वार्षिक रिपोर्ट

ANNUAL REPORT
2006 - 2007

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

वार्षिक रिपोर्ट

Annual Report

2006 - 2007

भारतीय कृषि अनुसंधान संस्थान

Indian Agricultural Research Institute

(मानद विश्वविद्यालय)

(Deemed University)

नई दिल्ली-110 012

New Delhi-110 012

Printed : October, 2007

Supervision and Guidance

S.A. Patil
Director

K.R. Koundal
Joint Director (Research)

Publication Team

Chacko Thomas
Editor (English)

Kehar Singh
Technical Officer

D.K. Parashar
Technical Officer

G.K. Kaushik
Technical Officer

Correct citation : *IARI. Annual Report 2006-2007, 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 M/s Royal Offset Printers, A-89/1, Naraina Industrial Area, Phase-I, New Delhi -110 028

Preface

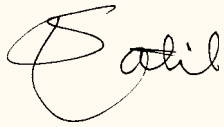
The Institute's research efforts continued to lay emphasis on achieving food and nutritional security for the nation by contributing to higher agricultural production, productivity, and quality. Protection of the environment and natural resource base, and creation of desired human resource for manning the country's agricultural system continued to receive attention. Multidisciplinary approaches were made to research, and extension activities.

This report summarises the various activities and achievements of the Institute during the year 2006-2007 under the major heads: (i) crop improvement, (ii) genetic resources, (iii) crop and resource management and environment, (iv) crop protection, (v) basic and strategic research, (vi) social sciences and technology transfer, (vii) empowerment of women and mainstreaming of gender issues, and (viii) post-graduate education and information system.

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

The report was prepared by Mr. Chacko Thomas, Editor (English) in association with Dr. Kehar Singh and Mr. D.K. Parashar, Technical Officers (T-7/8), and Mr. G.K. Kaushik, Technical Officer (T-6) under the technical guidance and supervision of Dr. K.R. Koundal, Joint Director (Research) & Incharge, Publication Unit. The research material included in this report was vetted by Dr. (Ms.) M. Dadlani, Head, Division of Seed Science & Technology, Dr. Anand Swarup, Head, Division of Soil Science & Agricultural Chemistry, and Dr. G.T. Gujar, Head, Division of Entomology. The Hindi version of the 'Executive Summary' was prepared by Mr. A.K. Dubey, Editor (Hindi). The computer typesetting of the manuscript was done by Mr. Mukesh Kumar, Lower Division Clerk, and Ms. Sunita Joshi, Stenographer, Grade-III.

My thanks are due to all.



(S.A. Patil)
Director

August 7, 2007
New Delhi

Contents

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.

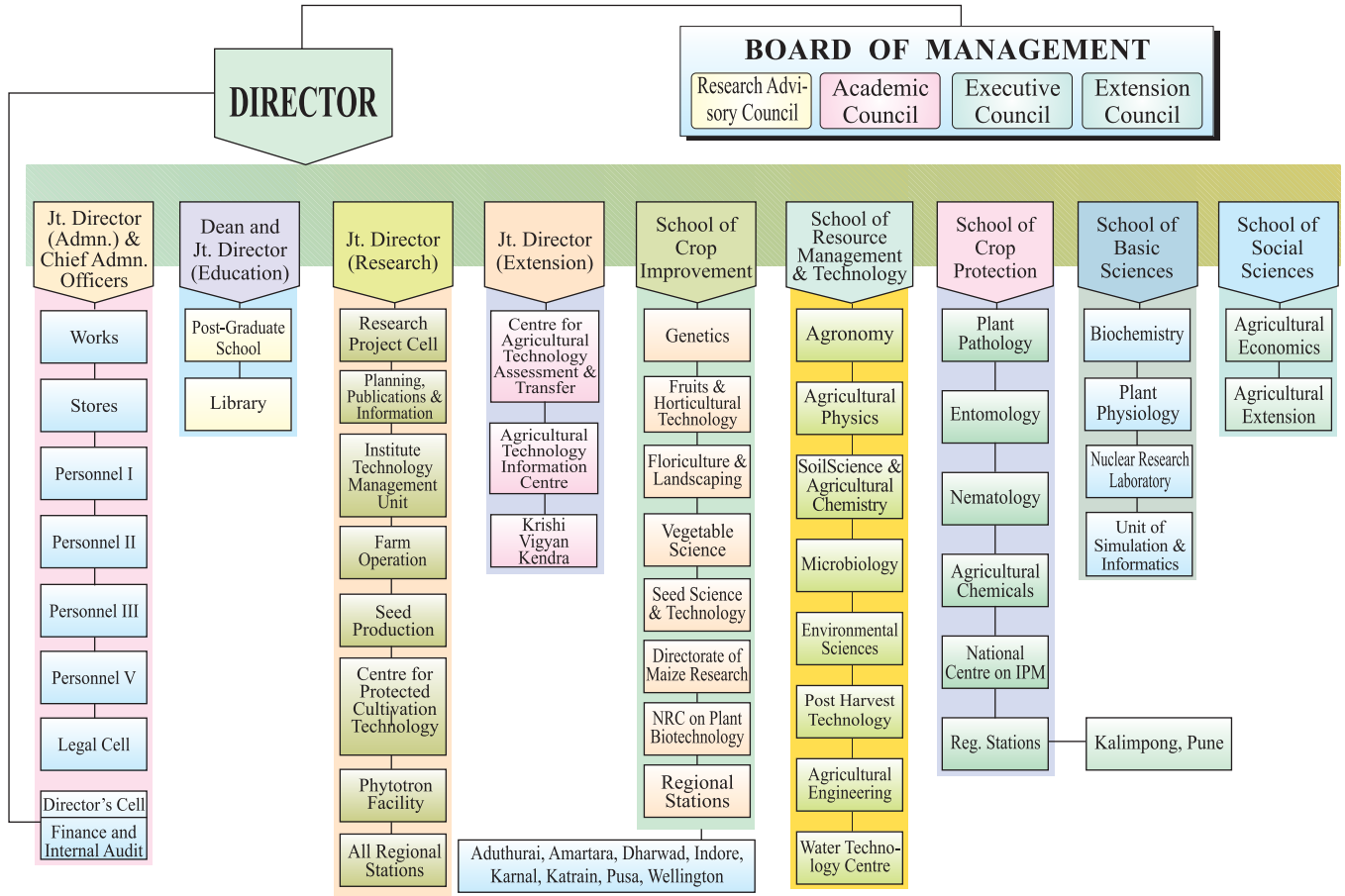
The growth of India's agriculture during the past 100 years, is closely linked with the researches done and technologies generated by the Institute. The Green Revolution stemmed from the fields of IARI. Development of high yielding varieties of all major crops which occupy vast areas throughout the country,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

The mandates of the Institute are as follows:

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

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

The Institute has 20 divisions as well as 5 multi-disciplinary centres situated in Delhi, 8 regional stations, 2 off-season nurseries, 3 all India coordinated research projects with headquarters at IARI, and 10 national centres functioning under the all India coordinated research projects. It has a sanctioned staff strength of 3606 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute for the year 2005-2006 were Rs. 9892.30 lakh.



Organizational set-up

विशिष्ट सारांश

संस्थान में वर्ष 2006–2007 के दौरान कृषि अनुसंधान, शिक्षा और प्रसार के अपने अधिदेशित क्षेत्रों में उल्लेखनीय योगदान किए हैं।

फसल सुधार के क्षेत्र में फसलों की अनेक किस्में या तो जारी की गईं या जारी किए जाने के लिए पहचानी गईं।

गेहूं में, एचआई 1531 (हर्षिता) जो अगेती पकने वाला व उच्च उपजशील, अर्ध–बौना ब्रैड गेहूं का प्रथम जीनप्ररूप है, मध्य भारत में सूखे को सहन करने की दृष्टि से विकसित किया गया। इसे मध्य आंचल में सीमित सिंचाई वाली स्थितियों तथा बारानी स्थितियों में उगाने के लिए जारी किया गया। एचआई 1531 जो एचडब्ल्यू 2004 की तुलना में लगभग 1 सप्ताह अगेती बालियां तैयार करती है व परिपक्व होती है, पाले तथा मौसम के अंत में आने वाले सूखे को सहन कर सकती है। इससे मध्य आंचल में गेहूं के उत्पादन में स्थिरता सुनिश्चित हुई है। *ट्रिटिकम ड्यूरम* गेहूं की एक किस्म एचडी 4713 को राष्ट्रीय राजधानी क्षेत्र दिल्ली में खेती के लिए पहचाना गया। एचडी 4713 की औसत उपज 4.71 टन/है. और इसकी उपज क्षमता 5.15 टन/है. है। एक अन्य उपजशील किस्म एचडी 2894 को दिल्ली राज्य में समय पर बुवाई वाली सिंचित स्थितियों में उगाए जाने हेतु जारी किए जाने के लिए पहचाना गया। इसने पिछले कई वर्षों के दौरान अब तक की श्रेष्ठ किस्मों की तुलना में लगातार बेहतर निष्पादन दिया है और सात परीक्षणों में से पांच में इसका प्रथम स्थान रहा है।

चावल में, पूसा 1401–97–7–1–4 को भा.कृ.अ.सं. किस्म निर्मुक्ति समिति द्वारा दिल्ली राज्य में जारी किए जाने के लिए पहचाना गया। इसकी उपज तरावड़ी बासमती की तुलना में 34.41 प्रतिशत अधिक थी और चावल की दिखावट, चिपचिपेपन, छूने और चबाने में मुलायम, स्वाद, सुगंध और दाने के लंबे होने की प्रवृत्ति के आधार पर बेहतर किस्म मानी गई। सकल स्वीकार्यता के आधार पर इसका पैनल स्कोर 4.07 है, जबकि इसकी तुलना में तरावड़ी का पैनल स्कोर 3.96 है।

मक्का में, भा.कृ.अ.सं. द्वारा विकसित रबी की स्थितियों के लिए उपयुक्त प्रथम इकहरे संकरण वाला संकर एएच 24003 अगेती परिपक्वता वाले समूह में तीन आंचलों के लिए पहचाना गया, क्योंकि अब तक के श्रेष्ठ संकरों की तुलना में इसका निष्पादन निरंतर श्रेष्ठ रहा है। इस किस्म की उत्पादन क्षमता आंचल II, III और IV में क्रमशः 7278 कि.ग्रा./है., 5703 कि.ग्रा./है. और 6910 कि.ग्रा./है. रही है। मक्का के एक अन्य संकर एएच 23029 ने अब तक के श्रेष्ठ संकरों नामतः सूर्य और हिम 129 की तुलना में क्रमशः 41% और 19% औसत श्रेष्ठता प्रदर्शित की है तथा समन्वित परीक्षणों में इसकी उत्पादन क्षमता 5.5 टन/है. रही है।

बाजरा में, एक संकर पूसा 751 (एमएस 576 ए x पीपीएमआई 23) ने अखिल भारतीय समन्वित बाजरा सुधार परियोजना के अंतर्गत किए गए परीक्षणों में श्रेष्ठ निष्पादन दिया है और इसके परीक्षण के तीन वर्ष पूरे हो गए हैं। बाजरा संकुल जनसंख्या एमपी 443 (पीपीएमपी 579) ने खरीफ 2005 में अखिल भारतीय समन्वित बाजरा सुधार परियोजना के अंतर्गत किए गए परीक्षणों में, परीक्षण के तीसरे वर्ष के दौरान भी प्रगत संकर जनसंख्या परीक्षणों में ए1 आंचल में अच्छा निष्पादन दिया है। इसमें अब तक के सर्वश्रेष्ठ संकर सीजैडपी 9802 की तुलना में 22.3% उच्च उपज दी है और मृदुरोमिल आसिता (डाउनी मिल्ड्यू) के विरुद्ध अच्छी प्रतिरोधिता प्रदर्शित की है।

चारा फसलों में, अनेक बार काटी जा सकने वाली

ज्वार की पूसा चरी 615 किस्म राष्ट्रीय राजधानी क्षेत्र, दिल्ली में उगाए जाने के लिए जारी की गई। इससे औसतन 70 टन/है. हरा चारा और 1.95 टन/है. शुष्क चारा प्राप्त हुआ, जबकि इसकी तुलना में अब तक की सर्वश्रेष्ठ किस्म एसएसजी 59–3 की हरा चारा उपज 65 टन/है. और सूखा चारा उपज 1.85 टन/है. थी। इससे अब तक की सर्वश्रेष्ठ किस्म पीसी 23 (1–1.2 टन/है.) की तुलना में बेहतर बीज उपज (1.2–1.5 टन/है.) प्राप्त हुई। पोषक तत्वों से भरपूर इसके चारे में 8.07% प्रोटीन तथा 8.72 टन/है. पाचनशील शुष्क पदार्थ और 55.3% इन विट्रो शुष्क पदार्थ पाचनशीलता है। यह किस्म प्रमुख कीटों–नाशकजीवों और पत्ती वाले रोगों के प्रति सहिष्णु है।

अनाजदार फलियों में, बड़े दाने वाली काबुली चने की किस्म बीजी 1108 देश के उत्तरी राज्यों में व्यावसायिक खेती के लिए जारी और अधिसूचित की गई। इस किस्म की बीज उपज 2.5 टन/है. से 3.5 टन/है. है। यह मृदावाहित रोगों की प्रतिरोधी है। इसकी कुकिंग गुणवत्ता श्रेष्ठ है और सब्जी या दाल के रूप में खाने की दृष्टि से श्रेष्ठ है। बड़े दाने वाली एक अन्य काबुली चने की किस्म बीजीडी 128 (पूसा शुभ्रा), जो दलहन सुधार केन्द्र, धारवाड़ द्वारा विकसित की गई थी, कृषि फसलों के लिए फसल मानक, अधिसूचीकरण और किस्म निर्मुक्ति की केन्द्रीय उप–समिति द्वारा मध्य आंचल में व्यावसायिक खेती के लिए जारी की गई। इस आंचल में मध्य प्रदेश, छत्तीसगढ़, महाराष्ट्र, गुजरात तथा राजस्थान और उत्तर प्रदेश के कुछ भाग आते हैं। यह एक अति उच्च उपजशील किस्म है, जिसकी औसत दाना उपज 1.9 टन/है. है जो चने की अब तक की सर्वश्रेष्ठ किस्म की तुलना में 21.3% उच्च है। एक देसी उत्प्रजनक बीजीएम 547 उत्तर पश्चिमी मैदानी क्षेत्र की पछेती बुआई वाली स्थितियों के लिए जारी और अधिसूचित किया गया। इसकी औसत दाना उपज 1.8 टन/है. है और उपज क्षमता 3.1 टन/है. है। इसके दाने बड़े और भारी होते हैं (100 बीजों का भार > 25.1 ग्रा.), जिनका रंग आकर्षक सुनहरी भूरा, छिलका पतला (जिसे उपभोक्ता बहुत पसंद करते हैं), स्वाद बढ़िया और कुकिंग गुण श्रेष्ठ होता है। इसकी परिपक्वता अवधि मध्यम (135 दिन) होती है तथा यह मुर्झान, जड़ सड़न, स्टंट रोगों तथा फली बेधक की प्रतिरोधी है। बड़े व भारी दाने वाली एक काबुली किस्म पूसा 2024 राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए पहचानी गई। इस किस्म में मृदा वाहित रोगों के प्रतिरोध की मध्यम क्षमता होती है, जबकि यह नमी प्रतिबल और उच्च तापमान की बेहतर प्रतिरोधी है। इसका कुकिंग गुण श्रेष्ठ है और यह सब्जी व दाल के रूप में खाने के लिए उपयुक्त है।

मसूर की एक किस्म एल 4594 राष्ट्रीय राजधानी क्षेत्र, दिल्ली में व्यावसायिक खेती के लिए जारी और अधिसूचित की गई। इस किस्म के पौधे मध्यम बढ़वार वाले और बीज छोटे होते हैं जिनके दानों का रंग नारंगी होता है। यह रतुआ की प्रतिरोधी है। मसूर की एक अन्य किस्म एल 4596 राष्ट्रीय राजधानी क्षेत्र, दिल्ली में जारी किए जाने के लिए पहचानी गई। इस किस्म की औसत बीज उपज 2.12 टन/है. है। इसका पौधा बौना होता है तथा सीधा बढ़ता है।

