Seeds and Development Corporation Ltd., Hyderabad.
- An R&D based MoU between IARI and Sipani Krishi Anusandhan Farm, Mandsaur (M.P.) signed for crop improvement in pigeonpea, soybean, maize and wheat varieties.
- An MoU between IARI and Multiplex Biotech Pvt. Ltd. Bangalore signed on entomopathogenic nematode (*Steinernema thermophilum*).
- An MoU between IARI and Bhawani Seeds and Biotech, Mathura signed on commercialization of wheat, mustard and rice varieties.
- An MoU between IARI and Amareshwara Agri-tech Ltd., Hyderabad signed on commercialization of mustard and rice varieties.

Technologies Assigned to NRDC for Commercialization

- License Agreement for the Process of Novel Superabsorbent Hydrogel and method of obtaining the same signed with two companies through NRDC, i.e., M/s Madhu Sudan and Company (P) Ltd., J-71, Ashok Chowk, Adarsh Nagar, Jaipur; and M/s Carborundum Universal Limited, Parry House, 6th Floor, 43, Moore Street, Chennai.
- Material Transfer Evaluation Agreement (MTEA) signed with M/s Nav Bharat Fertilizer Ltd., Hyderabad.

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, and Meteorology, 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 2008 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.	110
AP Cess Fund, National Fellow Scheme of ICAR	23
Outside India PPIC, USAID, IDRC, CIMMYT, UKIERI, UNEPRRC	7

12. BUDGET ESTIMATES

Rs. In lakh

Subhead	Budget estimates 2007-2008		Revised estimates 2007-2008		Budget estimates 2008-2009	
	Plan	Non-Plan	Plan	Non-Plan	Plan	Non-Plan
Estt. charges	0.00	5790.00	0.00	6350.00	0.00	6345.00
OTA	0.00	3.50	0.00	3.50	0.00	3.50
TA	3 0.00	16.00	3 0.00	28.00	39.00	20.00
Other charges	930.00	1160.50	1470.00	1734.50	1961.00	1200.50
Works	564.00	370.00	250.00	900.00	500.00	400.00
Other items	0.00	170.00	0.00	196.00	0.00	176.00
Total	**1524.00**	**7510.00**	**1750.00**	**9212.00**	**2500.00**	**8145.00**

13. STAFF POSITION

(As on 31.12.2008)

Category		No. of posts*	
		Sanctioned	Filled
A.	**SCIENTIFIC STAFF**		
1)	Research Management Personnel	7	5
2)	Principal Scientist	69	156 (32)
3)	Senior Scientist/Scientist (S.G.)	184	175(61)
4)	Scientist	355	47 (285)
B.	**TECHNICAL STAFF**		
1)	Category III	27	20
2)	Category II	343	298
3)	Category I	425	365
4)	Auxiliary	2	2
C.	**ADMINISTRATIVE STAFF**		
1)	Group A	20	16
2)	Group B	271	224
3)	Group C	249	210
D.	**SUPPORTING STAFF**		
1)	SS Grade IV	197	177
2)	SS Grade III	388	370
3)	SS Grade II	648	596
4)	SS Grade I	365	217

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 strength of the Directorate of Maize Research & NRC on Plant Biotechnology**

14. MISCELLANY

I. On-going Projects at IARI as on 31.12.2008

a)	School of Crop Improvement	39
b)	School of Resource Management	25
c)	School of Crop Protection	18
d)	School of Basic Sciences	14
e)	School of Social Sciences	13
f)	Mega & X Plan Projects	07
	Total	**116**

II. Scientific Meetings Organized

a)	Workshops	4
b)	Seminars	11
c)	Summer institutes	5
d)	Farmers' day (s)	42
e)	Others	14
	Total	**76**

III. Participation of Personnel in Scientific Meetings

India

a)	Seminars	154
b)	Scientific meetings	146
c)	Workshops	87
d)	Symposia	129
e)	Others	65
	Total	**581**

Abroad

a)	Seminars	2
b)	Scientific meetings	9
c)	Workshops	2
e)	Others	7
	Total	**20**

IV. Publications

a)	Research papers published in international journals	130
b)	Research papers published in national journals	351
c)	Symposia/conference papers	482
d)	Books	55
e)	Chapters in books	159
f)	Popular articles	282
	Total	**1459**

V. Honours and Awards

- Dr. A.K. Singh, Head, Division of Fruits and Horticultural Technology received the Shri Girdhari Lal Chadha Memorial Gold Medal of the Horticultural Society of India for the year 2008 for his significant contributions to horticulture and fruit sciences.
- Dr. Amrik Singh Sidhu, Head, Division of Vegetable Science was selected for the Shri L.C. Sikka Endowment Award of the National Academy of Agricultural Sciences for the year 2007-2008 for his outstanding contributions towards food and nutritional security.
- Dr. Anand Swarup, Head, Division of Soil Science and Agricultural Chemistry, received the FAI Golden Jubilee Award for Excellence in the field of development of fertilizer and best management practices.
- Dr. D.V.K. Samuel, Head, Division of Post Harvest Technology received the Commendation Medal of the Indian Society of Agricultural Engineers for 2006-07 for his distinguished services in the field of post harvest processing/food engineering.
- Dr. G.T. Gujar, Head, Division of Entomology received the Prof. K.P. Kushwaha Memorial Medal of MPUAT, Udaipur for his research contributions.