अरहर की एक किस्म पूसा 2001 राष्ट्रीय राजधानी क्षेत्र, दिल्ली में उगाए जाने के लिए पहचानी गई। इस किस्म की दाना उपज 1.87 टन/है. है और इसकी फसल 145 दिनों में तैयार हो जाती है। इसके सौ दानों का भार 8.2 ग्रा. होता है। अरहर की एक अन्य किस्म पूसा 2002–2 उत्तर पश्चिमी मैदानी क्षेत्र के लिए पहचानी गई। इस किस्म की दाना उपज 1.67 टन/है. है, जबकि इसकी तुलना में अब तक की सर्वश्रेष्ठ किस्म की उपज 1.5 टन/है. है और यह 143 दिनों में पक जाती है अर्थात् पकने में भी अगेती है (यूपीएएस 120: 160 दिनों और पूसा 992: 148 दिनों में पकती है)।

तिलहनी फसलों में, *ब्रैसिका कैरिनेटा* की किस्म एनपीसी 9 राष्ट्रीय राजधानी क्षेत्र, दिल्ली में बारानी तथा सीमांत क्षेत्रों में व्यावसायिक रूप से उगाए जाने के लिए जारी की गई। इस किस्म का औसत निष्पादन बारानी स्थितियों में 1.4 टन/है. प्रायोगिक खेतों में रहा, जबकि किसानों के खेतों में इसकी उपज 1.33 टन/है. रही। इसमें तेल

(40%) और प्रोटीन (19.7%) अंश उच्च मात्रा में होते हैं। यह मृदुरोमिल आसिता की रोधी, सफेद रतुए की प्रतिरोधी तथा *आल्टरनेरिया* झुलसा, *स्क्लेरोटीनिया* तना सड़न और चूर्णिल आसिता (पाउडरी मिल्ड्यू) के प्रति सहिष्णु है। यह किस्म खेत की स्थितियों में माहू या चेपा के प्रति भी सहिष्णु है। भारतीय सरसों की अगेती पकने वाली और दाने न झड़ने वाली किस्म ईजे 13 (पूसा तड़क) दिल्ली राज्य बीज उप–समिति द्वारा राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए जारी की गई। इस किस्म के बीज बड़े व भारी होते हैं (6.2 ग्रा./1000 बीज) तथा यह अगेती पकने वाली किस्म है। औसत बीज उपज 2.9 टन/है. होती है तथा तेल अंश 40% होता है।

सरसों की चार किस्में, नामतः एलईएस 1–27 (पूसा मस्टर्ड 21), एलईटी 17 (पूसा मस्टर्ड 22), एनपीजे 93 (पूसा विजय) और ईजे 14 पहचानी गईं। एलईएस 1–27 की उपज क्षमता 2.7 टन/है. है और इसे राष्ट्रीय राजधानी क्षेत्र दिल्ली के लिए पहचाना गया। किस्म एलईटी 17 में एरुसिक अम्ल अंश कम होता है (2.0%), लेकिन इसकी उपज परंपरागत श्रेष्ठ किस्मों, वरुण, क्रांति और आरएल 1359 की तुलना में क्रमशः 32.4% , 6.1% और 9.4% अधिक है। इसकी औसत बीज उपज 2.10 टन/है. है और उपज क्षमता 2.75 टन/है. है। इसे एरुसिक अम्ल संबंधी आंकड़ों के सत्यापन की शर्त के साथ आंचल II के लिए पहचाना गया। एनपीजे 93 को राष्ट्रीय राजधानी क्षेत्र, दिल्ली में समय पर बुआई वाली सिंचित स्थितियों के लिए पहचाना गया। इष्टतम स्थितियों में इसकी औसत उपज 2.4 टन/है. थी। ईजे 14 को राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए पहचाना गया। यह औसतन 2.0 टन/है. उपज देती है, 100 दिनों में पक जाती है और तोरिया का एक अच्छा विकल्प है।

सोयाबीन की किस्म, पूसा 9814 उत्तरी मैदानी क्षेत्र में उगाए जाने के लिए जारी की गई। इसमें पीले चित्ती रोग, सोयाबीन चित्ती विषाणु, फली झुलसा, चारकोल सड़न के प्रति रोधिता और तना मक्खी के प्रति मध्यम रोधिता होती है। पूसा 9814 की औसत उपज 2.25 टन/है. है और उपज क्षमता 3.4 टन/है. है।

गोसिपियम हिर्सुटम की किस्म पूसा अरविंदम् को पश्चिम बंगाल के लिए जारी किया गया। इसका पौधा सुगठित होता है और यह किस्म कपास के पत्ती मोड़क विषाणु रोग की प्रतिरोधी होने के साथ–साथ जैसिड के प्रति सहिष्णु है। यह अति अगेती परिपक्वता वाली किस्म है (130–135 दिन) और पश्चिम बंगाल के तटवर्ती क्षेत्र (सुंदरबन) में इसे रबी के मौसम के दौरान धान की कटाई के बाद खाली पड़े खेतों में उगाने की सिफारिश की गई है। इससे कपास की औसत बिनौला उपज 1.18 टन/है. प्राप्त होती है, जबकि इसकी तुलना में अब तक की श्रेष्ठ किस्म एलआरए 5166 की बिनौला उपज 0.86 टन/है. है। पीएसएस 2 की रेशा गुणवत्ता अब तक की सर्वश्रेष्ठ किस्म एलआरए 5166 के बराबर है।

सब्जी फसलों में, कोल फसलों, कुकरबिटों, सोलेनेसी कुल की फसलों, जड़दार और बल्बदार फसलों, फलीदार फसलों तथा माल्वेसियस फसलों पर अनेक सफल परीक्षण किए गए।

फलदार फसलों में आम के दो नए उदीयमान संकर, नामतः एच 1–1 और एच 1–6 जारी किए जाने के लिए पहचाने गए। ये दोनों संकर प्रति वर्ष नियमित रूप से फल देते हैं। इनके फल लाल छिलके वाले होते हैं जो लम्बे समय तक टिके रहते हैं और निर्यात बाजार के लिए उपयुक्त हैं। अन्य संकर जो निरंतर श्रेष्ठ निष्पादन दे रहे हैं, एच 2–6, एच 4–12 और एच 8–11 हैं। इसके अतिरिक्त अंगूर, नींबूवर्गीय फलों, पपीता, अनार, आंवला, सेब, खुबानी, कीवी फल, नाशपाती, स्ट्राबेरी और अखरोट पर भी मूल्यांकन परीक्षण किए गए।

संस्थान के टूटीकंडी (शिमला) स्थित क्षेत्रीय केन्द्र में पहचाने गए सेब के मूलवृंत प्रगतशील सेब बागान मालिकों को उपलब्ध कराए गए, ताकि इस नए मूलवृंत के बारे में बागान मालिकों की प्रतिक्रिया प्राप्त की जा सके। इस मूलवृंत से सेब का अर्ध बौना, अर्ध पुष्ट वृक्ष तैयार होता है और यह रोएंदार चेपा या माहू, चूर्णिल आसिता तथा सेब के स्कैब रोग का प्रतिरोधी होता है। अखरोट के मामले में,

एक अनूठे क्लोन को पूसा खोर नाम दिया गया और इसे पहचान कर इसका मूल्यांकन किया गया। इसके फल वृक्ष पर पार्श्व स्थिति में और शीर्ष स्थिति में लगते हैं। इसका छिलका पतला होता है और इससे 50% गिरी प्राप्त होती है। गिरी का रंग हल्का भूरा होता है और इसमें 55% तेल होता है तथा इसका स्वाद भी बढ़िया है।

अलंकारिक फसलों में गुलाब की दो संकर किस्में जिन्हें आईएफएल–बी14–आर10 तथा एफएल–बी12–आर12 संख्या दी गई है, जारी किए जाने के लिए पहचानी गईं। इसके अतिरिक्त ग्लेडियोलस, गुलदाउदी, गेंदा, ट्यूबरोज़, बोगनविलिया, जर्बेरा और लिलियम पर भी सुधार संबंधी कार्य जारी रहा। बोगनविलिया की कठोर जड़ वाली पांच किस्मों नामतः मेहरा, शुभ्रा, चेरी ब्लॉसम, लेडी मैरी बैरिंग और डॉ. आर.आर. पाल के लिए 1000 पीपीएम आईएए और 1000 पीपीएम आईबीए युक्त जड़ माध्यम को मानकीकृत किया गया। इसके परिणामस्वरूप पांचों किस्मों में जड़ विकास के प्रतिशत, प्राथमिक जड़ों की संख्या व लंबाई, पौधों की ऊंचाई, प्रति पौधा शाखाओं की संख्या और शाखाओं की लंबाई के संदर्भ में उल्लेखनीय अंतर पाए गए। जड़ विकास का सर्वाधिक प्रतिशत (67%) व्यावसायिक किस्म मेहरा में रिकार्ड किया गया जिसके बाद डॉ. आर.आर.पाल किस्म में जड़ विकास का स्थान रहा (65%), जबकि शुभ्रा में जड़ विकास का न्यूनतम प्रतिशत (63%) पाया गया।

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

गेहूं का लगभग 500 ग्रा. बीज निम्नलिखित पहचाने गए स्टॉकों के साथ पासपोर्ट डेटा सहित मध्यम अवधि के भंडारण के लिए राष्ट्रीय पादप आनुवंशिक संसाधन ब्यूरो में जमा कराया गया : डब्ल्यूआर 1392, डब्ल्यूआर 1421 और डब्ल्यूआर 1387 – दोजियां प्रति मीटर के लिए; और डब्ल्यूआर 1408, आरडी 1018, आरडी 1008, आरडी 1009, आरडी 1063 और आरडी 1095 को 1000 दानों के भार के संदर्भ में जमा कराया गया। गेहूं के पांच शरद जीनप्ररूप, नामतः फ्लीनोर, फेस्टिवल, जिंगदोंगी, मेगा और मैरिस–हंट्समैन को धारीदार रतुआ के दो उग्र रोगप्ररूपों (46S119 और 78S84) के प्रतिरोध के नए स्रोतों के रूप में पहचाना गया। दो नए जीनप्ररूप, एचएस 424 और एचएस 431 पत्ती और तना रतुओं के प्रतिरोधी स्रोतों के रूप में पहचाने गए व उनकी पुष्टि की गई, क्योंकि ये दोनों जीनप्ररूप पत्ती और तना रतुओं के सभी रोग प्ररूपों के प्रति रोधी पाए गए हैं। विविधि उपयोगों के लिए किस्में विकसित करने के प्रयास में स्वीट कॉर्न, पॉप कॉर्न, बेबी कॉर्न और स्टार्च विशिष्ट घटकों से युक्त मक्का के वंशक्रमों को विकसित करने के लिए नई पहलें की गईं।

नींबूवर्गीय फलों में, अनेक देसी और विदेशी प्रजातियां/प्रभेद एकत्रित किए गए और उनका दिल्ली की स्थितियों के अंतर्गत मूल्यांकन किया गया। रिपोर्टाधीन अवधि के दौरान पपीते के दो जीनप्ररूप जननद्रव्य ब्लॉक में शामिल किए गए।

सूक्ष्मजैविक आनुवंशिक संसाधनों पर अनुसंधान के अंतर्गत, छत्तीसगढ़ की मिट्टियों से प्राप्त किए गए बारह नए पृथक्कर संवर्धन संकलन में सम्मिलित किए गए। भारत के धान के खेतों से नील हरित शैवाल के अस्सी से अधिक प्रभेद पृथक किए गए, जिनमें से सोलह पृथक्कर कम उर्वरक प्रयुक्त की गई बासमती धान की फसल वाले खेतों की मिट्टी के थे।

जैववर्गिकी और पहचान सेवाओं के अंतर्गत संस्थान द्वारा किए गए कार्य में 597 कवकीय नमूने वर्ष 2006 के दौरान भारतीय हर्बेरियम संकलन (एचसीआईओ) में प्रविष्ट किए गए और इस प्रकार अब इन नमूनों की संख्या 46,619 हो गई है।

इक्टेनोडोमेलियोला वाल्सुरी, जो मेलियोलेसी कुल का gen.et.sp.nov. है, को *वाल्सुरा ट्राइफोलिया* पर वर्णित किया गया; एक नए एनामोर्फिक हाइफोमाइसेटस कवक *वेनिबैंधा* सुन्दरा gen. et. sp.nov. को जमीन पर गिरी टहनियों से लेकर उसका वर्णन किया गया; तथा एक नए हाइफोमाइसेटस कवक *कोरीनेसेर्कोस्पोरा टेराएइन्सिस*

gen. et. sp.nov. का *एलियोडेंड्रॉन ग्लाउकम* एल. पर वर्णन किया गया।

रूपाभास (एनामॉर्फिक) चूर्णिल आसिता की तेरह नई जातियों, नामतः *ओडियम एलिसिकार्पे, ओ.बडलेई, ओ.कोकुलस, ओ.लाउनेइ, ओ.ओसिमी–सैंक्टम, ओ.सीसमे, ओ.सस्बेनिई, ओ.साइडी, ओ.स्पिरिएई, ओ.ब्रैसिकी, ओडियोप्सिस सोलनी, ओव्यूलेरिओप्सिस मैलोटी* और *किस्टोथीका क्वैरसिना* को प्रस्तावित किया गया। *क्वैरकस इन्काना* पर चूर्णिल आसिता की परिपूर्ण अवस्था का भी वर्णन किया गया। हाइफोमाइसिटयस कवक सात नई जातियां, नामतः, *ट्राइकोक्लैडियम सिग्मॉइडी, टी.पाल्मी, एक्रोडिक्टिस, एलिप्टिका, ए.लिग्निकोला, चेइरोमाइसिस एनाथग्रियेंसिस, मैम्नोनियेला मोहनरामी* और *ज़ाइगोस्पोरियम* अनुपमवर्मी सृजित की गई। *मेलियोलेसियस* कवक की आठ नई जातियां, नामतः *मेलियोला साइनैन्ची, एम.पटेरीगोटी, एम.स्ट्रॉम्बोसिई, एम.एमेस्पैटिली, एस्टेरिना लोरानथिजेना, ए.टोडालिकोला, एस्टेरोस्टोमेला ओटोनेफेली* और *ए.स्ट्राम्बोसिई* प्रस्तावित की गईं। *मेलियोला डेस्मोडी लेक्सीलौरे* किस्म इंडिका और *एम.टेबरनीमोन्टेनी*, किस्म *रिघटिई* भारत में वर्णित की गई नई किस्में हैं। डेमाटिएसिएस हाइफोमाइसिटियस कवक की 4 नई जातियां, नामतः, *स्पोरिडेस्मियम मेहरोत्राई, एस.कुरवुला, एस.लैग्नीफोर्मे* और एस.अन्सिनेटस प्रस्तावित की गईं।

इंडियन टाइप कल्चर कलेक्शन (आईटीसीसी) को 55 नए विभिन्न कवक संवर्धनों को शामिल करके समृद्ध किया गया। प्रविष्टीकृत कुछ उल्लेखनीय पादप रोगजनकों में सम्मिलित हैं – *लेंटिनस एडोडेस* से *एस्पर्जिलस एम्सटेलोडमी*; *जैट्रोफा* से *प्लियोरोटस लेसिडा, पी.क्रिन्जी, पी.ऑस्ट्रिटस, हाइफाज़िअस, अल्मेरियस, यूज़ेरियम इक्विसिटी, आल्टरनेरिया आल्टरनेटा* और *नाइग्रोस्पोरा ओराइज़ी*; चावल के बीज से *ज़ाइलोकिया ओराइज़ी* जाति nov; एलोए वेरा से *बाइसोक्लैमाइस निवी* तथा *गिल्मेनिएला हयूमिकोला*; गन्ने से *फैकंडोस्टिलबम* सैकरी gen.nov; डल्बर्जिया सिसू से *फोमोप्सिस डल्बर्जिया*; *एल्बिज़िया* से डाइबैक रोग उत्पन्न करने वाला *फोमा एल्बिज़िई*; *ग्लेडियोलस* के बल्ब से *पेनिसिलियम आउरेंटियोग्रिसेयम*; लहसुन और तम्बाकू की पौदों से *राइज़ोक्टोनिया सोलेनी*; और पैशन फ्रूट से रुपाभास (एनामॉर्फ) *कोलेक्टोट्राइकम ग्लियोस्पोरॉयडस* सहित *ग्लोमेरिला सिंगुलेटा* ।

पहचान सेवाओं के अंतर्गत 151 कवकीय संवर्धनों/नमूनों की जाति स्तर तक पहचान की गई। इस अवधि के दौरान पहचानी गई कुछ कवक हैं : किन्नों से *जियोट्राइकम कैंडिडम*; स्टोन वीविल (घुन) से *बीवेरिया बेसियाना*; अमरूद के फल से *पेस्टालोटिया पाल्मेरम*; जठरोफा से *फ्यूज़ेरियम इक्विसेटी* और *एफ.पेलिडोरोसियम*; तथा रागी के दानों से ड्रैशलेरा और *कोकिलियोबोलस नोडुलोसस* की एक अवस्था।