- Dr. H.G. Kamble, Head, FOSU was elected Honorary Secretary of the Institution of Engineers (I), Delhi State Centre for the period, 2008-2010.
- Dr. Prem Dureja, Head, Division of Agricultural Chemicals received Bharat Ratna Dr. C. Subramaniam Award for Outstanding Teachers.
- Dr. R.K. Jain, Head, Division of Plant Pathology was declared President Elect (2008) of the Indian Phytopathological Society, New Delhi.
- Dr. P.K. Chhonkar, former Head, Division of Soil Science and Agricultural Chemistry, IARI and ICAR Emeritus Scientist received the Prof. S.K. Mukherjee Commemoration Award of the Indian Science Congress Association.
- Dr. V.K. Chopra, Professor, Division of Agricultural Physics was elected Vice-Chairman of the Indian Society of Remote Sensing (Delhi Chapter).
- Dr. B.M. Prasanna, National Fellow, Division of Genetics was selected as a Fellow of the National Academy of Agricultural Sciences.
- Dr. K.S. Rana, Principal Scientist, Division of Agronomy received the Best Pearl Millet Agronomist Award from AICPMIP (ICAR) for his significant contribution to pearl millet agronomy.
- Dr. Krishan Pal Singh, Principal Scientist and Head, Division of Floriculture and Landscaping was elected Secretary of the Indian Society of Ornamental Horticulture for a period of two years from July 2008 to June 2010.
- Dr. Premlata Singh, Principal Scientist, Division of Agricultural Extension received the G.S. Vidyarthi Memorial Award – 2008 of the Indian Society of Extension Education for her contribution to extension education.
- Dr. Ram Bahal, Principal Scientist, Division of Agricultural Extension received the Dr. S. Radhakrishnan Memorial Award – 2008 of the Delhi Shiksha avam Khel Vikas Sangh and Healthy Universe Foundation for his excellent performance in the field of education.
- Dr. S.N. Sharma, Principal Scientist, Division of Agronomy, received the IPNI – FAI Award for best research on management and balanced use of input in achieving maximum yield.
- Dr. A. Sarangi, Senior Scientist, Water Technology Centre received the Associateship of the National Academy of Agricultural Sciences for his research contributions.
- Dr. (Ms.) Charanjit Kaur, Senior Scientist, Division of Post Harvest Technology received the J.C. Anand Medal for her significant research in the field of post harvest technology.
- Dr. Kalyan K. Mondal, Senior Scientist, Division of Plant Pathology received the Prof. M.K. Patel Memorial Young Scientist Award of the Indian Phytopathogical Society for his contribution to the field of plant bacteriology.
- Dr. Madan Pal, Senior Scientist, Division of Plant Physiology received the J.J. Chinoy Gold Medal (2008) of the Indian Society of Plant Physiology.
- Dr. M. Hasan, Senior Scientist, Centre for Protected Cultivation Technology was elected Vice-Chairman of the Executive Committee of the Delhi Chapter of the Indian Society of Agricultural Engineering.
- Dr. Monica Wason, Senior Scientist, Division of Agricultural Extension received the Dr. S. Radha Krishnan Memorial Award – 2008 of the Delhi Shiksha avam Khel Vikas Sangh and Healthy Universe Foundation for her excellent performance in the field of education.
- Dr. N.P. Singh, Senior Scientist, Division of Agricultural Economics received the Associateship of the National Academy of Agricultural Sciences (2008-2012).
- Dr. Robin Gogoi, Senior Scientist, Division of Plant Pathology received the Prof. H.C. Dube Outstanding Young Scientist Award-2008 from the Indian Society of Mycology and Plant Pathology, Udaipur.
- Dr. Shelly Praveen, Senior Scientist, Division of Plant Pathology was elected Fellow of the National Academy of Sciences, Allahabad.

- Dr. Y.S. Shivay, Senior Scientist, Division of Agronomy received the Norwegian Government Scholarship of Norwegian University of Life Sciences.
- Dr. Anupama, Scientist, Division of Agricultural Chemicals received the Lal Bahadur Shastri Young Scientist Award of the ICAR for the year 2008 and the Young Scientist Award of the National Academy of Agricultural Sciences in plant protection.
- Dr. M.C. Singh, Scientist (Senior Scale), Centre for Protected Cultivation Technology was awarded the DST Boycast Fellowship for the year 2007-2008.
- Dr. N. Kumbhare, Scientist, Division of Agricultural Extension received the Young Scientist Award (2008) from the Indian Society of Extension Education for his contribution to research, extension and teaching.
- Dr. V.B. Patel, Scientist (Senior Scale), Division of Fruits and Horticultural Technology received the associateship of the National Academy of Agricultural Sciences (2008-2012). He also received the Young Scientist Award (2005-2006) of the Council of Science and Technology, Government of Uttar Pradesh for his contributions to horticulture and fruit sciences.
- Dr. Virendra Kumar, Technical Officer (T-7/8) received the FAI Golden Jubilee Award 2007-2008 based on his popular article in *Kheti.*

VI. Significant Suggestions Given/Decisions Taken at Senior Management Personnel (SMP) Meetings during the Period January 1 to December 31, 2008

Board of Management

- Dr. (Mrs.) Rekha Bhagat, Head, Division of Agricultural Extension has been nominated for the Executive Council in place of Dr. Baldeo Singh, Joint Director (Extension).
- New Extension Council has been constituted under rule (iii), (iv), (v), (vi) and (ix).
- The revised guidelines for Best Worker Award have been approved.