सैकारिन आफिसिनेरम की पत्तियों से स्टिलबेलिसी के एक नए कवक, फैकन्डोस्टिलबम सैकरम sp.nov का वर्णन किया गया।

कीट जैव–वर्गिकी पर अध्ययनों के एक अभिन्न अंग के रूप में कीट पहचान सेवा के अंतर्गत 1064 कीट नमूनों की पहचान की गई। उप–कुल फार्मिसिनी के 16 वंशों के अंतर्गत 27 भारतीय जातियों का पुनर्वर्णन किया गया।

आर्थिक दृष्टि से महत्वपूर्ण हेमिप्टेरा पर किए गए वर्गिकी संबंधी अध्ययनों के परिणामस्वरूप दो उप–कुलों, नामतः, डिनोडोर्डी और पेइरेटिनी (रेडुवीडी) की चैकलिस्टों का संकलन किया गया। मत्कुण की एक नई जाति *मेगिमैनम खेसियंसिस* को स्थापित करके उसका वर्णन किया गया। तीन किस्म–जातियों, *कोर्डियस जेनस* (*फैब्रिसियस*), *साइक्लोपेल्टा ओब्सक्यूरा* (*लेपेल्टियर* और *सर्विले*) तथा *केटामेरियस ब्रेविपेनिस* (*सर्विले*); और *हेमिप्टेरा* की छः अन्य जातियों, नामतः, *कोरिडियस ब्रुनेयस* (*थनबर्ग*), *मेगिमेनम पेरालेनम* (*वोलेनहोवन*), *गेलिया नाइग्रीपेनिस* (*डलास*), *एक्टोमोकोरिस एट्राक्स* (*स्टाल*), *पेइरैटेस एफिनिस* (*सर्विले*) और *पी.लैप्टुरोयडेस* (वॉल्फ) को भारत में पहली बार उनके आकृतिविज्ञानी गुणों और उनके महत्वपूर्ण वर्गिकी गुणों के चित्रों सहित पुनर्वर्णित किया गया।

सूत्रकृमिविज्ञान जैववर्गिकी और पहचान सेवाओं के अंतर्गत मोननकिडा गण के कृषि को लाभ पहुंचाने वाले प्रीडेसियस सूत्रकृमियों की तीन नई जातियों, नामतः, *पैराहैड्रोन्कस मैंगीफेरी, माइकोन्कस सरधानैन्सिस* और

प्रियोन्कुलस प्रसादी के मेरठ, उत्तर प्रदेश में उगाए जा रहे आम के जड़ क्षेत्र में पाए जाने का वर्णन किया गया। इस सूत्रकृमि के किस्म नमूने नेशनल निमेटोड कलेक्शन ऑफ इंडिया (एनएनसीआई) में जमा कराए गए।

कीटरोगजनक (एंटोमोपैथोजेनिक) सूत्रकृमि *स्टेइनर्नेमा थर्मोफिलम* से सम्बद्ध एक सहजीवी (*ज़ैनोरैब्डस इंडिका*) और एक अ–सहजीवी (*प्रोविडैन्सिया वर्मिकोला*), जो भारत से प्राप्त की गई इन गणों की पहली नई जातियां हैं, का वर्णन किया गया। इन जातियों का वर्णन उनके आकृतिविज्ञानी, संवर्धनात्मक, जैवरसायनविज्ञानी और आण्विक गुणों के आधार पर किया गया।

997 bp के *एस.थर्मोफिलम* के rDNA के सम्पूर्ण आईटीएस क्षेत्र को आवर्धित करके क्रमबद्ध किया गया। इस क्रम को एनसीबीआई के जीनबैंक में प्रविष्टि संख्या DQ665651 के अंतर्गत जमा कराया गया।

जड़–गांठ सूत्रकृमियों की 14 जातियों, *स्टेइनर्नेमा* वंश के कीटरोगजनक सूत्रकृमियों की 46 जातियों को टैबुलर कम्पेंडिया और डाइकोटोमस कुंजियों से विकसित किया गया और भारत में इन जातियों के वितरण का मानचित्रण किया गया।

नेशनल नेमोटोड कलेक्शन ऑफ इंडिया (एनएनसीआई) में 215 वैट सस्पेंशनों तथा नव–वर्णित सूत्रकृमियों की 8 जातियों के 18 प्रकारों की स्लाइडों को शामिल करके संकलन को और समृद्ध किया गया। एनएनसीआई के वर्तमान डेटाबेस को अद्यतन किया गया और इसे उपयोगकर्ता–मित्र डिसिजन सपोर्ट सिस्टम (डीएसएस) फार्मेट में परिवर्तित किया गया।

गुजरात, जम्मू व कश्मीर, उत्तर प्रदेश, केरल और कर्नाटक से प्राप्त किए गए पादप परपोषी, मुक्तजीवी और कीटरोगजनक सूत्रकृमियों के कुल 67 सूत्रकृमि नमूनों की पहचान की गई। पहचानी गई महत्वपूर्ण जातियां थीं: *मेलोइडोगाइने जेवेनिका, ज़िफिनेमा इन्सिग्ने, स्टेइनर्नेमा बाइकोर्नुटम, एस.कार्पोकैप्सी, एस.फैल्टिई, हेटेरोरेब्टिस* इंडिका और *एच. बैक्टीरियोफोरा*।

फसल एवं संसाधन प्रबंधन तथा पर्यावरण के अंतर्गत अनेक महत्वपूर्ण अध्ययन किए गए। सस्यविज्ञानी अध्ययनों में : सुगंधित चावल की उत्पादकता पर जिप्सम से समृद्ध यूरिया और पूर्ववर्ती अल्पावधि की चारा फसलों का प्रभाव; जुताई की विविध स्थितियों के अंतर्गत नाइट्रोजन उर्वरक के प्रति गेहूं की फसल की प्रतिक्रिया और मूंग–गेहूं फसल प्रणाली में फसल स्थापना संबंधी प्रथाएं; मूंग–सरसों फसल प्रणाली में प्रयुक्त किए गए पोषक तत्वों का प्रत्यक्ष और अपशिष्ट प्रभाव; जुताई की विभिन्न प्रणालियों के अंतर्गत कपास के Bt और गैर–Bt जीनप्ररूपों का तुलनात्मक निष्पादन; कैनोला तथा गैर–कनौला किस्म की तोरिया–सरसों पर नाइट्रोजन और गंधक के स्तरों का प्रभाव; सोयाबीन की गंधक और बोरॉन पोषक तत्वों के प्रति प्रतिक्रिया; उत्पादकता पर भूमि संरचना और सिंचाई की विधियों का प्रभाव; सूरजमुखी–आधारित अंतरफसल प्रणाली की जल उपयोग दक्षता तथा उसमें खरपतवार नियंत्रण; बारानी स्थितियों के अंतर्गत जलीय–उर्वरीकरण के स्तरों और बुआई की तिथियों का भारतीय सरसों की फसल के निष्पादन पर प्रभाव; सुगंधित चावल की फसल में यूरिया की पर्त चढ़े व नीम के तेल के घटकों से युक्त उर्वरक के उपयोग का सस्यविज्ञानी मूल्यांकन; फूलगोभी –आधारित फसल प्रणालियों में कार्बनिक स्रोतों के माध्यम से पोषक तत्वों का प्रबंधन; अरहर–गेहूं फसल प्रणाली में फास्फोरस प्रबंधन; सिंचित स्थितियों के अंतर्गत बुआई की विभिन्न तिथियों में गेहूं के नए जीनप्ररूप का निष्पादन; बुआई की विभिन्न तिथियों के अंतर्गत उत्तर–पूर्वी मैदानी क्षेत्र में सामान्य बुआई और पछेती बुआई वाली किस्मों के श्रेष्ठ निष्पादन एवं स्थापन का तुलनात्मक मूल्यांकन; परंपरागत जुताई और शून्य जुताई की स्थितियों के अंतर्गत गेहूं की उपयुक्त किस्मों का मूल्यांकन; तथा गेहूं की फसल पर *एज़ोटोबैक्टर* तथा पीएसबी संवर्धन के बीजोपचार का प्रभाव प्रमुख थे।

बीज विज्ञान एवं प्रौद्योगिकी में अनेक महत्वपूर्ण अध्ययन किए गए। ये थे : संकर धान के बीज उत्पादन में परागण संबंधी अध्ययन; ड्रिप एवं सतही सिंचाई के अंतर्गत सब्जी वाली फसलों का गुणवत्तापूर्ण बीजोत्पादन;

टमाटर में संकर बीज उत्पादन प्रौद्योगिकी; फूल गोभी में संकर बीजोत्पादन प्रौद्योगिकी; लौकी में संकर बीजोत्पादन प्रौद्योगिकी; बरसीम बीज की गुणवत्ता एवं बीजोपज पर बुआई के समय और कटाई प्रबंधों का प्रभाव; प्याज की बीज वाली फसल में समेकित पोषक तत्व प्रबंध का गंठों के आकार पर प्रभाव; संकर धान के बीजोत्पादन के लिए पीआरएच 10 के पूर्वज वंशक्रमों का 'निकिंग' व्यवहार; गुणवत्तापूर्ण प्रोटीन युक्त मक्का की बीज गुणवत्ता पर उत्पादन मौसमों का प्रभाव; मक्का में डीयूएस परीक्षण हेतु आकृतिविज्ञानी एवं आण्विक गुण; बीज पुष्टता एवं उसकी वृद्धि; सोयाबीन में बीज का जीवन काल बढ़ाने हेतु उत्तरदायी भौतिक, कार्यिकीय तथा जैवरासायनिक घटक; कैप्सिकम के अंकुरण तथा उसकी पुष्टता पर विभिन्न प्राइमिंग उपचारों का प्रभाव; *बाइपोलेरिस ओराइज़ी* से संक्रमित चावल की बीज गुणवत्ता एवं उपज घटकों पर बीजोपचार का प्रभाव; मक्का की पौद के जड़ एवं प्ररोहों संबंधी गुणों पर चुम्बकीय क्षेत्र उपचार का प्रभाव; चारे वाली फलीदार फसल *स्टाइलोसैंथस सीब्राना* में कठोर कवच बीज सुप्तावस्था को कम करने के लिए सूक्ष्मतरंग ऊर्जा; और औषधीय फसलों के लिए बीज परीक्षण संबंधी प्रोटोकॉल।

संस्थान (दिल्ली) तथा संस्थान के करनाल, पूसा, इंदौर और कटराईं स्थित क्षेत्रीय केन्द्रों की बीजोत्पादन इकाइयों द्वारा अनाजों, दालों, तिलहनों, सब्जियों और अलंकरण फसलों के बीज रिपोर्टाधीन अवधि के दौरान कठोर गुणवत्ता नियंत्रण रखते हुए उत्पन्न किए गए। बीज उत्पादन के अतिरिक्त बीज उत्पादन इकाई (दिल्ली) में फलों व फूलों की 845 कलमें तैयार की गईं। करनाल स्थित क्षेत्रीय केन्द्र में लगभग 5500 बागवानी पौधों का उत्पादन किया गया। क्षेत्रीय केन्द्र, पूसा (बिहार) में पपीते (व्यावसायिक किस्म–पूसा ड्वार्फ) की 3372 पौदें तैयार की गईं।

मृदा प्रबंधन के अंतर्गत, विभिन्न कृषि प्रबंध अभ्यासों एवं भूमि उपयोग के तहत मृदा जैविक कार्बन गतिकी; विभिन्न मृदा के अभ्रक खनिज के क्रिस्टल आकार और क्रिस्टल स्ट्रेन का आकलन; क्ले–ह्यूमस संकुल की स्थिरता; मिट्टी के मृत्तिका–खनिज संयोजन पर चावल फसल चक्र का दीर्घावधि प्रभाव; विभिन्न कृषि पारिस्थितिकी मृदाजनक विकास के प्रबंध में मृत्तिका खनिजों की स्थिरता; फसल प्रतिक्रिया एवं मृदा विश्लेषण के परिणामस्वरूप बोरॉन एवं सल्फर के बीच अंतर–क्रिया; सरसों में सल्फर की आवश्यकता का निर्धारण करने के लिए समतापशीलता की प्रभावशीलता; अपशिष्ट अभ्रक से पोटेशियम का कार्बनिक घूर्णन; कार्बन अनुक्रमण और नाइट्रोजन साइक्लिंग बढ़ाने के लिए मृदा जैविक गतिकरण; वातावरण में कार्बन डाइऑक्साइड के बढ़े हुए स्तर के अंतर्गत गेहूं की खेती में उर्वरक नाइट्रोजन उपयोग की प्रभावशीलता; उन्नत वातावरणीय कार्बन डाइऑक्साइड के अंतर्गत उगाए गए चावल तथा गेहूं के जड़ क्षेत्र में फॉस्फेट सक्रियता तथा कार्बनिक फास्फोरस गतिशीलता; पादप पोषक तत्वों के स्रोत के रूप में कृषि अपशिष्ट का प्रबंध–समृद्ध कंपोस्टिंग के दौरान पौष्टिकता संचरण की निगरानी पर अनेक अध्ययन किए गए।

जल प्रबंधन के तहत भूतल सिंचाई; मौसम विज्ञान; जलसंभर; आधुनिक युक्तिओं का अनुप्रयोग (सुदूर संवेदन); सिंचाई सस्य–विज्ञान; दबावयुक्त सिंचाई; वायवीय चावल की खेती; जल की गुणवत्ता; तथा सीमा से अधिक दोहन किए गए भू–जल के दोषपूर्ण मूल्यांकन के लिए आइसोटोपिक तथा हाइड्रो–रासायनिक मॉडल्स पर अध्ययन किए गए।

समेकित पोषण प्रबंध एवं पोषण उपलब्धता पर महत्वपूर्ण अध्ययन किए गए। ये थे :– सोयाबीन–आलू फसल अनुक्रम में फसल उत्पादकता एवं मृदा उर्वरता पर समृद्ध कार्बनिक–खनिज उर्वरकों की समृद्धता का मूल्यांकन; मूंग–सरसों अनुक्रम में बीज उपज एवं गुणवत्ता पर सल्फर की प्रतिक्रिया; मक्का–गेहूं फसल प्रणाली के तहत खाद एवं उर्वरकों के अनुप्रयोग का मृदा पर्यावरण पर दीर्घावधि प्रभाव; गेहूं तथा बाजरा के लिए मूल आंकड़ों का विकास और मृदा परीक्षण आधारित उर्वरकों की सिफारिश; अरहर–गेहूं प्रणाली में समेकित पोषण प्रबंध; समेकित पोषण आपूर्ति एवं प्रबंध द्वारा फसलों की उत्पादकता एवं गुणवत्ता बढ़ाने के लिए टिकाऊ मृदा स्वास्थ्य को बनाए रखना; ट्रेसर का इस्तेमाल करते हुए गेहूं–उड़द

फसल अनुक्रम में कुछ कार्बनिक खनिजों से फॉस्फोरस के ग्रहण व विमोचन की क्रियाविधि; बाजरा–सरसों फसल अनुक्रम के तहत उगाई गई सरसों के बीजों में तेल की मात्रा एवं तेल पैदावार का मूल्यांकन; फलदार फसलों में समेकित पोषण प्रबंध; विभिन्न कृषि पारिस्थितिक क्षेत्रों में मृदा उर्वरता स्तर; गेहूं जीनप्ररूपों में जिंक तथा फाइटेट की मात्रा; तथा अनुपलब्ध स्वरूप में मिट्टी में प्रयुक्त जिंक का प्रत्यावर्तन जैसे विषयों पर अध्ययन किए गए।

चावल–गेहूं फसल प्रणाली के अंतर्गत संस्थान में ये अध्ययन किए गए– जुताई तथा समेकित पोषण प्रबंध से प्रभावित चावल–गेहूं फसल प्रणाली के अंतर्गत कार्बन भंडारण एवं खनिजीकरण; पारंपरिक तथा बढ़ी हुई क्यारियों में रोपण के तहत चावल में नाइट्रोजन उपयोग की दक्षता; गेहूं में भूमि–सतह के नीचे जड़ बायोमास एवं नाइट्रोजन का मूल्यांकन; और गेहूं तथा चावल में क्लोरोफिल सूचकांक पर आधारित उर्वरक नाइट्रोजन अनुप्रयोग पर भी अध्ययन किए गए।

बागान प्रबंध के तहत संस्थान में ये अध्ययन किए गए–सिट्रस मूलवृंत में लवण सहिष्णुता; सिट्रस में मूलवृंत–वंशज पारस्पारिकता; सेब के लिए सूक्ष्म सिंचाई एवं फर्टिगेशन समय–सारणी का मानकीकरण; आम की घनी बागवानी वाली आम्रपाली किस्म के लिए उर्वरक की मात्रा का मानकीकरण; तथा फलीय वृक्षों की कार्बनिक खेती।

संरक्षित खेती के अंतर्गत 6 माह की अवधि (अगस्त–जनवरी) के लिए 40 मेश की uv स्टेब्लाइज्ड नायलॉन का उपयोग करते हुए कीटरोधी जालीदार नेटहाउस में वायरस मुक्त टमाटर की फसल (किस्म जी एस 600) सफलतापूर्वक उगाई गई जिससे 1.5 टन/300 m^2 फल पैदावार प्राप्त की गईं तथा 98 प्रतिशत फसल वायरस से मुक्त पाई गई। कीटनाशकों के प्रयोग को न्यूनतम किया गया और उसका प्रयोग मुख्यतः वर्षा एवं वर्षा उपरांत मौसम में रोगवाहक मक्खी एवं फल छिद्रक के विरुद्ध किया गया। दिल्ली की परिस्थितियों के अंतर्गत कीट–रोधी नेट हाउस में टमाटर की खेती की लागत : लाभ दर 1:2.15 पाई गई। अन्य अध्ययन भी किए गए जिनमें शामिल थे– ग्रीन हाउस में उगाई गई दखनी मिर्च की पौध बढ़वार एवं फल पैदावार पर सूक्ष्म पोषक तत्वों के पर्णीय छिड़काव का प्रभाव; ग्रीन हाउस में उगे टमाटर की फल गुणवत्ता पर फल विरलन का प्रभाव; वाष्प शीतलित और प्राकृतिक रूप से वातायित ग्रीनहाउसों में उगे टमाटरों का तुलनात्मक मूल्यांकन; ग्रीनहाउस में गैर–मौसमी गुलदाऊदी पर ब्रैसिनीस्टेरॉइड प्रतिक्रिया; बंदगोभी में फर्टिगेशन समय–सारणी तथा पोषण गतिकी; प्राकृतिक रूप से हवादार ग्रीनहाउस के तापमान एवं नमी पर हवादार क्षेत्र का प्रभाव; ग्रीनहाउस तथा सफेद छायादार नेट हाउस के अंतर्गत शाकीय उत्पादन; और–जैव सामग्री को सुखाना आदि पर अध्ययन किए गए।

राष्ट्रीय राजधानी क्षेत्र में तथा उसके आसपास विभिन्न प्लास्टीकल्चर एवं संरक्षित खेती अनुप्रयोग के उपयोग के मूल्यांकन हेतु एक सर्वेक्षण किया गया। सर्वेक्षण में किसानों के खेतों, फार्महाउसों और भू–दृश्य इकाइयों, अनुसंधान संस्थानों आदि को शामिल किया गया। फसल खेती के लिए इन क्षेत्रों में ग्रीनहाउस एवं छायादार नेट्स का इस्तेमाल किया गया। उच्च मूल्य वाली सब्जियों, जड़ी–बूटियों, फूलों की खेती और नर्सरी बढ़ाने के लिए इन क्षेत्रों में मुख्य तौर पर मल्टीस्पेन और क्योन्सेट किस्म के ग्रीनहाउसों का इस्तेमाल किया गया।

संस्थान द्वारा अधिकतम फसल उत्पादन प्राप्त करने और कृषि कार्यों में लगने वाले श्रम को कम करने के उद्देश्य से खेती से जुड़े बहुत से उपकरण, मशीनरी और प्रौद्योगिकियां विकसित की गईं। अरहर–दाल की पॉलिश के लिए रोलर, कन्केव फीड हॉपर तथा फ्रेम की सहायता से अरहर की दाल के लिए एक पॉलीशर विकसित किया गया। रबड़ रोल के शेलर, छिलका हटाने के लिए ब्लोअर तथा दाल पॉलिश करने वाली छोटी क्षमता की दाल मिल का विकास किया गया। इस वर्ष, इसे ग्रेडर के साथ जोड़ा गया। एक्वा–फर्टि–सीड ड्रिल (AFSD) पर आधारित पहले से विकसित पेरीस्टाल्टिक पम्पिंग में खेत

परीक्षणों और हरियाणा एवं राजस्थान की वास्तविक खेत परिस्थितियों में, मशीन के प्रदर्शन के दौरान किसानों से मिलने वाले सुझावों के आधार पर, सुधार किया गया। पहले से विकसित पौधे से प्याज की गांठों को काटने वाले यंत्र में सुधार किया गया। पंक्तिदार फसलों के लिए 2.8kW इंजन वाला एक इन्टर–कल्टीवेटर विकसित किया गया। खाद्यान्नों एवं दलहनों के लिए हाथ से चालित एक रोलर फ्लेकर का विकास किया गया। संस्थान द्वारा मक्का के दानों को भूनने के लिए भी एक मशीन का विकास किया गया। इसका उपयोग भारतीय कृषि अनुसंधान संस्थान द्वारा विकसित मक्का की विभिन्न किस्मों के भुनाई संबंधी गुणों का मूल्यांकन करने के लिए किया जाएगा। भारत में खेती के लिए लगभग 240 मिलियन खेत कामगारों के द्वारा हाथ से चालित 800 मिलियन औजार इस्तेमाल किए जाते हैं। संस्थान द्वारा खेती में काम आने वाले इन औजारों का श्रम संबंधी मूल्यांकन किया गया और कामगारों के हाथों को सुरक्षा प्रदान करने के उद्देश्य से औजारों में हैंडल पर टेफलॉन कपड़े के उपयोग की विधि खोजी गई। अध्ययन क्षेत्र में फसल उत्पादकता बढ़ाने और कृषि मशीनों के समुचित उपयोग को सुनिश्चित करने के उद्देश्य से तथा इनके बीच मशीनीकरण अंतराल और उठाए जाने वाले आवश्यक कदमों को जानने हेतु प्रोटोकॉल के तौर पर उत्तर प्रदेश में सामान्य मशीनीकरण स्तर पर सूचना के लिए मुज़फ्फरनगर जिले से आवश्यक जानकारी एकत्र की गई।

संस्थान द्वारा कटाई उपरांत प्रौद्योगिकी एवं विभिन्न फसलों के प्रबंध पर महत्वपूर्ण अध्ययन किए गए। इनमें शामिल थे– आम में परिपक्वता पर अध्ययन; अमरूद में वृक्ष आयु तथा फल गुणवत्ता संबंधी अध्ययन; भारतीय कृषि अनुसंधान संस्थान द्वारा विकसित करेले की परिष्कृत वातावरण पैकेजिंग से संबंधित अध्ययन; गेंदे के फूलों की परिष्कृत वातावरण पैकेजिंग; तथा आम की दशहरी और चौसा किस्मों में ताजगी बनाए रखने के लिए जैव–प्रभावशीलता परीक्षण; सेब का जीर्णन काल बढ़ाने के लिए गर्मी में सिकुड़ जाने वाली फिल्म के उपयोग की संभावना पर अध्ययन; शुष्कीकरण के लिए प्याज जीनप्ररूपों की स्क्रीनिंग; परासरणी शुष्कन; परासरण विधि से सुखाई गई आम की फांकों हेतु शक्कर की इष्टतम मात्रा एवं तापमान का अध्ययन; जामुन के रस सांद्र एवं भंडारण का अध्ययन; निर्जलीकरण प्रयोजन एवं पोषण गुणवत्ता के लिए गाजर की विविध किस्मों का मूल्यांकन; आंवला की फांकों का परासरणी प्रसंस्करण; भोजन में बढ़ी हुई ऑक्सीडेटिव स्थिरता के लिए प्राकृतिक संघटक के रूप में फिनोलिक्स; हिमीकृत गाजर के टुकड़ों को उपयोग योग्य बनाना; पेय तैयार करने के लिए किण्वित गूदे का भंडारण; मक्का के भौतिक गुण; अरहर की दाल का कुकिंग समय कम करने हेतु एन्ज़ाइम पूर्व–उपचार; अरहर की कुछ चुनी हुई किस्मों के कुकिंग समय में कमी लाने के लिए रासायनिक उपचारों एवं फ्लेकिंग की जांच; गेंदा के लिए शुष्कन तकनीकों का मानकीकरण; तथा पादप प्रतिक्रिया का जैव–शारीरिक चरित्रांकन एवं कृषि उत्पादों का कटाई उपरांत गुणवत्ता बनाए रखते हुए परिरक्षण।

सूक्ष्मजीवविज्ञान के क्षेत्र में संस्थान द्वारा अनेक पहलुओं पर अध्ययन किए गए जिनमें प्रमुख हैं– कृषि अवशेषों का पुनःचक्रण तथा उनकी टिकाऊ एवं जैविक खेती में उपयोगिता; फसल उत्पादन के लिए सूक्ष्मजीवों का उपयोग; कृषि की दृष्टि से महत्वपूर्ण जैव–अवयवों का आण्विक गुण निर्धारण; कृषि एवं उद्योग के लिए सायनोबैक्टीरियाई आनुवंशिक संसाधनों की खोज तथा उपयोग; H_2 उत्पादन एवं N_2 स्थिरीकरण हेतु सायनोबैक्टीरिया का आनुवंशिक मूल्यांकन; कम उर्वरक निवेश वाले बासमती चावल के लिए नील–हरित शैवाल उर्वरकों का विकास एवं उनका योगदान; चावल–गेहूं–मूंग फसल चक्र में नील हरित शैवाल/एज़ोला तथा अन्य जैव–टीकों की पारस्परिक क्रिया संबंधी क्षमता; एज़ोला का उपयोग करते हुए व्यर्थ जल का जैव–उपचार तथा एनाबीना के लिए PCR आधारित मार्कर का विकास।

पर्यावरण विज्ञान से संबंधित प्रमुख अध्ययन थे– चावल या धान की फसल की विश्व ऊष्मन क्षमता का स्थानिक मानचित्रण; चावल–गेहूं फसल चक्र के तहत मिट्टी की विश्व उष्मन क्षमता (GWP) पर जुताई प्रबंध

का प्रभाव; जेट्रोफा उत्पादों की नाइट्रीफिकेशन अवरोधक क्षमता का मूल्यांकन; भारत के विभिन्न प्राकृतिक क्षेत्रों में मृदा से कार्बन डाइऑक्साइड के तीव्र प्रवाह का अनुक्रिया आधारित तापमान; विभिन्न फसलों की बढ़वार एवं पैदावार पर उच्च तापमान का प्रभाव; गेहूं में परागण वंध्यता पर तापमान का प्रभाव; चने के मुरझान रोग पर बढ़ते तापमान का प्रभाव; जेट्रोफा का कृषि प्रबंध; मक्का तथा ज्वार से जैव–इथानॉल; बायोगैस उत्पादन के लिए सॉलिड–स्टेट किण्वन तकनीक; भूमिगत पारिस्थितिक प्रणाली पर Bt कपास के cryI Ac(Bt टॉक्सिन) के प्रभाव का मूल्यांकन; कृषि–औद्योगिक निःस्रावों की सिंचाई एवं पौष्टिक क्षमता का मूल्यांकन तथा कृषि–औद्योगिक निःस्राव से सिंचाई के लिए उपयुक्त फसल किस्मों की पहचान; परिनगरीय कृषि में भारी धातु भार का परिमाणन; गैर–खाद्य व्यावसायिक फसलों के माध्यम से भारी धातुओं का पादप–उपचार; पर्यावरणीय प्रभाव का मूल्यांकन करने वाली युक्तियों का उन्नयन; खाद्य शृंखला में निकेल हस्तांतरण पर सुधारकों का प्रभाव; मिट्टी पर भारी धातु संदूषण प्रभाव एवं उसका उपचार; ब्रैसिका किस्मों के संदर्भ में पादप–निष्कर्षक के रूप तांबे एवं निकेल का मूल्यांकन; तथा चावल में ^{137}Cs के स्थानांतरण कारक पर पोटेशियम उर्वरक के अनुप्रयोग का प्रभाव।

पादप सुरक्षा के तहत पादप रोगविज्ञान, कीटविज्ञान, सूत्रकृमिविज्ञान तथा कृषि रसायन के क्षेत्र में महत्वूपर्ण निष्कर्ष प्राप्त किए गए।

पादप रोगविज्ञान के अंतर्गत गेहूं, चावल, मक्का, चना, उड़द, मूंग, अरहर, तोरिया तथा सरसों, सब्जियों, फलीय फसलों और बड़ी इलायची को प्रभावित करने वाले फफूंद रोगों पर महत्वपूर्ण अनुसंधान परिणाम प्राप्त किए गए। विषाण्विक रोगों पर अनुसंधान किये गए जिनसे अनेक महत्वपूर्ण निष्कर्ष निकाले गए। सरलीकृत सांचा तैयारी प्रोटोकॉल का इस्तेमाल करते हुए नींबू वर्गीय ऊतकों में हरापन लाने वाले जीवाणुओं और नींबू वर्गीय पीले चित्ती विषाणु (MMBV) की PCR पहचान का मानकीकरण किया गया। खाने योग्य खुम्बी में प्रभेद सुधार संबंधी अध्ययन भी किए गए।

कीटविज्ञान के क्षेत्र में अनाजों, तिलहनों, सब्जियों, सोयाबीन तथा दालों पर कीट व नाशकजीव प्रबंध संबंधी अध्ययन किए गए। इसके अलावा भण्डारण कीटविज्ञान, जैविक नियंत्रण, कीट शरीरक्रियाविज्ञान और आविषालुता पर भी अध्ययन किए गए।

सूत्रकृमिविज्ञान में जैव–विविधता, आण्विक गुणनिर्धारण, प्रतिरोधिता यांत्रिकी और प्रबंध पर महत्वपूर्ण अध्ययन किए गए।

कृषि रसायन के क्षेत्र में प्राकृतिक एवं कृत्रिम कृषि रसायनों और उनके सहायक रसायनों के विकास; नाशीजीवनाशी निरूपण; नाशीजीवनाशी जोखिमों के मूल्यांकन; तथा नाशकजीवनाशियों का पर्यावरण के संदर्भ में भविष्य एवं उनमें सुधार पर महत्वपूर्ण अनुसंधान कार्य किया गया।

खरपतवार प्रबंध अध्ययन के तहत प्याज में समेकित खरपतवार प्रबंध; मृदा संचरीकरण; शाकनाशियों तथा खरपतवारों की वृद्धि को रोकने के लिए विभिन्न पौध सामग्रियों के उपयोग के तुलनात्मक प्रभाव का अध्ययन एवं सोयाबीन की उत्पादकता; और खरपतवार नियंत्रण व गेहूं की उत्पादकता पर रोपण विधियों एवं शाकनाशियों का प्रभाव; जैसे विषय शामिल किए गए।

संस्थान द्वारा आधारभूत एवं रणनीतिपरक अनुसंधान के क्षेत्रों में अनेक महत्वपूर्ण अध्ययन किए गए।

पादप जैवप्रौद्योगिकी पर किए गए अध्ययन हैं– Bt बैंगन का विकास एवं परीक्षण; टमाटर जीनोम अनुक्रमण; चावल में जीवाण्विक अंगमारी के प्रतिरोधी जीनों हेतु मार्कर सहायी चयन; *ब्रैसिका जुन्सिया* के उन्नत साइटोप्लाज्मी नर वंध्य (CMS) वंशक्रम का विकास एवं आण्विक गुणनिर्धारण; फलीय फसलों का आण्विक गुणनिर्धारण एवं सूक्ष्मप्रवर्धन; तथा भ्रूण बचाव के माध्यम से अंगूर प्रजनन।

जैवरसायनविज्ञान संबंधी अध्ययन इस प्रकार हैं– लिपिड जैव–संश्लेषण में शामिल जीनों का विलगन; *बोगेनविलिया ब्यूटियाना* की पत्तियों से AVP/RIP के

कार्यशील क्षेत्र का गुणनिर्धारण; सोयाबीन से लिए गए *fad 2–1* जीन संलेपित ω-6 असंतृप्त का विलगन एवं गुणनिर्धारण; तथा जलवायु परिवर्तन द्वारा प्रभावित गेहूं की विभिन्न किस्मों में नाइट्रेट की कमी।

पादप शरीरक्रियाविज्ञान से संबंधित महत्वपूर्ण अध्ययन थे–उत्पादकता को सीमित करने वाली शरीरक्रियाविज्ञानी बाधाएं; फसलीय पौधों में अजैविक प्रतिकूलता के प्रति सहिष्णुता में सुधार; फलों, सब्जियों तथा फूलों का कटाई उपरांत शरीरक्रियाविज्ञान; वैश्विक जलवायु परिवर्तन के प्रति फसलों की प्रतिक्रिया के संबंध में उनका लक्षण वर्णन; गेहूं में जस्ते की दक्षता के संदर्भ में आनुवंशिक एवं फाइटोसाइडेरफोर उत्पादन का आनुवंशिक व उसका शरीरक्रियाविज्ञानी नियमन; उच्च फाइटोसाइडेरफोर उत्पादन के लिए गेहूं का आनुवंशिक रूपांतरण तथा जस्ते की कमी के तहत जस्ता दक्षता संबंधी गुणों का मूल्यांकन; और गेहूं की नई किस्मों के समग्र पौधे में नाइट्रोजन की घटी हुई मात्रा का प्रभाव आदि।