Extension Council

- A detailed paper should be prepared in consultation with the Director, TAFE on exploring the feasibility of the proposal of linking IARI website with a private website – TAFE, keeping in view that the financial implications on the part of IARI are within limits.
- Vermi-compost units may be established at IARI regional stations wherever possible.
- A special cell should be created to take care of the effective monitoring of IARI websites in terms of contents, editing, uniformity and timely updating with relevant information about new technologies, programmes, activities, publications, etc.
- The participatory seed production programmes of IARI varieties in farmers' fields at different locations should be vigorously provided in collaboration with selected SAUs.
- The entrepreneurship development training modules should be effectively packaged with appropriate technology and business orientation to benefit the farmers and rural youth to obtain the desired objectives of employment and income generating opportunities.
- A booklet on success story on new *basmati* variety of rice developed by IARI should be brought out.
- The ATIC should ensure adequate availability of seed of improved varieties of crops for selling round the year for which necessary arrangements with seed production unit should be made well in advance.
- The specific feedback/queries from the farming community should be forwarded to the concerned division/scientists for solving the problem and revising the new research agenda.
- The experiences and feedback of beneficiary farmers of 'conducted tours' undertaken by the KVK should be documented, analyzed and the results presented in relevant reports.
- The feedback of the farming community/rural youths generated through various means as a result of KVK

interventions should be systematically documented, processed and utilized for improvement of future programmes.

- Adequate emphasis should be given on conducting HRD/trainings on important aspects including PHT, agro-processing for farmmen, farmwomen and rural youth for their capacity building and empowerment.
- The beneficiary/adopted farmers of the designated projects under the new extension programme of learning implemented in collaboration with selected SAUs, ICAR institutes in different states of the country should be encouraged to intensify seed multiplication programme.
- The demonstrations conducted under various projects should include the aspects like cropping pattern, yield potential, economic returns/yield economy, feedback of farmers, linkages with departments/agencies/ companies, marketing, etc.

Research Advisory Committee

School of Crop Improvement

- There is an urgent need to popularize the varieties and hybrids of vegetable and horticulture crops for the benefit of the end-user. As in the case of field crops, the parental lines of vegetable hybrids be made available to seed producing agencies /companies on agreed terms and conditions.
- Efforts should be made to promote public-private partnership by liaisoning and establishing contact with private companies in the area of fruits, vegetables and floriculture. Mango seedling raising and grafting technology need to be popularized and promoted at the Institute, and among young farmers and educated youth by imparting vocational training to them to enhance their income.
- Research relating to the impact of climate change on crop productivity needs to be strengthened and given high priority.
- Research work of NRC on Plant Biotechnology should be made an integral part of the School of Crop Improvement as there is an effective inter-disciplinary linkage with the plant breeders and seed technologists.
- Programmes pertaining to identification and exploitation of genes for heat tolerance at grain maturity in cereals should be given priority in the breeding programmes.
- A good and well equipped screening system for abiotic stress tolerance at different stages of growth should be developed at the Institute.
- There is a need to have more inter-disciplinary interaction and coordination at the school level in future.

School of Plant Protection

- Current efforts of each division appear to be independent and not inter-disciplinary. Also, there is a need for active collaboration of the School of Crop Protection with other Schools as well asdisciplines.
- Studies on IPM with special emphasis on the use of bio-pesticides should be given priority while reorienting the research agenda.
- Programmatic linkages with other centers located in the Campus (NBPGR, NCIPM) should be encouraged in national interest. For this, participation and presentation of the significant achievements by the heads of each institution in this meeting will be mutually rewarding.
- IARI needs to take up the lead role at the national level for research on bio-control agents for controlling important diseases and pests, including harmful microorganisms.

School of Resource Management

- Focused and well thought out efforts towards integrated natural resource management (NRM) are required wherein emerging challenges concerning NRM are addressed.
- Work on improved fertilizer use efficiency in cereal based cropping systems, especially rice-wheat, should be taken up on a priority basis.
- Studies on the effect of climate change in relation to adaptation and mitigation need to be undertaken in an inter-disciplinary manner.

- Priority be given to the area of conservation agriculture, and the soil fertility work should be integrated with crop improvement programmes.
- Special research orientation towards organic farming is urgently needed by ensuring effective interaction with farmers. Also, a well equipped Referral Lab for testing of organic foods needs to be set up at the Institute immediately.

School of Basic Sciences

- Major emphasis be given to MAS and gene pyramiding work in collaboration with crop breeders in the School of Crop Improvement. Current work appears to be in isolation and independent of each other.
- Focused work on transgenic chickpea should be given high priority.
- Participation of IARI in wheat genome sequencing programme of Kansas State University, USA may be ensured.
- Collaboration of the School of Basic Sciences with Vegetable Science and Fruits and Horticultural Technology disciplines needs to be strengthened. The NRCPB may give high priority to the solving of serious problem of mango malformation.
- The mandate of Basic Science School may be enlarged to include also the relevant and more basic work of the Divisions of Plant Pathology, Nematology, and Plant Physiology, etc.

School of Social Sciences

- Studies on research impact and livelihood analysis of farmers around IARI need to be given high priority.
- Attention needs to be given to analyze cost-benefit ratio of all new technologies, especially those on NRM, IPM and CA related innovations.
- Special attention should be given by the scientists of the School to link farmers with the markets to enhance their income.
- There is a critical need to strengthen the Division of Agricultural Economics by ensuring effective collaboration and linkage with NCAP both for research and teaching at the post-graduate level.
- A model on content development should be developed for effective relevance of extension education programmes in the transfer of technology. Role of agri-clinics and young private entrepreneurs through vocational training be further emphasized and encouraged.
- Studies on value addition, economic feasibility and marketing of organic food should be given priority while reorienting research agenda of the School.

General

- Programmatic approach be brought at the Institute level around and across various schools of the Institute. A Coordinator/Facilitator at the school level may be made responsible for the programmes identified at the school level through frequent meetings for development of research programmes.
- Major research programmes at IARI may be reorganized and a document on New Strategic Development Plan be prepared.
- The concept of challenge programmes (2-3) instead of mega projects at the Institute level be implemented.
- Work on climate change should be an integral part of research programmes at IARI.
- The Institute should have a provision for Post Doctoral research (2-3 years' duration) in certain disciplines with suitable funding in view of the depleting scientific staff.
- Establishment of a Technology Park at IARI for commercialization of technologies needs to be planned.
- Food Technology programmes should be given more focus in the XI plan.
- RAC must include additional representatives both from private sector and farmer community as perthe constitution of the IARI- RAC meeting.

- Efforts should be made for allocating appropriate and challenging research projects to post graduate students at IARI. Activities of PG school need to be highlighted during the RAC meeting.
- Presentation by National Fellows should be included in the RAC meeting.
- National Facility should not only be used by IARI but by other institutes also.
- Keeping in view the serious shortage of scientific staff at the Institute, efforts should be made to induct manpower in the Institute by resorting to lateral entry at the middle level in addition to the enhanced entry level on priority.
- The present status of administrative and supporting staff should be reviewed from the perspective of outsourcing some of these posts.
- The Institute should have a contingent work plan for the renovation and upkeep of the laboratories, residential buildings as well as other infrastructure in all the divisions. Additional funding needs to be provided in the non-plan contingency for this purpose on priority.

Staff Research Council

School of Crop Improvement

Division of Genetics

- Need to improve lysine content in wheat
- Need to understand the factor which restricted the productivity in farmer's field in comparison to that in FLDs.
- A strategy to improve yield/disease resistance through molecular markers be worked out.
- Develop simple workable screening procedures for identifying plants for drought tolerance.
- Molecular characterization of germplasm along with identification of specific traits/ genes in breeding programme through Marker aided selection be undertaken.

Division of Fruits and Horticultural Technology

- Strengthen research in high density orchard. Cost : benefit ratio of high density plantings needs to be looked into.
- Elite germplasm and indigenous material(s) of fruit crops should be made available to NBPGR
- Experiment to control mango malformation with brewed tea should be done following appropriate statistical design and data analysis. Scientific basis to choose brewed tea must be ascertained before bringing out any recommendation.
- Mechanism of salt tolerance in mango, citrus and grapes needs to be studied.
- Germplasm of mango needs to be enriched with new cultivars/accessions.
- Network project on mango malformation needs to be developed with the concurrence of ICAR
- Biotechnological approaches should be considered to develop strategies for better understanding and control of mango malformation.

Division of Vegetable Science

- Productivity of tomato may be improved.
- Need to get feed back from Mau, UP for seed production of hybrid vegetables; and seed production should be given high priority.

Division of Post Harvest Technology

- Innovating the indigenous technologies needs to be addressed for packaging.
- Linkages with industry required for understanding the problems related to PHT.
- Research agenda should be focused as per consumer requirement in the case of ginger-onion-garlic (GOG) powder.

Division of Seed Science and Technology

- Liaison with the Director of Seed Research, Mau, UP required.

- In view of the increasing global trade and the importance of seed borne diseases more emphasis shoul be given on research on seed health. The Division may be provided a plant pathologist.
- The technologies for seed standards should be worked out for underutilized/unexplored crops.
- New technology for seed health with low cost required.
- A review paper on the role of IARI in basic studies on seed vigour and invigoration is a must.
- Develop an alternative /a substitute to GOT test.
- A bulletin on hybrid seed production in tomato, brinjal, and cauliflower with protected condition for quality be published.
- Seed invigoration be developed for rapid emergence and successful establishment of crop stand under high temperature conditions.
- Emphasis should be given to prepare a status paper on testing of all the varieties developed at IARIwith regard to seed health/germination

Division of Floriculture and Landscaping

- Work on post-harvest technology of flower crops including value addition may be strengthened.
- Work on production technology of flower crops like water requirement, and use of bio-fertilizers (microbial association) may be initiated.
- Research may be initiated in new flower crops suitable for agro-climatic conditions.
- Work on tuberose should be continued in the Division and not in the Centre for Protected Cultivation Technology.
- Work on mutation breeding may be explored on more flower crops.
- Research project on *Bougainvillea* may be initiated.
- Scientists from Plant Pathology and Entomology may be associated for work on the management of pests and diseases in flower crops.