संस्थान में किए गए आनुवंशिक अध्ययनों में गेहूं, चावल, मक्का, बाजरा, चना, मूंग, अरहर, *ब्रैसिका* तथा सोयाबीन फसलों को शामिल किया गया। म्यूटेंट लीज़न और इसके व्यवहार से संबंधित कार्यप्रणाली के बीच पारस्परिक संबंध का अध्ययन करने के उद्देश्य से *ड्रोसोफिला मेलानोगैस्टर* के तीन विशेषकों *stm A2, stmAΔP 1, stmAPΔ 6* में 4.7 kbstmA अनुक्रम के अनुक्रमण का प्रयास किया गया।

कृषि भौतिकी में मृदा भौतिकीय सुदूर संवेदन तथा कृषि मौसमविज्ञान पर अध्ययन किए गए।

कृषि अर्थशास्त्र के तहत संस्थान में जिन विषयों पर अध्ययन किए गए उनमें प्रमुख हैं– भारत के गंगा–यमुना के मैदानों की ग्रामीण अर्थव्यवस्था पर मजदूरों के पलायन का प्रभाव; भारत में बागवानी जिंसों के लिए बाजार सूचना प्रणालीय स्तर, बाधाएं और संभावनाएं; दिल्ली में परि–नगरीय कृषि और उसका प्रबंधन; भारतीय कृषि पर व्यापार उदारीकरण का प्रभाव; गंगा–यमुना के मैदानों में संसाधन बचाव प्रौद्योगिकियों को अपनाने का खेत अर्थव्यवस्था पर प्रभाव; खाद्य सुरक्षा उपाय और भारत का बागवानी निर्यात; तथा भारत में बागवानी बाजारों का सह–समेकन।

कृषि प्रसार के तहत टिकाऊ विकास के लिए फार्मिंग प्रणाली अनुसंधान और प्रसार; कृषि प्रौद्योगिकियों के सामाजिक–आर्थिक तथा पर्यावरणीय प्रभाव का मूल्यांकन; प्रसार संगठनों की प्रभावशीलता को बढ़ाना; सहभागिता प्रसार कार्यप्रणाली का विकास और अंतर–क्षेत्रीय सूक्ष्म योजनाएं; कृषि प्रसार में सी ए एस के तहत आयोजित प्रशिक्षण कार्यक्रमों के प्रभाव का विश्लेषण; ग्रामीण संसाधन प्रबंध में क्षमता विकास मूल्यांकन; कार्यक्रम मूल्यांकन पर एक पायलट कार्य अनुसंधान; तथा आदिवासी क्षेत्रों के ग्रामीणों के पलायन की जांच एवं दुर्गम क्षेत्रों तक पहुंचना; आदि विषयों पर अध्ययन किये गए।

प्रौद्योगिकी मूल्यांकन एवं हस्तांतरण के अंतर्गत संस्थान द्वारा विभिन्न कृषि पारिस्थितिक क्षेत्रों में फसलों की उत्पादकता में सुधार लाने के लिए बहुत से कार्यक्रम आयोजित किए गए व अनेक अग्रणी प्रदर्शन आयोजित किए गए। दिनांक 23 फरवरी से 25 फरवरी, 2006 के दौरान वार्षिक पूसा कृषि विज्ञान मेले का आयोजन किया गया जिसका मुख्य विषय था ''दूसरी हरित क्रांति की ओर भारतीय कृषि अनुसंधान संस्थान के बढ़ते कदम'' । मेले का उद्घाटन श्री कांति लाल भूरिया, माननीय कृषि राज्य मंत्री, भारत सरकार ने किया। इसके अतिरिक्त संस्थान द्वारा परिसर से दूर प्रदर्शनियों/खेत–दिवसों तथा किसान दिवसों आदि जैसी प्रसार से जुड़ी अन्य गतिविधियों का आयोजन भी किया गया। संस्थान का कृषि प्रौद्योगिकी सूचना केन्द्र या एटिक 'एकल खिड़की आपूर्ति प्रणाली' के रूप में विभिन्न पणधारकों को उत्पादों, सेवाओं, प्रौद्यागिकियों और सूचनाओं को प्रभावी रूप में प्रदान करने में कार्यरत है।

संस्थान का शिकोहपुर, गुड़गांव, स्थित कृषि विज्ञान केन्द्र प्रौद्योगिकी सशक्तिकरण कार्यक्रम के माध्यम से ग्रामीण युवाओं में बेरोजगारी की समस्या से लड़ने में

महत्वपूर्ण भूमिका निभा रहा है तथा इसके साथ–साथ विभिन्न 'टी ओ टी' कार्यक्रमों के माध्यम से किसानों की चेतना और कृषि की उत्पादकता में सुधार लाने में संलग्न है।

संस्थान द्वारा महिलाओं के सशक्तिकरण और लिंग भेद जैसे मुद्दों पर अनेक गतिविधियों का आयोजन किया गया।

संस्थान का 44वां दीक्षांत समारोह 10 फरवरी, 2006 को आयोजित किया गया। इस समारोह में 67 एम.एससी. और 81 पीएच.डी. छात्रों को उपाधियां प्रदान की गईं। इसके अलावा, संस्थान द्वारा अनेक नियमित/अल्पावधि प्रशिक्षण पाठ्यक्रमों का भी आयोजन किया गया। कृषि सूचना प्रणाली और जैवसूचना प्रणाली ने एक बार पुनः संस्थान का ध्यान अपनी ओर आकर्षित किया।

भारतीय कृषि अनुसंधान संस्थान का पुस्तकालय छात्रों तथा वैज्ञानिक समुदाय को निरंतर अपनी सेवाएं प्रदान कर रहा है।

संस्थान की अधिदेशित गतिविधियों पर जानकारी के प्रसार के उद्देश्य से संस्थान द्वारा हिन्दी तथा अंग्रेजी दोनों भाषाओं में अनेक नियमित और तदर्थ प्रकाशन निकाले गए।

संस्थान द्वारा 9 पेटेन्टों के लिए आवेदन प्रस्तुत किए गए और दो समझौता ज्ञापनों को अंतिम रूप दिया गया। मैसर्स विश्वाजैल्स लिमिटेड (अर्थ इंटरनेशल प्राइवेट लिमिटेड का एक संभाग), नई दिल्ली को व्यवसायीकरण हेतु सुपर एब्जोरबेंट/हाई एब्जोरबेंट हाइड्रोजेल पर प्रौद्योगिकी का लाइसेंस दिया गया।

संस्थान का बहुत सी राष्ट्रीय और अंतरराष्ट्रीय संस्थाओं के साथ संपर्क एवं सहयोग जारी है।

EXECUTIVE SUMMARY

The Institute made significant contributions in its mandated areas of agricultural research, education and extension during the year 2006-2007.

In the area of crop improvement, several crop varieties were either released or identified.

In wheat, HI 1531 (Harshita), the first early maturing, high yielding, semi-dwarf bread wheat genotype developed for drought tolerance in central India, was released for rainfed as well as limited irrigation cultivation in the Central Zone. HI 1531, being nearly one week earlier in heading and maturity, compared to HW 2004, can escape frosting and terminal drought, ensuring stability in wheat production in Central Zone. A variety of *Triticum durum* wheat, HD 4713, was identified for cultivation in NCR, Delhi. The average yield of HD 4713 is 4.71 t/ha with a potential of 5.15 t/ha. Another high yielding variety HD 2894 was identified for release in Delhi state under timely sown irrigated conditions. It performed consistently better than checks over the years scoring first rank in five out of seven trials.

In rice, Pusa 1401-97-7-1-4 was identified by the IARI Variety Release Committee for release in Delhi state. It yielded 34.41% higher than *Taraori* Basmati and was judged better in quality based on appearance, cohesiveness, tenderness on touching and chewing, taste, aroma and elongation. Its panel score based on overall acceptability was 4.07 as compared to 3.96 of *Taraori* Basmati. It matures a week earlier than *Taraori* Basmati.

In maize, the first single cross maize hybrid AH 24003 for *rabi* condition from IARI was proposed for identification in three zones under early maturity group because of its consistently superior performance over that of the checks. Production potentiality of this variety is 7278 kg/ha, 5703 kg/ha, and 6910 kg/ha in zones II, III and IV, respectively. A maize hybrid AH 23029 showed mean superiority of 41% and 19% over the checks, Surya and Him 129, respectively, with a production potential of 5.5 t/ha in the coordinated trials.

In pearl millet, a hybrid, Pusa 751(MS 576 A × PPMI 23), performed well in the AICPMIP trial and completed 3 years of testing. A pearl millet composite population MP 443 (PPMP 579) performed well in A1 Zone in Advance Hybrid Population Trials during the 3rd year of testing in *kharif* 2005 of AICPMIP trials. It outyielded the best check CZP 9802 by 22.3% and showed good resistance against downy mildew disease.

In forage crop, a multi-cut forage sorghum variety Pusa Chari 615 was released for cultivation in the National Capital Region of Delhi. It gave an average of 70 t/ha of green fodder and 1.95 t/ha of dry fodder yield compared to 65 t/ha of green fodder and 1.85 t/ha of dry fodder yield given by the best check SSG 59-3. It also gave better seed yield (1.2 - 1.5 t/ha) compared to that (1 - 1.2 t/ha) of the best check PC 23. Its nutritious fodder has 8.07% protein, and 8.72 t/ha digestible dry matter with a 55.3% *in vitro* dry matter digestibility. The variety is tolerant to major insect-pests and foliar diseases.

In grain legumes, a bold seeded *Kabuli* chickpea variety BG 1108 was released and notified for commercial cultivation in the northern states of the country. The seed yield of the variety ranges from 2.5 t/ha to 3.5 t/ha. It is resistant to soil borne diseases. It has excellent cooking quality and is good for table purpose. Another bold seeded *Kabuli* chickpea variety BGD 128 (Pusa Shubhra), developed by the Centre for Pulses Improvement, Dharwad, was released by the Central Sub-committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops for commercial cultivation in Central Zone comprising Madhya Pradesh, Chhattisgarh, Maharashtra, Gujarat, parts of Rajasthan and Uttar Pradesh. It is a very high yielding variety with an average grain yield of 1.9 t/ha, which is 21.3% higher than that of the best check. BGM 547, a *desi* chickpea mutant, was released and notified for North Western Plains Zone for late sown conditions. The average grain yield is 1.8 t/ha with a potential yield of 3.1 t/ha. It has bolder seeds (100-seed weight > 25.1 g) with attractive golden brown colour, thin testa (preferred by the consumers), good taste and cooking quality. It has a medium maturity period (135 days), and is tolerant to wilt, root rot, stunt diseases and pod borer. A bold seeded *Kabuli* variety Pusa 2024 was identified for NCR, Delhi. The variety has a moderate resistance to soil borne diseases, and resistance to moisture stress and high temperature. It has excellent cooking quality and is good for table purpose.

A lentil variety L 4594 was released and notified for

commercial cultivation in NCR, Delhi. This variety has medium growth habit, and smaller seeds with orange cotyledons, and is resistant to rust. Another lentil variety L 4596 was identified for release in NCR, Delhi. The variety with an average seed yield of 2.12 t/ha is dwarf in height, and has erect growth habit.

A pigeonpea variety Pusa 2001 was released for cultivation in NCR, Delhi. The grain yield of the variety is 1.87 t/ha with a maturity duration of 145 days and a 100-grain weight of 8.2 g. Another pigeonpea variety Pusa 2002-2 was identified for North Western Plains Zone. The variety gives 1.67 t/ha of grain yield against the yield of the best check (1.5 t/ha) and matures early in 143 days (UPAS 120: 160 days, and Pusa 992: 148 days).

In oilseed crops, a *Brassica carinata* variety NPC 9 was released for commercial cultivation in NCR, Delhi for rainfed and marginal areas. The average performance of this variety was 1.4 t/ ha under rainfed conditions in the experimental trials and 1.33 t/ha in farmers' fields. It has high oil (40%) and protein (19.7%) contents. It is immune to downy mildew, resistant to white rust and tolerant to Alternaria blight, Sclerotinia stem rot, and powdery mildew. The variety is also tolerant to aphid under field conditions. EJ 13 (Pusa Tarak), an early maturing and non-shattering Indian mustard variety, was released by the Delhi State Seed Sub-committee for NCR, Delhi. The variety is bold seeded among the early maturing mustard (6.2 g/1000 seeds). The average seed yield is 2.9 t/ ha with 40% oil content.

Four mustard varieties, LES 1-27 (Pusa Mustard 21), LET 17 (Pusa Mustard 22), NPJ 93 (Pusa Vijay) and EJ 14 were identified. LES 1-27 with a yield potential of 2.7 t/ha was identified for NCR, Delhi. The variety LET 17 having low erucic acid content (2.0%) yields higher than the conventional checks, Varuna, Kranti and RL 1359 by 32.4%, 6.1%, and 9.4%, respectively. Its mean seed yield is 2.10 t/ha with a potential yield of 2.75 t/ha. It was identified for Zone II with the condition of verification of erucic acid data. NPJ 93 was identified for NCR, Delhi for timely sown irrigated conditions. The average yield of this variety under optimum conditions was 2.4 t/ ha. EJ 14 was identified for NCR, Delhi. It gives an average yield of 2.0 t/ ha, matures in 100 days and is a good substitute to *toria*.

A soybean variety Pusa 9814 was released for cultivation in Northern Plains Zone. It has resistance against yellow mosaic, soybean mosaic virus, pod blight, charcoal rot and moderate resistance to stem fly. The average yield of Pusa 9814 is 2.25 t/ha and the yield potential is 3.4 t/ha.

A *Gossypium hirsutum* variety Pusa Arvindam was released for West Bengal. It has compact plant type, resistance to cotton leaf curl virus disease and tolerance to jassid. It is very early in maturity (130-135 days) and is recommended for rice fallows in the coastal region of West Bengal (Sunderbans) during *rabi* season. It gave an average seed cotton yield of 1.18 t/ha as compared to 0.86 t/ha of the check variety LRA 5166. The fiber quality of PSS 2 was on a par with that of the check LRA 5166.

In vegetable crops, many successful trials were conducted involving cole crops, cucurbits, solanaceous crops, root and bulbous crops, leguminous, and malvaceous crops.

In fruit crops, two new promising mango hybrids, namely, H1-1 and H 1-6, were identified for release. Both these hybrids are regular bearing with red peeled fruits having good shelf-life, suited for export market. Other hybrids which are performing consistently well are H 2-6, H 4-12 and H 8-11. Evaluation trials were also conducted in grape, citrus, papaya, pomegranate, *aonla*, apple, apricot, kiwifruit, pear, strawberry, and walnut.

A promising apple rootstock identified at the Institute's regional station at Tutikandi (Shimla), was made available to progressive growers to obtain the response of the orchardists to this new rootstock. This rootstock was observed to produce semi dwarf, semi vigorous apple tree and is resistant to woolly aphid, powdery mildew and apple scab. In walnut, a unique clone christened Pusa Khor was identified and evaluated. Its fruits appear to be borne in lateral position as well as terminally. The nut is thin shelled with 50% kernel recovery. The kernel colour is light yellow with 55% oil percentage and good taste.

In ornamental crops, two rose hybrids numbered as IFL-B14-R10 and FL-B12-R12 were identified for release. Improvement work also continued on gladiolus, chrysanthemum, marigold, tuberose, bougainvillea, gerbera and lilium. The rooting medium having 1000 ppm each of IAA and IBA was standardized for five difficult to root cultivars of bougainvillea, namely, Mahara, Shubhra, Cheery Blossom, Lady Marry Baring and Dr. R.R. Pal. Significant differences were observed among the five cultivars in respect of rooting percentage, number and length of primary roots, plant height, number of branches per plant and length of branches. Maximum rooting percentage (67%) was recorded in cv. Mahara followed by Dr. R.R. Pal (65%) whereas minimum rooting percentage (63%) was found in Shubhra.

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.