Centre for Protected Cultivation Technology

- Organic farming under protected agriculture should be attempted.
- More crops may be added in protected agriculture.
- IARI should develop varieties for protected cultivation.

School of Plant Protection

Division of Agricultural Chemicals

- Should have indigenous technology for new chemicals, registered in India, and which are at present being imported from abroad.
- Divisional Referral Laboratory should operate more vigorously.

Division of Nematology

- Studies on identification and management of nematode problem in new emerging crops need to be carried out.
- Feasibility of using animal feed as soil amendment needs to be work out.
- Cost : benefit ratio/economic feasibility needs to be considered from the farmer's point of view while formulating strategies for nematode management.
- Nemagel may be tried against white grub in groundnut.
- Diseases complexes along with major fungi need to be addressed.
- Systematic survey on identification of nematode problems should be carried out.

Division of Plant Pathology

- The Division should work out MODEM System (Microorganism, disease, epidemiology and management)
- The Division should conduct research on national problems like *Ug 99* rust, pomegranate wilt, and guava wilt.
- Bioformulations should be tested in field in different locations.
- Integrated disease management needs to be worked out.

- A project on diagnostic of fungus and bacterial diseases needs to be submitted.

Division of Entomology

- Basic and strategic research is needed to develop centre for excellence.
- Effort should be made on basic aspects of IPM.
- Research contribution on biological control needs to be critically reviewed.
- Involvement of scientists in too many projects be avoided.

School of Resource Management

Division of Agronomy

- Emphasis be given on crop residues and recycling of farm wastes as sources of nutrients.
- Cross comparison of various sources of major nutrients along with other micro-and secondary nutrients needed to give meaningful comparisons.
- Economics of crop production should involve all costs to give realistic income.
- Problems of national importance should be identified after thorough review of literature.
- Basic soil data for soil fertility need to be generated.
- Farmer's practice check along with local practice check should be included in the research programme.
- Nutrient uptake and root distribution studies should be given due emphasis.
- Studies with respect to the effect of climatic change, organic farming, INM and soil health and crop planning be taken up in future.

Division of Agricultural Physics

- Variability in soil physical parameters be reflected in yield.
- Soil health with regard to fertility and climate change should be given prime importance.
- Future studies on the mobility of nutrients in the soil need to be undertaken.
- Studies on diversification of crop and soil property should be undertaken.
- Correlation of data with crop growth and productivity required.
- Relevance of research to common man be highlighted.
- Need to create a centre of excellence in soil biology.

Division of Soil Science and Agricultural Chemistry

- Strengthen some of the laboratories like radio tracer and pedology labs.
- Strengthening of the soil testing laboratory with manpower for resource generation under revolving fund be given priority.
- Funds may be provided to understand the micronutrient status of IARI farm.

Unit of Simulation and Informatics

- The Unit needs to be strengthened with scientists keeping in view the responsibilities entrusted upon them for maintaining the website for the Institute besides their involvement in research and teaching.

Division of Microbiology

- Publications should be made to impact factor Journals.
- Promotion of microbial products through industries be given priority.
- The Division be strengthened with a molecular taxonomist.
- Emphasis on microbial bioremediation of heavy metals required.

Division of Agricultural Engineering

- Research may be taken up in the area of energy generation from bio-mass and bio-fuels. Possible strategies to feedstock from agricultural residues and household wastes were also suggested.
- Research on mechanization of fruit, vegetable and sugarcane crops and straw management of wheat and paddy crops was suggested.

- Interdisciplinary linkages in research need to be strengthened.
- The implements developed under the revolving fund scheme, etc., should be manufactured in the Division.
- The technology developed at the Division should be patented.

Division of Environmental Science

- Prepare inventories of methane and NO_2 for different agro-climatic zones.
- Adaptation strategies to meet the impact of climate change need to be proven experimentally.
- Look for alternative crops which adapt to climate change.
- Cost : benefit ratio of *Jatropha* on field scale be analysed before drawing any definite conclusion.
- Impact of *Jatropha* on microbial population needs to be assessed.

Water Technology Centre

- The research work and the interactive activities should be carried out in irrigation command areas.
- The research work should address drainage aspect of water management, which is equally important.
- Some of the technology like AFSD should be popularized among the farming community.

School of Basic Sciences

National Research Centre on Plant Biotechnology

- Focused research directed towards development of products/technology/process should aim at benefiting end consumers.

Division of Biochemistry

- Concerted efforts need to be made with respect to studies on intermediately/regulatory plant metabolism
- More intensive research programmes pertaining to studies on starch biosynthesis, oil biosynthesis and protein synthesis should be undertaken.
- Studies on the effect of high temperature/salinity/ moisture stress in the present scenario of changing climate need to be given due emphasis.

Division of Plant Physiology

- Varietal/cultivar responses to elevated CO_2/temperature under field conditions need to be studied.
- Focus should be given to study the adaptive mechanisms/features of plants under long term exposure to elevated CO_2..
- Research efforts should be directed towards increasing NUE (nitrogen use efficiency) in crop plants under elevated CO_2 conditions
- Anti-sense approach for down regulating the *etr* gene for ethylene insensitivity can be followed while studying the response of ethylene in relation to senescence.
- Efforts are needed to identify crop plants tolerant to soil salinity.

Nuclear Research Laboratory

- Field studies on the aspect of seed quality in relation to magnetic field required.
- Studies on the dynamics of soil texture/soil type should be taken up in future research progammes.
- Non-ionizing radiation may be addressed as an alternative to ionizing (*gamma*) radiations for future research studies.
- NRL should take lead in developing cost effective technologies for the treatment of waste water.

School of Social Sciences

Division of Agricultural Economics

- Data analysis needs to be done in the projects for arriving at a meaningful conclusion.
- While finalizing the research programmes of the Division, latest data need to be computed.
- The Division should focus on issues of national policy and guidelines.

Division of Agricultural Extension

- The Division in future should undertake research on national priority issues. Research information so generated should benefit the end user/society.
- Method of testing, and review of literature need to be specific.
- Focus on extension organization.
- Due emphasis should be given on inter-divisional linkage.

VII. Resource Generation (Post Graduate School)

Training Programme

(a)	Foreigners & Indians	Rs. 1,75,499

M.Sc./Ph.D Programme

(b)	Institutional economic fee from foreign scholars under Work Plan	US$ 32000 + Rs. 6,79,120
(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. 36,14,305
(d)	Cash transferred from Syndicate Bank to Director's Account No. C-49(9029.305.17) from sale of information bulletin	Rs. 4,59,175
(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. 1,21,350
	Total	***US$ 32000 + Rs. 50,49,449***

VIII. Infrastructural Development

- The Pesticide Referral Laboratory of the Division of Agricultural Chemicals accredited vide no. ISO 17025 by NABL.
- "Vigyan Bhavan" extension building of the Institute's regional station at Indore constructed.
- An apiary and a tissue culture laboratory established at the Institute's regional station at Katrain.

IX. All India Coordinated Research Projects in Operation during the year 2008

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

X. Foreign Visitors during 2008

Sl. No.	Visitor (s)	Month
1.	A 6-member delegation from the United Kingdom (UK)	January
2.	A 28-member delegation from Israel	January
3.	Mr. Eric Rubayita, First Secretary, Embassy of Republic of Rwanda	January
4.	Prof. John Alliston, Dean (Agriculture), Royal Agricultural College, University of UK	January
5.	A high level delegation from Canada	February
6.	A 4-member delegation from Japan	February
7.	Dr. Nina Fedroff, Science and Technology Advisor to US Secretary of State, (USA) United States of America	February
8.	His Excellency Niu Dun, Vice-Minister of Agriculture, Peoples Republic of China	February
9.	A high level delegation from SAARC countries	March
10.	Dr. Jerome, Vice-President, Saskatchewan University, Canada	March
11.	A 6-member American delegation from USA	April
12.	A 15- member delegation from Bhutan	April
13.	A 4-member delegation from CSIRO and ACIAR	April
14.	A high level delegation from the University of Alberta, Canada	April
15.	A group of 15 students from Industrial College of Armed Forces (ICAF), Washington, USA	May
16.	A 3-member delegation from Sri Lanka	May
17.	A high level delegation from Poland	June
18.	Dr. Thomas A Lumpkim, Director-General, CIMMYT, Mexico	July
19.	A 10-member delegation from Kansas Agriculture and Rural Leadership (KARL), USA	July
20.	A high level Japanese delegation	August
21.	A high level delegation from Phillipines	August
22.	Dr. Agnes M. Rimando of the University of Missippi, USA	September
23.	A 20-member delegation from ASEAN countries	September
24.	Prof. Marek-Houszka, former Vice-Dean of Faculty of Veterinary Medicine, Polland	September
25.	His Excellency Arefaine Berhe, Minister of Agriculture, Eritrea	September
26.	A 7-member delegation from Rice Research Institute, Iran	September
27.	Dr. Prem Warrior, Senior Programme Officer, Bill and Melinda Gates Foundation, USA	October
28.	Dr. Rene Amador of Citrex Inc., USA	October
29.	Dr. Silvio Crestana, President and Dr. Elisio Contini, Head for International Cooperation Department, Embrapa, Brazil	October
30.	A 5-member delegation from Date Palm Centre, Saudi Arabia	October
31.	An 8-member delegation from China	October

Sl. No.	Visitor (s)	Month
32.	A 13-member delegation from Afghanistan	October
33.	A 13-member delegation from China	October
34.	His Excellency Christophe Bazivamo, Minister of Agriculture and Animal Resource of Rwanda	November
35.	A high level delegation from the University of Belgrade, Serbia	November
36.	A 35-member delegation from Argentina	November
37.	A 5-member delegation from Vietnam	December
38.	Dr. Sham Goyal, Agronomy/Plant Physiology Scientist, Plant Science Department, University of California, USA	December

An Israeli delegation led by His Excellency Shalom Sim Chon, Minister of Agriculture (second from left) visiting the Centre for Protected Cultivation Technology at IARI

Dr. Nina Fedroff, Science & Technology Advisor to the US Secretary of State (right) addressing the officials of IARI during her visit to the Institute. Seated with her is Dr. S.A. Patil, Director, IARI

Appendix 1
Members of Board of Management of IARI
(As on 31.12.2008)