About 500 g seeds along with passport data of each of the following identified wheat stocks were deposited for medium term storage with NBPGR: WR 1392, WR 1421 and WR 1387 for tillers per meter**;** and WR 1408, RD 1018, RD 1008, RD 1009, RD 1063, and RD 1095 for 1000-grain weight. Five winter genotypes of wheat, viz., Flinor, Festival, Jingdongi, Mega and Maris-Huntsman, were identified as new sources of resistance against two virulent pathotypes (46S119 & 78S84) of stripe rust. Two new genotypes, HS 424 and HS 431, were identified and confirmed as resistant source for leaf and stem rusts as these two genotypes were found to be resistant against all the pathotypes of leaf and stem rusts. In an effort to develop varieties for diversified uses, new initiatives were taken up to develop sweet corn, popcorn, baby corn and maize lines with starch specific components.

In citrus, several indigenous and exotic species/strains were collected and evaluated under Delhi conditions. During the year, two genotypes of papaya were added in germplasm block.

Under the research on microbial genetic resources, twelve new isolates from the soils of Chhattisgarh were added to the culture collection. More than eighty blue green algal strains were isolated from paddy fields of India, including sixteen isolates from low fertilizer input *basmati* rice soils.

Under the Institute's work on biosystematics and identification services, five hundred ninety-seven fungal specimens were accessioned in HCIO during 2006 raising the total number of specimens to 46,619.

Ectendomeliola walsurae gen. et. sp. nov. of the family Meliolaceae was described on *Walsura trifolia; Vanibandha sundara* gen. et. sp. nov., a new anamorphic hyphomycetous fungus, was described on fallen twigs; and *Corynecercospora teraiensis* gen. et. sp. nov., a new hyphomycetous fungus, was described on *Eleodendron glaucum* L.

Thirteen new species of anamorphic powdery mildews, viz., *Oidium alysicarpe, O. buddleiae, O. cocculus, O. launeae, O. ocimi-sanctum, O. sesame, O. sesbaniae, O. sidae, O. spiraeae, O. brassicae, Oidiopsis solani, Ovulariopsis malloti* and *Cystotheca quercina,* were proposed. A perfect state of powdery mildew was also described on *Quercus incana***.** Seven new species of hyphomycetous fungi, viz., *Trichocladium sigmoidea, T. palmae, Acrodictys elliptica, A. lignicola, Cheiromyces ananthgiriensis, Memnoniella mohanramii* and *Zygosporium anupamvarmae,* were created. Eight new species of Meliolaceous fungi, viz., *Meliola cynanchi, M. pterigotae, M. strombosiae, M. emespatilii, Asterina loranthigena, A. toddaliicola, Asterostomella otonephelii* and *A. strombosiae,* were proposed. *Meliola desmodii-laxiflore* var. *indica, and M. tabernaemontanae* var. *wrightiae* are new varieties described from India. Four new species of dematiaceous hyphomycetous fungi, viz., *Sporidesmium mehrotrai, S. curvula, S. lageniforme* and *S. uncinatus,* were proposed.

The Indian Type Culture Collection (ITCC) was enriched by a new addition of 55 different fungal cultures. Some noteworthy plant pathogens accessioned include *Aspergillus amstelodermi* from *Lentinus edodes*; *Pleurotus flasida, P. cryngii, P. ostreatus, Hyphazyius ulmarius, Fusarium equisitii, Alternaria alternata* and *Nigrospora oryzae* from Jatropha; *Xylochia oryzae* sp. nov. from rice seed; *Byssochlamys nivea, and Gilmaniella humicola* from *Aloe vera; Fecundostilbum sacchari* gen. nov. from sugarcane; *Phomopsis delbergia* from *Delbergia sissoo; Phoma albizziae* from Albizia causing dieback; *Pencillium aurentiogriseum* from gladiolus bulb; *Rhizoctonia solani* from garlic and tobacco seedlings; and *Glomerella singulata* along with its anamorph *Colletotrichum gloeosporoides* from passion fruit.

Under identification services, one hundred fifty-one fungal cultures/specimens were identified up to species level. Some of the important fungi identified during the period were: *Geotrichum candidum* from kinnow; *Beavaria bassiana* from stone weevils; *Pestalotia palmarum* from guava fruit; *Fusarium equisetii* and *F. pallidoroseum* from *Jatropha*; and *Drechslera* and state of *Cochiliobolus nodulosus* from *ragi* grain.

A new fungus of Stilbellaceae, *Fecundostilbum saccharum* sp. nov., *was* described from the leaves of *Saccharin officinarum.*

As integral to the studies on insect biosystematics, 1064 insect specimens were identified under the insect identification service. Twenty-seven Indian species under 16 genera of subfamily Formicinae were redescribed.

Systematic studies on economically important Hemiptera resulted in the compilation of checklists of two subfamilies, viz., Dinodoridae and Peiratinae (Reduviidae). A new bug species *Megymenum khasiensis* was established and described. Three type-species, *Coridius janus* (Fabricius),

Cyclopelta obscura (Lepeltier & Serville) and *Catamiarus brevipennis* (Serville), and six other species of Hemiptera, namely, *Coridius brunneus* (Thunberg), *Megymenum parallelum* (Vollenhoven), *Gellia nigripennis* (Dallas), *Ectomocoris atrox* (Stal), *Peirates affinis* (Serville) and *P. lepturoides* (Wolff), were redescribed along with morphometrics and illustrations of their important taxonomic characters for the first time from India.

Under nematode biosystematics and identification services, three new species of agriculturally beneficial predaceous nematodes of the order Mononchida, namely, *Parahadronchus mangiferi, Miconchus sardhanensis,* and *Prionchulus prasadi,* from the rhizoshere of mango being grown in Meerut, Uttar Pradesh, were described. The type specimens were deposited in the National Nematode Collection of India (NNCI).

A symbiont (*Xenorhabdus indica*) and a non-symbiont (*Providencia vermicola*) associated with entomopathogenic nematode *Steinernema thermophilum,* which are the first new species of these genera from India, were described. The species were erected based on their morphological, cultural, biochemical and molecular characteristics.

The complete ITS region of rDNA of *S. thermophilum* of 997 bp was amplified and sequenced. The sequence was deposited in the GenBank, NCBI, vide Accession No. DQ665651.

Identification aids for 14 species of root-knot nematodes, *Meloidogyne* spp., and 46 species of entomopathogenic nematodes of the genus *Steinernema,* were developed in the form of tabular compendia and dichotomous keys, and the distribution of species in India was mapped.

The NNCI was augmented with 215 wet suspensions, and 18 type slides of 8 newly described nematode species. Existing database of NNCI was updated and converted into user-friendly Decision Support System (DSS) format.

Altogether 67 nematode specimens of plant parasitic, free living and entomopathogenic nematodes received from Gujarat, J. & K., U.P., Kerala and Karnataka, were identified. The important identified species were: *Meloidogyne javanica*, *Xiphinema insigne, Steinernema bicornutum, S. carpocapsae, S. feltiae, Heterorhabditis indica* and *H. bacteriophora*.

Under the research on crop and resource management and environment, many important studies were conducted. The agronomic study covered: effect of preceding short duration forage crops and gypsum-enriched urea on productivity of aromatic rice; response of wheat to N fertilization under varying tillage and crop establishment practices in mungbean-wheat cropping system; direct and residual effect of applied nutrients on mungbean–mustard cropping system; comparative performance of Bt and non-Bt genotypes of cotton under different tillage systems; effect of nitrogen and sulphur levels on canola and non-canola type rapeseed mustard; response of soybean to sulphur and boron nutrition; effect of land configuration and method of irrigation on productivity, weed control and water use efficiency of sunflower-based intercropping system; performance of Indian mustard as influenced by date of sowing and level of aqua-fertilization under rainfed conditions; agronomic evaluation of urea coated with neem oil components at varying doses in aromatic rice; nutrient management through organic sources in cauliflower-based cropping systems; phosphorus management in pigeonpea-wheat cropping system; performance of a new wheat genotype at different dates of sowing under irrigated condition; comparative evaluation of well performing and established normal sown and late sown varieties of North Eastern Plains Zone under different dates of sowing; evaluation of suitable wheat varieties under conventional tillage and zero-tillage conditions; and effect of seed treatment with *Azatobactor* and PSB culture on wheat.

In seed science and technology, several important studies were conducted. These were: pollination studies in hybrid rice seed production; quality seed production of vegetable crops under drip and surface irrigation; hybrid seed production technology in tomato; hybrid seed production technology in cauliflower; hybrid seed production in bottle gourd; effect of sowing time and cutting management on seed yield and quality of *berseem* seed; effect of bulb size and integrated nutrient management in onion seed crop; integrated nutrient management in onion bulb production; nicking behaviour of parental lines of PRH 10 for hybrid rice seed production; effect of production seasons on seed quality of quality protein maize; morphological and molecular characteristics for DUS testing in maize; seed vigour and its enhancement; physical, physiological and biochemical factors for seed longevity in soybean; effect of different priming treatments on germination and vigour in capsicum; effect of seed treatment on seed quality and yield components of rice infected with *Bipolaris oryzae*; effect of magnetic field treatment of seeds on root and shoot characteristics of maize seedling; microwave energy for reducing hard coat dormancy in fodder legume *Stylosanthes seabrana*; and seed testing protocols for medicinal crops.

At the Seed Production Unit of the Institute (Delhi) and at the Institute's regional stations at Karnal, Pusa, Indore and Katrain, nucleus, breeder and IARI seeds of different varieties of cereals, pulses, oilseeds, vegetables and ornamental crops were produced during the year under strict quality control. Apart from seed production, 845 saplings of fruits and flowers were produced at the Seed Production Unit (Delhi). At the Regional Station, Karnal, about 5500 horticultural plants were produced. At Regional Station, Pusa (Bihar) about 3372 seedlings of papaya (cv. Pusa Dwarf) were produced.

Under soil management, several studies were conducted on dynamics of soil organic carbon under different agricultural management practices and land uses; estimation of crystallite size and crystal strain of micaceous minerals of different soils; stability of clay–humus complexes; long-term effect of rice cropping on clay mineral compositon of soil; stability of clay minerals in relation to pedogenic progression in different agro-ecosystems; inter-relationship between boron and sulphur as measured by crop response and soil analysis; effectiveness of adsorption isotherms for determining the sulphur requirements of mustard; biological mobilization of potassium from waste mica; soil biodiversity assessment for enhancing carbon sequestration and nitrogen cycling; fertilizer nitrogen use efficiency by wheat grown under elevated levels of atmospheric carbon dioxide; phosphatase activity and organic phosphorus mobilization in rhizospheres of rice and wheat grown under elevated atmospheric carbon dioxide; and management of agricultural wastes as a source of plant nutrients – monitoring of nutrient transformation during enriched composting.

Under water management, studies were conducted on surface irrigation; meteorology; watershed; application of modern tools (remote sensing); irrigation agronomy; pressurized irrigation studies; aerobic rice cultivation; water quality studies; and isotopic and hydrochemical models for vulnerability assessment of overexploited groundwater.

Important studies were conducted on integrated nutrient management and nutrient availability. These were on: evaluation of enriched organo-mineral fertilizers on crop productivity and soil fertility in a soybean-potato cropping sequence; response of sulphur on seed yield and quality in mungbean-mustard sequence; long-term effects of application of manures and fertilizers on soil environment under maize-wheat cropping system; basic data and soil test-based fertilizer recommendations for wheat and pearl millet; integrated nutrient management in pigeonpea–wheat system; sustaining soil health for increasing productivity and quality of crops through integrated nutrient supply and management; release and uptake of phosphorus from some organic materials in wheat-blackgram sequence by the use of tracer; assessment of oil content and oil yield of mustard grown under pearl millet–mustard cropping sequence; integrated nutrient management in fruit crops; soil fertility status in different agro-ecological regions; zinc and phytate contents in wheat genotypes; and reversion of applied zinc in soils into unavailable forms.

Under rice-wheat cropping system, the Institute's conducted studies on: carbon storage and mineralization under rice-wheat system as influenced by tillage and integrated nutrient management; nitrogen use efficiency in rice under conventional and raised bed-planting; evaluation of below ground root biomass and nitrogen in wheat; and fertilizer N application based on chlorophyll index in wheat and rice.

In orchard management practices, the Institute conducted studies on: salt tolerance in citrus rootstock; rootstock-scion interaction in citrus; standardization of micro-irrigation and fertigation schedules for apple; standardization of fertilizer dose for high density Amrapali mango; and organic cultivation in fruit trees.

Under protected cultivation, a virus-free tomato crop (var. GS 600) was grown successfully under insect-proof net house fabricated by using 40 mesh U.V. stabilized nylon net for a period of 6 months (August to January). Fruit yield of 1.5 t/300 m^2 was harvested and the crop was 98% virus free. Pesticide application was minimized and mainly used against vector white fly and fruit borer during rainy and post rainy seasons. The cost: benefit ratio of tomato cultivation under insect-proof net house was worked out as 1:2.15 under Delhi conditions. Other studies conducted were on: effect of foliar spray of micronutrients on plant growth and fruit yield of greenhouse grown sweet pepper; effect of fruit thinning on fruit quality in greenhouse tomato; comparative performance of tomato grown in evaporatively-cooled and naturally ventilated greenhouses; studies on brassinosteriod response on off-season chrysanthemum in greenhouse; fertigation scheduling and nutrient dynamics in cabbage; effect of vent area on the temperature and humidity in a naturally ventilated greenhouse; vegetable production under green house and white shade net house; and drying of bio-materials.

A survey was conducted in and around NCR for assessment of the use of different plasticulture and protected cultivation applications. The survey sites belonged to

farmers' fields, farmhouses and landscaping units, research institutions, etc. Greenhouses, and more prevalently shade nets, were used in these regions for crop cultivation. Multispan and Quonset type greenhouses were mainly used in these regions for the cultivation of high value vegetables, herbs, and flowers, and for nursery raising.

The Institute developed several farm related equipment, machinery and technology for optimizing crop production and reducing drudgery. A pulse polisher consisting of roller, concave, feed hopper and frame, was developed for polishing of pigeonpea *dal*. A small capacity rice mill consisting of rubber roll sheller, blower for husk separation, and polisher, was developed last year. This year, it was integrated with a grader. An earlier developed peristaltic pumping based aqua-ferti-seed drill (AFSD) was modified based on field tests and suggestions of farmers obtained during the demonstration of the machine in actual field conditions in Haryana and Rajasthan. An onion detopper developed earlier was modified. An inter-cultivator propelled by 2.8 kW engine was developed for row crops. A hand operated roller flaker was developed for cereals and pulses. The Institute also developed a maize roasting machine. It would be used to evaluate the roasting characteristics of IARI developed varieties of maize. There are 800 million hand tools used on Indian farms by 240 million farm workers. The Institute did ergonomic evaluation of farm hand tools, and developed an intervention in the form of finger guard made of teflon cloth to prevent hand tool injuries. Information on general mechanization status in Uttar Pradesh and farm machinery use protocol in Muzaffarnagar district was collected to know the mechanization gaps and steps needed to ensure proper use of agricultural machines to enhance crop productivity in the study area.

Important studies were also conducted by the Institute in post-harvest technology and management of different crops. These were: maturity studies in mango; tree age and fruit quality studies in guava; studies related to modified atmosphere packaging of IARI developed bittergourd, modified atmosphere packaging of marigold flowers, and bio-efficacy trials of smart fresh in mango cvs. Dashehari and Chausa; studies on the feasibility of heat shrinkable films for extending shelf-life of apple, screening of onion genotypes for dehydration; optimization of sugar concentration and temperature for osmotic dehydrated mango slices; *jamun* juice concentrate and storage study; evaluation of carrot cultivars for dehydration purposes and nutritional quality; effect of packaging on osmotic dehydrated *aonla* segments; phenolics as natural ingredients for enhanced oxidative stability in foods; functionalised frozen carrot slices; storage of irradiated pulp for beverage preparation; physical properties of maize; enzymatic pre-treatments of pigeonpea *dal* for reducing the cooking time; investigation on the effect of chemical treatments and flaking on reduction in cooking time of selected varieties of pigeonpea; standardization of drying techniques for marigold; and biophysical characterization of plant responses and post harvest quality preservation of agri-products.

In microbiology, important studies were conducted on recycling of agricultural residues and their utilization in sustainable and organic agriculture; exploitation of microorganisms for crop production; molecular characterization of agriculturally important microorganisms; exploration and exploitation of cyanobacterial genetic resources for agriculture and industry; genetic evaluation of cyanobacteria for H_2 production and N_2 fixation; development and contribution of BGA inoculant in low fertilizer input *basmati* rice; interactive potential of BGA/*Azolla* and other bioinoculants in rice-wheat-mungbean cropping system; bioremediation of wastewaters by the use of *Azolla*; and development of PCR based markers for *Anabaena*.

The major studies related to environmental sciences were on spatial mapping of the global warming potential from rice paddies; impact of tillage management on global warming potential (GWP) of soils under rice-wheat cropping; evaluation of nitrification inhibition potential of *Jatropha* products; temperature dependent response of soil CO_2 efflux in different physiographic regions of India; effect of heat stress on growth and yield of different crops; impact of temperature on pollen sterility in wheat; impact of increasing temperature on wilt in chickpea; agri-management of *Jatropha*; bio-ethanol from maize and sorghum; solid-state fermentation technology for biogas production; impact assessment of cry1 Ac (Bt toxin) of Bt cotton on underground ecosystem; evaluation of irrigation and nutrient potential of agro-industrial effluents and identification of crop varieties suitable for agro-industrial effluent irrigations; quantification of heavy metal load in peri-urban agriculture; phytoremediation of heavy metals through non-edible commercial crops; upgradation of an environmental impact assessment tool; effect of ameliorants on the transference of nickel to food chain; impact of heavy metal contamination on soil biota and its remediation; evaluation of *Brassica* species as phyto-extractors of copper and nickel; and effect of potassium fertilizer application on transfer factor of $^{137}C_s$ in rice.

Under crop protection, important findings were made in

plant pathology, entomology, nematology, and agricultural chemicals.

In plant pathology, findings were made on fungal diseases affecting wheat, rice, maize, chickpea, urdbean, mungbean, pigeonpea, rapeseed and mustard, vegetables, fruit crops, and large cardamom. Research was also conducted on viral diseases leading to many important findings. PCR detection of greening bacterium and *Citrus yellow mosaic virus* (CMBV) in citrus tissues was standardized using a simplified template preparation protocol. Strain improvement studies were also conducted in edible mushrooms.

In entomology, insect-pest management studies were conducted on cereals, oilseeds, vegetables, soybean, and pulses. Other studies covered storage entomology, biological control, insect physiology and toxicology.

In nematology, important studies were made on biodiversity, molecular characterization, mechanism of resistance, and management.

In agricultural chemicals, important research was conducted on development of natural and synthetic agrochemicals and their adjuvants; pesticide formulation; and pesticide risk assessment, environmental fate of pesticides, and remedies.

Under weed management, studies were conducted on integrated weed management in onion; comparative effect of soil solarization, herbicides and incorporation of various plant materials on weed growth and productivity of soybean; and effect of planting methods and herbicides on weed control and productivity of wheat.

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

In plant biotechnology, the studies were on development and testing of Bt brinjal; tomato genome sequencing; marker assisted selection for bacterial blight resistance genes in rice; development and molecular characterization of an improved CMS line of *Brassica juncea*; molecular characterization and micropropagation in fruit crops; and grape breeding through embryo rescue.

In biochemistry, studies were conducted on isolation of genes involved in lipid biosynthesis; characterization of functional domains of AVP/RIP from the leaves of *Bougainvillea xbuttiana*; isolation and characterization of *fad2-1* gene encoding ω-6 desaturase from soybean; and nitrate reductase in various cultivars of wheat as affected by climatic changes.

In plant physiology, important studies were made on physiological constraints limiting productivity; improvements in abiotic stress tolerance in crop plants: physiological approaches; post-harvest physiology of fruits, vegetables and flowers; characterization of crop responses to global climate change; genetic and physiological regulation of phytosiderophore production in relation to zinc efficiency in wheat; genetic transformation of wheat for high phytosiderophore production and evaluation for zinc efficiency traits under zinc deficiency; and ontogenic changes in reduced nitrogen content of the whole plant of new wheat types.

The genetic studies conducted at the Institute covered the crops, wheat, rice, maize, pearl millet, chickpea, mung bean, pigeonpea, *Brassicas*, and soybean. An attempt was made to sequence the 4.7 kb stmA sequence in three alleles (*stm A2, stmAPΔ 1, stmAPΔ 6*) of *Drosophila melanogaster* in order to study the relation between the mutant lesion and its functional relation to behavior.

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

In agricultural economics, the Institute conducted studies on labour migration and its impact on rural economy of Indo-Gangetic Plains of India; marketing information systems for horticultural commodities in India: status, constraints and prospects; study on peri-urban agriculture and its management in Delhi; impact of trade liberalization on Indian agriculture; adoption and impact of resource conserving technologies on farm economy in Indo-Gangetic Plains; food safety measures and India's horticultural exports; and cointegration of horticultural markets in India.

In agricultural extension, studies were conducted on farming systems research and extension for sustainable development; assessment of socio-economic and environmental impacts of agricultural technologies; enhancing the efficiency of extension organization; development of participatory extension methodology and intersectoral micro-plans; impact analysis of training programmes conducted under CAS in agricultural extension; evaluation capacity building in rural resource management: a pilot action research on programme evaluation; and reaching un-reached areas and checking rural migration from tribal areas.

Under technology assessment and transfer, the Institute made several interventions to improve the productivity of the crops in different agro-eco regions. Several front-line demonstrations were conducted. The annual *Pusa Krishi*

Vigyan Mela was conducted from February 23 to 25, 2006, on the theme "IARI's March Towards Second Green Revolution". The *mela* was inaugurated by Shri Kanti Lal Bhuria, Hon'ble Minister of State for Agriculture, Government of India. The Institute also conducted several other extension related activities like off-campus exhibitions/ field days, farmers' day, etc. The Institute's Agricultural Technology Information Centre (ATIC) continued to work as a 'Single Window Delivery System' for effectively providing products, services, technologies and information to different stakeholders.

The Institute's Krishi Vigyan Kendra at Shikohpur, Gurgaon, continued to play a vital role in combating unemployment of rural youth through technological empowerment, and by improving the farmers' awareness and farm productivity through various TOT programmes.

The Institute continued to give emphasis on empowerment of women and mainstreaming of gender issues through various activities.

The 44th convocation of the Institute was held on February 10, 2006. At this convocation, 67 M.Sc. and 81 Ph.D. students were awarded degrees. The Institute also conducted several regular/short-term training courses. Agri-informatics and bio-informatics continued to receive the Institute's 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, in order to disseminate information on the Institute's mandated activities.

The Institute filed applications for nine patents, and signed two MoUs. A technology on super absorbent/high absorbent hydrogels was licensed for commercialization to M/s Vishwagels Limited (a division of Earth International Pvt. Ltd.), New Delhi.

Linkages and collaborations existed with several national and international institutions.

1. CROP IMPROVEMENT

1.1 CEREALS

1.1.1 Wheat

1.1.1.1 Varieties released

HI 1531 (Harshita). The first early maturing, high yielding, semi-dwarf bread wheat genotype HI 1531 (Harshita) developed for drought tolerance in central India, was released in 2006 for rainfed as well as limited irrigation cultivation in the Central Zone. Late maturity of other popular varieties of this zone, viz., Sujata and HW 2004, hindered their spread to Gujarat, southern Rajasthan and Malwa tract of Madhya Pradesh, which are prone to frosting and terminal drought at maturity. HI 1531, being nearly one week earlier in heading and maturity, compared to HW 2004, can escape frosting and terminal drought, ensuring stability in wheat production in Central Zone. It yielded 4.5 t/ha in farmers' fields with just two irrigations.

1.1.1.2 Varieties identified

HD 4713. A variety of *Triticum durum* wheat, HD 4713, based on its consistent performance for three consecutive years in coordinated trials, was identified for cultivation in NCR, Delhi. The average yield of HD 4713 is 4.71 t/ha with a potential of 5.15 t/ha. This variety is suitable for pasta products as the average yellow berry incidence is only 2.8%. The variety also possesses the band 45 for γ-Gliadin, which is a desirable trait.

HD 2894. The high yielding variety HD 2894 was identified for release for cultivation in Delhi state under timely sown irrigated conditions. HD 2894 performed consistently better than checks over the years scoring first rank in five out of seven trials. Its yield superiority ranged from 8.6% to 17.1%. The variety is in non-1B/1R genetic make up imparting non-sticky dough along with acceptable grain quality. The variety also brings in diversity in leaf rust resistance by deploying *Lr13*, an APR gene.

1.1.1.3 Entries in pipeline

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

Trials	Entry Names/ Numbers
Advance Varietal Trials (AVTs)	HD 2940 (AVT-II), HD 2959, HD 2952, HD 2962, HD 2963, HD 2964 (SHZ), HD 2954, HD 2956 (NEPZ), HD 2956 (CZ), HD 2937 (NHZ), HD 2946 (NWPZ), HD 2955 (NEPZ), HD 2930 (CZ), HD 2932 (CZ, PZ, NEPZ), HD 2930, HD 2932, HD 2957 (AVT, RI, PZ), HD 4717 (AVT, TS, NWPZ),
National Initial Varietal Trials (NIVTs)	HD 2975, HD 2979, HD 4719 *(T. durum)*, HD 2968, HD 2969, HD 2971, HD 2974, HD 2976, HD 2977, HD 2980, HD 2981, HD 2993, HD 2995, HD 2996, HD 2990, HD 2992, HD 2967, HD 2970, HD 2972, HD 2973, HD 2978, HD 2983, HD 2984, HD 2994, HD 2986, HD 2987, HD 2989, HD 2982, HD 2985, HD 2991 (IVT SHZ)
NIVT (Triticale)	DT 171, DT 172, DT 173 *(Triticales)* (NIVT), DT 174, DT 175, DT 176, DT 177 (IVT North Hill Zone)
Common Varietal Trials	108
Station Trials	280

The following wheat genotypes developed at IARI Regional Station, Indore are being tested in advanced varietal trials:

Genotype	Zone	Cultivation condition
T. aestivum		
HI 1539	NEPZ	Irrigated timely sown
HI 1544	CZ	-do-
T. durum		
HI 8663	CZ and PZ	Irrigated timely sown
HI 8671	CZ and PZ	-do-
HI 8672	PZ	-do-
HI 8673	PZ	-do-
HI 8678	CZ	Rainfed and limited irrigation

It may be noted that *durum* genotypes, HI 8663 and HI 8671, having wider adaptability performed well across two agroclimatic zones.

Under early October sown conditions, advanced line V 21-23 gave 5.1 t/ha yield of high quality grain (60.7 g-1000

grain weight, 12% protein, and 7.3 ppm â-carotene), as against the check varieties HI 8627 (4.7 t/ha grain yield, 12.7% protein, and 5.6 ppm â-carotene) and Lok 1 (3.8 t/ha grain yield, 12.8% protein, and 2.4 ppm â-carotene) with four irrigations. Newly released bread wheat cultivar Harshita (HI 1531) gave 5.0 t/ha grain yield with 10.8% protein, and 3.0 ppm â-carotene content. V 21-78 (7.8 ppm) and V 21-79 (7.4 ppm), the two advanced *durum* lines, were found to have high â-carotene content. Thus, high yields of good quality grain can be achieved under early October sown conditions with just four irrigations.

Four advanced *durum* lines, S 16-82, S 16-83, S 16-91 and S 16-93, with earliness and fair levels of rust resistance were selected for late sown conditions. S 16-91 gave 4.65 t/ha grain yield with 54.8 g 1000-grain weight, as against Lok 1, which gave 4.51 t/ha grain yield and 50.5 g 1000-grain weight.

Out of 42 *durum* wheat genotypes planted in December, 22 were significantly superior to the *aestivum* check DL 788-2 in grain yield with genotypes, ID 58, ID 519 and ID 51 performing better than other genotypes. It was also observed that *durum* wheat genotypes yield better than the *aestivum* varieties under late sown conditions with 2 or 3 irrigations (mean yield of 3.36 t/ha in *durums*, against the mean yield of 2.9 t/ha in bread wheat varieties). Under late sowing, the grain weight reduced both in *aestivum* and *durums*, whereas â–carotene and protein contents showed an increasing trend due to cool conditions prevailing during grain filling.

Vernalization experiments confirmed that long vegetative phase under high temperatures is related to the vernalization requirement of the variety justifying the introgression of winter wheats. Long vegetative phase ensures a high biomass even under high temperatures, which ultimately results in high yields.

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

The following entries developed at IARI Regional Station, Pusa were advanced to the all India coordinated wheat improvement trials:

Entry	Zone	Condition	Trial	Remarks
HP 1900 (HD 2733/CP.305.RK-45)	NEPZ	Irrigated (TS)	AVT	
HP 1903 (PBW 343/RAJ 3765// HW 2045)	NEPZ	Irrigated (LS)	AVT	
HP 1894 (PBW 343/HP 1761// HW 2045)	NWPZ	Irrigated (TS)	AVT	Ranked I in NIVT-1A (2005-06)
HP 1896 (HD 2733/HP 1761)	NWPZ	Irrigated (TS)	AVT	
HP 1907 to HP 1915 (9 entries)	-	-	NIVT	HP 1910 is particularly good with reference to uniformity and adaptability
PS 830 to PS 876 (41 cultures)	-	-	CVT	To conserve wide genetic base and to evaluate Res-genes

HW 1095, a dwarf *dicoccum* developed at IARI Regional Station, Wellington using nuclear technique was promoted to AVT-1 based on its high yielding potential. This variety confers a high degree of resistance to stem and leaf rusts and moderate resistance to stripe rust. High yielding dwarf *dicoccum* wheat varieties, HW 5304 and HW 2308, carrying effective recessive resistance gene are in IVT special *dicoccum* trials. Wheat variety HW 3094 carrying specific rust resistance genes for all three rusts and tolerant to heat was promoted to AVT, Central Zone, and another variety HW 5030 to North Eastern Plains Zone, for late sown conditions. Rust resistant, high yielding wheat varieties, HW 5044*, HW 5021*, HW 5205, HW 5204, HW 5206, HW 5207, HW 5208, HW 5209, HW 5102, HW 5103 and HW 5104, which carry specific rust resistance genes are being currently tested in AVT trials at Southern Hills Zone (SHZ).

Among several of the interspecific and intergeneric derivatives, 60 promising bread wheat lines were isolated. Based on preliminary observations, two entries, viz., WSD 001 and WSD 002, were entered in the CVT trials of IARI in SHZ.

Cytological characterization of the first intergeneric hybrid between wheat and maize was completed. Molecular characterization using SSRs is in progress.

HS 461, a facultative genotype developed at IARI Regional Station, Tutikandi (Shimla), was promoted to final year of testing in coordinated trials under summer season of very high altitude of Northern Hills Zone. Genotypes, HS 491 and HS 492, under early sown, rainfed, and genotypes, HS 490 and HS 493, under late sown, restricted irrigation were promoted to second year of testing in coordinated trials of Northern Hills Zone. In addition to these, 8 genotypes, viz., HS 495, HS 496, HS 497, HS 498, HS 499, HS 500, HS 501 and HS 502, were included in all India coordinated trials for further evaluation under different production conditions of Northern Hills Zone on the basis of high yield potential and high degree of rust resistance.

1.1.1.4 Breeding material

Different segregating generations were raised and selections made in each generation. More than 12000 segregating progenies (F_2-F_6) were handled and selections made on the basis of desirable traits as per the objectives of the programme. Over eight thousand segregating lines belonging to F_2–F_6 were planted for evaluation under artificial epiphytotic conditions of leaf rust for onward selection of desirable plant type coupled with resistance during the crop season. This year, evaluation of promising lines in organic farming was started. About 150 advance breeding lines were planted for farming without inorganic fertilizers and weedicide applications. More than 1000 fresh crosses and backcrosses involving identified donors/recurrent parents for various traits were made. Summer nursery facilities at Lahaul and Wellington were also availed for advancing the segregating generations and screening for rusts.

In all, 608 F_{1s}, 535 F_{2s}, 687 F_{3s}, 663 F_{4s} and 1626 advance generation lines were grown by the IARI Regional Station, Pusa. All potential genes for leaf rust resistance, such as *Lr* 9, *Lr* 19 + *Sr* 25, *Lr* 24 + *Sr* 24, *Lr* 28 and *Lr* 37 were utilized in the breeding programme. Against the threat of black rust virulent race Ug 99, many resistant donor sources, viz., FLW 2, FLW 4, HW 1085, RAJ 4120, RAJ 4124 and RAJ 4125, were utilized in crossing programme. Simple three-way, and double crosses were attempted to introgress diverse genes. Buitre lines and PHR lines, viz., PHR 1004, PHR 1006, PHR 1007, PHR 1008, PHR 1009, PHR 1010, PHR 1011, PHR 1012, PHR 1014, PHR 1015, PHR 1021 and PHR 203, which were utilized in crossing programme have produced many desirable segregants, which are being improved through bi-parental mating. Chirya 3 was identified as a potential donor against foliar blight (*Helminthosporium spp*.) and its incorporation in diverse genetic backgrounds provides an added advantage of simultaneous resistance against all the three rusts, leaf blight, and powdery mildew, viz., Chirya 3 // W 76 / HP 1761.