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 (Extension), IARI
7. Dr. (Mrs.) M. Dadlani
   Head, Division of Seed Science & Technology
   IARI
8. Dr. A.S. Sidhu
   Head, Division of Vegetable Science
   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 (Rajasthan)
14. DDG (CS), ICAR, Krishi Bhavan
    New Delhi- 110 001
15. Director, IVRI
    Izatnagar, Bareilly (U.P.)
16. Agricultural Commissioner, Deptt. of Agriculture
    and Cooperation, Ministry of Agriculture,
    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. Director (F), ICAR
    Krishi Bhawan, New Delhi-110001
20. Development Commissioner
    Govt. of NCT of Delhi, 5/9 Under Hill Road
    Delhi-110054

Member-Secretary

21 Shri P.C. Jacob
   Joint Director (Administration), IARI

Appendix 2
Members of Research Advisory Committee of IARI
(As on 31.12.2008)

Chairman

1. Dr. R.S. Paroda
   Chairman
   Trust for Advancement of Agricultural Sciences
   Library Avenue, IARI Campus
   Pusa, New Delhi 110012

Members

2. Dr. H.S. Dhaliwal
   Professor
   Department of Biotechnology
   IIT, Roorkee (Uttarakhand)

3. Dr. J.C. Katyal
   Vice Chancellor
   Chaudhary Charan Singh
   Haryana Agricultural University
   Hisar (Haryana)

4. Prof. S.L. Mehta
   Vice Chancellor
   Maharana Pratap University of Agriculture
   & Technology, Udaipur (Rajasthan)

5. Prof. A. N. Mukhopadhyay
   Sangini, 151 Akanksha
   Udhyan II, Raibareilly Road
   Lucknow -226025 (U.P.)

6. Dr. R.K. Pathak
   Ex-Director
   Central Institute for Subtropical Horticulture
   Chief Consultant, Room No. 37-B
   Ministry of Agriculture, Krishi Bhawan
   New Delhi-110001

7. Dr. S. N. Shukla,
   Asstt. Director General (F&FC)
   Indian Council of Agricultural Research
   Krishi Bhawan,
   New Delhi-110001

Two non-official Members from Board of Management

8. Shri Subhash Bapurao Patil
   Post Palsa, Taluk Hadgaon
   Distt. Nanded(Maharashtra)

9. Shri Bipin Shankar Rao Kohle
   Post Kopargad
   Distt. Ahamadnagar (Maharashtra)

Member-Secretary

10. Dr. K.R. Koundal
    Joint Director(Research)
    IARI, New Delhi 110012

Appendix 3
Members of Academic Council of IARI
(As on 31.12.2008)

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. B S. Hansra
   Director
   School of Agriculture, IGNOU
   New Delhi
5. Dr. Baldeo Singh
   Joint Director (Extension), IARI
6. Dr. S.K. Sharma
   Director, NBPGR, New Delhi
7. Dr. P.G. Chengappa
   Vice Chancellor
   UAS, GKVV, Bangalore
8. Dr. V.K. Bhatia
   Director, IASRI, New Delhi
9. Dr. K. R. Koundal
   Joint Director (Research), IARI
10. Dr. N.P..S. Sirohi
    Professor of Agricultural Engineering
11. Dr. P.S. Datta
    Project Director, NRL
12. Dr. P.A. Kumar
    Director, NRCPB, New Delhi
13. Dr. A.K. Dixit
    Professor of Agricultural Chemicals
14. Dr. Puran Chand
    Professor of Agricultural Economics
15. Dr. S.N. Puri
    Vice Chancellor, CAU, Imphal
16. Dr. K. Vijayaraghavan
    Professor of Agricultural Extension
17. Dr. (Ms.) U.K. Chopra
    Professor of Agricultural Physics
18. Dr. V.K. Bhatia
    Professor of Agricultural Statistics
19. Dr. R.K. Rai
    Professor of Agronomy
20. Dr. (Ms.) Archna Sachdev
    Professor of Biochemistry
21. Dr. P.K. Malhotra
    Professor of Computer Application
22. Dr. R.D. Gautam
    Professor of Entomology
23. Dr. S.D. Singh
    Professor of Environmental Sciences
24. Dr. S.S. Singh
    Professor of Genetics
25. Dr. P. Kalia
    Professor of Horticulture
26. Dr. K.P. Singh
    Head, Division of Floriculture & Landscaping
27. Dr. R.K. Pal
    Head & Professor, Post Harvest Technology
28. Dr. D. Prasad
    Professor of Nematology
29. Dr. P. Ramachandran
    Professor of Plant Pathology
30. Dr. R.K. Sairam
    Professor of Plant Physiology
31. Dr. I.S. Bisht
    Professor of Plant Genetic Resources

32. Dr. S.S. Parihar
Professor of Seed Science & Technology

33. Dr. L.M. Shukla
Professor of Soil Science & Agricultural 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. Man Singh
Faculty Representative

38. Dr. Vijendra Singh
Faculty Representative

39. Shri V. Mangeshwaran
President, PGSSU

40. Shri Bibhash Chandra Varma
Students' Representative

41. Dr. K.C. Bansal
Professor of Molecular Biology and Biotechnology

42. Dr. (Ms.) P. Lata
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

46. Dr. Sain Das
Project Director
Directorate of Maize Research
New Delhi

47. Dr. B.R. Yadav
Project Director, WTC

Member-Secretary

48. Shri P.C. Jacob
Registrar (Academic)

Appendix 4
Members of Extension Council of IARI
(As on 31.12.2008)

Chairman

1. Dr. S.A. Patil
   Director, IARI

Members

2. Dr. P. Das
   Deputy Director-General (Extension)
   ICAR, KAB, Pusa, New Delhi
3. Dr. Baldeo Singh
   Joint Director (Extension)
   IARI
4. Dr. K.R. Koundal
   Joint Director (Research)
   IARI
5. Dr. I.P.S. Ahlawat
   Head
   Division of Agronomy, IARI
6. Dr. K.V. Prabhu
   Head
   Division of Genetics, IARI
7. Dr. Anand Swarup
   Head
   Division of Soil Science & Agricultural Chemistry
   IARI
8. Project Director
   Water Technology Centre
   IARI
9. Dr. (Ms.) Malvika Dadlani
   Head
   Division of Seed Science & Technology, IARI
10. Dr. K. Vijayaragavan
    Professor
    Division of Agricultural Extension, IARI
11. Dr. S.K. Adlakha
    Head
    Division of Agricultural Engineering, IARI
12. Dr. R.K. Jain
    Head
    Division of Plant Pathology, IARI
13. Dr. V.C. Mathur
    Head
    Division of Agricultural Economics, IARI
14. Dr. G.T. Gujar
    Head
    Division of Entomology, IARI
15. Dr. S.N. Sinha
    Head
    IARI Regional Station, Karnal, Haryana
16. Dr. N.B. Singh
    Agricultural Commissioner (Crops)
    Department of Agriculture & Cooperation,
    Ministry of Agriculture, Krishi Bhawan, New Delhi
17. Shri Mahto
    Director (Agriculture Marketing)
    Govt. of NCT of Delhi
    49, Sham Nath Marg, Old Sectt., Delhi-110054
18. Dr. D.K. Thakur
    Joint Director (Agriculture)
    Govt. of NCT of Delhi
    MSO Building, 11th floor, IP Estate, New Delhi
19. Dr. D.S. Brar
    Principal Scientist (Agricultural Extension)
    NDRI, Karnal
20. Dr. M. Kazmi
    Director (Farm Information)
    Directorate of Extension,
    Krishi Vistar Sadan, Pusa Campus
    IARI, New Delhi
21. Shri P.C. Jacob
    Joint Director (Administration)
    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 31.12.2008)

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 31.12.2008)

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. Head
   Division of Agricultural Physics, IARI
9. 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 31.12.2008)

Chairman

1. Dr. S. A. Patil
   Director, IARI

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 Radhey Sham
   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
(Up to 21/07/2008)

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 R.N. Jain
3. Shri Ishwari Singh
4. Shri Davinder Rai

Member-Secretary

5. Shri Umesh Chandra Sharma

Appendix 9
Personnel
(As on 31.12.2008)

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. Sanjay Kant

Chief Finance and Accounts Officer
Mr. Radhey Sham

Editor (Hindi)/T-9
Mr. Dubey, A.K.

Editor (English)/T-9
Mr. Thomas, Chacko

Sr. Administrative Officers
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. Dixit, A.K.

National Fellow
Dr. Gopal, Madhuban

Principal Scientists
Dr. Devakumar, C.
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. Walia, Suresh

Sr. Scientists/Scientists (S.G.)
Dr. (Ms.) Gupta, Suman
Dr. Jitender Kumar
Dr. (Ms.) Mann, Anupama
Dr. Rajesh Kumar
Dr. Shakil, N.A.
Dr. (Ms.) Singh, Neera

Agricultural Economics

Head
Dr. Mathur, V.C.

Professor
Dr. Mathur, V.C.

Principal Scientists
Dr. Atteri, B.R.
Dr. Kar, Amit
Dr. Puran Chand

Dr. (Ms.) Singh, Alka
Dr. Tyagi, V.P.

Sr. Scientists/Scientists (S.G.)

Ms. Bisaria, Geeta
Dr. Jha, G.K.
Dr. Parmod Kumar

Scientists

Mr. Sekar, I.
Dr. Singh, N.P.

Agricultural Engineering

Head

Dr. Adlakha, S.K.

Professor

Dr. Sirohi, N.P.S.

Principal Scientists

Dr. De, Dipankar
Mr. Kalra, M.S.
Mr. Saxena, J.P.
Dr. Sharma, P.K.
Dr. Shrivastava, Ranjan
Mr. Singh, Amar
Mr. Singh, J.K.
Dr. Tomar, S.S.

Sr. Scientists/Scientists (S.G.)

Dr. Adarsh Kumar
Dr. Indra Mani
Dr. Sahoo, P.K.

Scientists

Mr. Arvind Kumar
Dr. (Ms.) Gupta, M.J.

Agricultural Extension

Head

Dr. (Ms.) Bhagat, Rekha

Professor

Dr. Vijayaragavan, K.

Principal Scientists

Dr. Bahal, Ram
Dr. (Ms.) Singh, Prem Lata
Dr. Vashishtha, S.B.

Sr. Scientists/Scientists (S.G.)

Dr. Burman, R.R.
Dr. Dommeti, U.M.R.
Dr. Padaria, R.N.
Dr. Singh, Rashmi
Dr. (Ms.) Wasan, Monika

Scientist

Mr. Kumbhare, Narayan

Agricultural Physics

Head

Dr. Chakravarthy, N.V.K.

Professor

Dr. (Ms.) Chopra, Usha Kiran

Principal Scientists

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