Under shuttle breeding programme, 510 and 660 lines of breeding material were grown at Lahaul Spiti and Wellington, respectively. Nurseries such as NGSN, EIGN, YCSN, TPN, LBSN, IPPSN and PDSN were evaluated for their disease and ancillary characters. Four hundred eighty-one wheat germplasm were maintained for utilization in crossing programme and to provide protection against genetic erosion.

1.1.1.5 Breeding for new varieties carrying specific rust resistance genes

Under an institutional project, new leaf rust genes(*Lr*35, *Lr*39, *Lr*40, *Lr*41, *Lr*42, *Lr*44 and *Lr*45), stem rust genes (*Sr*25, *Sr*26, *Sr*27, *Sr*36, *Sr*39, *Sr*40, *Sr*41, and *Sr*44 to combat the threat from the new pathotype Ug99 virulent on *Sr*31) and stripe rust genes(*Yr*10, *Yr*15, and *Yr*16) in popular Indian bread wheat cultivars, Lok 1, KS, C 306, HD 2885, HD 2402, PBW 226, PBW 343, WH 147, HUW 234, HD 2687, UP 2338, UP 262, etc., are in BC_2-F_2 and BC_3-F_3 stages. In HUW 234, WH 147, Lok 1, C 306, and HD 2402, the pyramiding of *Sr*24 with *Sr*26, *Sr*27 and *Sr*36 is complete and molecularly confirmed and published.

1.1.1.6 Pyramiding of rust resistance genes through molecular technique

Under an ICAR ad-hoc project, pyramiding of rust resistance genes, *Lr*24, *Lr*28, *Lr*35 and *Lr*37, *Yr*10 and *Yr*15 in popular Indian bread wheat cultivars HD 2733, HD 2687, PBW 343, HUW 234, Lok 1 and WH 147 is under progress, and transfer of *Lr*24, *Lr*28, and *Lr*37 into all these cultivars is complete. The transfer of *Lr*35, *Yr*10 and *Yr*15 is at BC_3 stage.

Selections were made from the ear-to-row F_5 lines derived from the 'Susceptible × Resistant' crosses involving three susceptible *durum* lines 'Motia', 'Malvi Local' and 'Sarangpur Local', and five resistant ones, viz., 'B 662', 'ED 2398-A', 'HG 110', 'IWP 5019' and 'Line 1172'. This material carrying diverse rust resistance genes in the background of the three above mentioned susceptible, but locally adapted, drought tolerant *durums* holds promise for evolving rust resistant *durum* wheat cultivars for limited input conditions.

1.1.2 Rice

1.1.2.1 Variety identified/variety proposed for identification

Pusa 1401-97-7-1-4 (IET 18005). The variety Pusa 1401-97-7-1-4 was tested in the National Basmati Trial from 2002 to 2004. It yielded 34.41% higher than *Taraori* Basmati and was judged better in quality based on appearance, cohesiveness, tenderness on touching and chewing, taste, aroma and elongation. Its panel score based on overall acceptability was 4.07 as compared to 3.96 of *Taraori* Basmati. It matures a week earlier than *Taraori* Basmati. Based on its overall performance it was identified by the IARI Variety Release Committee for release in Delhi state.

Pusa 1460-01-32-6-7-67 (IET 18990). A bacterial blight resistant line Pusa 1460-01-32-6-7-67 developed through pyramiding of genes xa13 and Xa21 using marker assisted backcross breeding was tested in the National Basmati Trial during 2004. In the national disease-screening nursery, it gave a susceptibility score of 4.8 comparable to the resistant check, Ajay (4.2), and susceptible recurrent parent, Pusa Basmati 1 (7.1). The susceptibility index more than 6.0 is recorded as susceptible. This entry completed three years of testing in the National Basmati Trial and will be proposed for

identification during 42nd Annual Rice Group Meeting.

1.1.2.2 Development and evaluation of restorer lines

A station trial consisting of 14 entries (12 newly developed *Basmati* restorer lines, Pusa Basmati 1 and Pusa Sugandh 5) was conducted. Three entries (ET05-2-5, TCPP03-22A-11 and ET05-2-2) showed significantly higher yield (8.3-16.6%) compared to that of the best check, Pusa Sugandh 5.

Yield performance of *basmati* restorer lines in the station trial during *kharif* 2006

Name of the entry	Yield (kg/ha)	% Superiority over check
ET 05-2-5	5600	16.6
TCPP 03-22A-11	5300	10.4
ET 05-2-2	5200	8.3
Pusa Sugandh 5 (check)	4800	
CD	350	

1.1.2.3 Development and evaluation of CMS lines

Four new CMS lines of *basmati* quality, namely, Pusa 7A, Pusa 8A, Pusa 9A, Pusa 10 A, and three non-*basmati* quality CMS lines, Pusa 11A, Pusa 12A and Pusa 13A are at different stages of back crossing for conversion.

CMS lines under conversion

CMS Line	Type	Pedigree	Source of cytoplasm	Type of cytoplasm	Backcross generation	Important features
Pusa 7A	*Basmati*	Pusa 1280-7-4-2-4	PMS-2A	WA	9	Long slender, fine grain
Pusa 8A	*Basmati*	Pusa 1280-7-4-1-2	PMS-2A	WA	8	Long slender fine grain
Pusa 9A	*Basmati*	Pusa 1280-7-4-2-1	PMS-2A	WA	8	Long slender, fine grain
Pusa 10A	*Basmati*	Pusa 1280-7-4-1-6	PMS-2A	WA	8	Long slender, fine grain
Pusa 11A	Non-*basmati*	Pusa 1266-96-50-1	Pusa 5A	WA	5	Short medium grain, strong culm
Pusa 12A	Non-*basmati*	Pusa 1266-96-50-1-2	Pusa 5A	WA	5	Short medium long grain, strong culm
Pusa 13A	Non-*basmati*	Pusa 1266-E-15-99-168	Pusa 5A	WA	5	Short bold grain, strong culm

1.1.3 Barley

Two genotypes, BHS 365 and BHS 366, were promoted to final year of testing under dual purpose coordinated trial while two other genotypes, BHS 369 and BHS 371, were promoted to final year of testing in Northern Hills Zone for grain purpose. Five genotypes, viz., BHS 377, BHS 378, BHS 379, BHS 380 and BHS 381, were included in all India coordinated barley trials for further evaluation under both grain as well as dual purpose quality. The study for dual purpose barley showed high heritability for fodder yield and tiller regeneration characters.

1.1.4 Maize

1.1.4.1 Maize hybrids proposed for identification

AH 24003. The first single cross maize hybrid AH 24003 for *rabi* condition from IARI was proposed for identification in three zones under early maturity group because of its consistently superior performance over that of the checks. Production potentiality of AH 24003 is 7278 kg/ha, 5703 kg/ha, and 6910 kg/ha in zones II, III and IV, respectively. It exhibited flexibility under different levels of nitrogen with a superiority of 14-16% over the checks in agronomy trials.

AH 23029. Maize hybrid AH 23029 showed mean superiority of 41% and 19% over the checks, Surya and Him 129, respectively, with a production potential of 5.5 t/ha in the coordinated trials. This was also reflected in the agronomy trials under different nitrogen levels with a mean superiority of 50-80% over the checks.

Maize hybrids/composites in pipeline

Name of hybrid/composites	Zone	Testing stage
AH 23029	4	AET II
AH 48007	3,4	AET I
AH 48012	1	AET I
AH 31037	2	AET I
AH 31021	1	AET I
ANEP COMP–04	5	AET I
AH 56197	All	IET
AH 5502	All	IET
AH 5503	All	IET
AH 56193	All	IET
AH 5504	All	IET
AH 56191	All	IET
AH 5506	All	IET

1.2 MILLET

1.2.1 Pearl millet

1.2.1.1 Hybrid/composite proposed for identification

Pusa 751(MS 576 A × PPMI 23). A hybrid, Pusa 751(MS 576 A × PPMI 23) performed well in the AICPMIP trial and completed 3 years of testing. The identification proposal for release of this hybrid will be submitted in the forthcoming AICPMIP workshop.

MP 443 (PPMP 579). A composite population MP 443 (PPMP 579) performed well in A1 Zone in Advance Hybrid Population Trials during 3rd year of testing in *kharif* 2005 of AICPMIP trials. It outyielded the best check CZP 9802 by 22.3% and showed good resistance against downy mildew

disease. The identification proposal for release will be submitted in the forthcoming AICPMIP workshop in 2007.

1.2.1.2 Evaluation of new hybrids/composites in AICPMIP trials

Four new hybrid entries, namely, MS 411 A × PPMI 69, MS 411 A × PPMI 301, MS 576 A × D 23 and MS 576 A × PPMI 295, out yielded the best check Pusa 605 by 18-25%. The said entries were included in the Initial Hybrid Trial – *kharif* 2006 of AICPMIP for the first year of testing. A new population, namely, Pusa Composite 612 was included in Initial Population Trial – *kharif* 2006 of AICPMIP for the first year of testing.

1.3 FORAGE CROP

1.3.1 Forage Sorghum Variety Released

Pusa Chari 615. A multi-cut forage sorghum variety Pusa Chari 615 was released for cultivation in the National Capital Region of Delhi. Pusa Chari 615, developed from a cross Pusa Chari 40 × Pusa Chari 67, is characterized by tall (3.0-3.2 m) plants, 10-12 long dark green leaves (70-75cm long), medium thick cane and stay green character. PC 615 gave an average of 70 t/ha of green fodder and 1.95 t/ha of dry fodder yield compared to 65 t/ha of green fodder and 1.85 t/ha of dry fodder yield of the best check SSG 59-3. It also gave better seed yield (1.2-1.5 t/ha) compared to that (1 - 1.2 t/ha) of the best check PC 23. Its nutritious fodder has 8.07% protein, and 8.72 t/ha digestible dry matter with a 55.3% *in vitro* dry matter digestibility. The variety is tolerant to major insect-pests and foliar diseases.

Forage sorghum variety Pusa Chari 615

1.4 GRAIN LEGUMES

1.4.1 Chickpea

1.4.1.1 Varieties released

BG 1108. The bold seeded *Kabuli* chickpea variety BG 1108 was released and notified for the commercial cultivation in the northern states of the country. It was developed by a multiple cross, viz., [(BG 315 x ILC 72) x (ICCV 13 x Flip 85-11)] x (ICCV 32 x Surutoto 77). The seed yield of the variety ranges from 2.5 t/ha to 3.5 t/ha. It is resistant to soil borne diseases. It has excellent cooking quality and is good for table purpose.

Chickpea variety BG 1108

BGD 128 (Pusa Shubhra). BGD 128 (Pusa Shubhra), a bold seeded *Kabuli* chickpea variety developed by the Centre for Pulses Improvement, Dharwad, was released by the Central Sub-committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops for commercial cultivation in Central Zone comprising Madhya Pradesh, Chattisgarh, Maharashtra, Gujarat, parts of Rajasthan and Uttar Pradesh. It was derived from the cross ICCV 2 × ICCV 5 following the pedigree breeding method. It is a very high yielding variety with an average grain yield of 1.9 t/ha, which is 21.3% higher than that of the best check. It consistently out yielded check varieties in all three years of testing and showed a stable yield performance under drought prone rainfed conditions of central India. The characteristic feature of BGD 128 is its unique plant type with more number of secondary branches resembling those of *desi* chickpea. Its duration is about 115 days and has a 100-seed weight of 27g to 28 g. It is moderately resistant to Fusarium wilt, dry root rot, collar rot, viral stunt, nematodes and pod borer. It has excellent grain quality.

BGM 547. A *desi* chickpea mutant, was released and notified for North Western Plains Zone for late sown conditions. The average yield superiority is 15.84% over the

yields of all ruling checks. The average grain yield is 1.8 t/ha with a potential yield of 3.1 t/ha. It has bolder seeds (100-seed weight > 25.1 g) with attractive golden brown colour, thin testa (preferred by the consumers), good taste and cooking quality. It has a medium maturity period (135 days), and is tolerant to wilt, root rot, stunt diseases and pod borer.

1.4.1.2 Variety identified

Pusa 2024. A bold seeded *Kabuli* variety Pusa 2024 was identified for NCR, Delhi. Developed from a double cross, *viz.*, (BG 261 × ICC 88503) × (GL 920 × BG 1003), it yields, on an average, between 2.5 t/ha and 3.5 t/ha. The variety has a moderate resistance to soil borne diseases, and resistance to moisture stress and high temperature. It has excellent cooking quality and is good for table purpose.

Chickpea varieties in pipeline

Trial	Entry
IVT-*Desi*	BGD 1041, BGD 1042, BG 2067, BG 2068, BGM 556
IVT-Bold	BGD 1043, BGD 1044, BG 2065, BG 2066, BGM 558
IVT-Rainfed	BGD 1045, BG 2069, BG 2070
IVT-late	BGD 1046, BG 2071, BG 2072, BGM 557
IVT-*Kabuli*	BG 2052, BG 2053, BG 2054, BG 2060, BGM 559, BGM 560
IVT-K-EB	BG 2061, BG 2062, BG 2063, BG 2064
Cold tolerant nursery	BG 1103, Pusa 112
High input nursery	BG 1073
Extra-early nursery	BG 376, BG 1044, BG 1054

1.4.1.3 Hybridization and advancement of segregating populations

Various segregating populations, viz., F_2 to F_8 comprising more than 1000 populations were selected for screening under multiple sick plot environment.

Segregating chickpea populations

Generation	Families	Crosses
F_2	37	-
F_3	111	-
F_4	98	-
F_6	692	105
F_7	141	53
F_8	28	11

1.4.2 Mungbean

1.4.2.1 Entries in pipeline

The following mungbean entries are in pipeline:

Season	Trial	Zone	Entry
Rabi	AVT II	SZ	Pusa 951
Kharif	AVT I	NHZ	Pusa 0571, Pusa 0572
		SZ	Pusa 0572
Spring	IVT	All zones	Pusa 0731, Pusa 0732
Kharif	IVT	All zones	Pusa 0671, Pusa 0672

1.4.3 Lentil

1.4.3.1 Variety released

L 4594 (Pusa Masoor 5). Lentil variety L 4594 was released and notified for commercial cultivation in NCR, Delhi. This variety has medium growth habit, and smaller seeds with orange cotyledons, and is resistant to rust.

Lentil Variety L 4594

1.4.3.2 Variety identified

L 4596 (Pusa Masoor 6). Lentil variety L 4596 is a small seeded variety with green cotyledons having yield superiority over the yields of the prevailing checks. The variety with an average seed yield of 2.12 t/ha is dwarf in height, and has erect growth habit. The variety was identified for release in NCR, Delhi.

1.4.4 Pigeonpea

1.4.4.1 Variety released

Pusa 2001. On the basis of 10% superior yield over that

Pigeonpea variety Pusa 2001

of the best check variety after three years of testing in Coordinated Trials, Pusa 2001 was released for cultivation in NCR, Delhi. The grain yield of the variety is 1.87 t/ha with a maturity duration of 145 days and a 100-grain weight of 8.2 g. In large-scale demonstrations in farmers' fields, it showed 10% superiority over the variety Pusa 991.

1.4.4.2 Variety identified

Pusa 2002-2. Developed from the cross, Selection 90310 × H 85-45, the variety Pusa 2002-2 was identified for North Western Plains Zone (NWPZ). The variety gives 1.67 t/ha of grain yield against the yield of the best check (1.5 t/ha) and matures early in 143 days (UPAS 120: 160 days and Pusa 992: 148 days). Its seeds are bolder with a 100-grain weight of 8.79 g (check 7.8 g). In farmer's field demonstration, it out yielded Pusa 992 (1.49 t/ha) with an average yield of 1.58 t/ha.

1.5 OILSEED CROPS

1.5.1 *Brassicas*

1.5.1.1 Varieties released

NPC 9 (Pusa Aditya). A *Brassica carinata* variety NPC 9 was released for commercial cultivation in NCR, Delhi for rainfed and marginal areas. The average performance of this variety was 1.4 t/ ha under rainfed conditions in the experimental trials and 1.33 t/ha in farmers' fields. It has high oil (40 %) and protein (19.7 %) contents. It is immune to downy mildew, resistant to white rust and tolerant to Alternaria blight, Sclerotinia stem rot, and powdery mildew. The variety is also tolerant to aphid under field conditions.

EJ 13 (Pusa Tarak). EJ 13 is an early maturing and non-shattering Indian mustard variety with initial quick growth and synchronous maturity. The variety has wider adaptability and responds well to intensive cropping system. The variety is bold seeded among the early maturing mustard (6.2 g/1000 seeds). The average seed yield is 2.9 t/ha with 40% oil content. The Delhi State Seed Sub Committee for NCR, Delhi, released the variety.

***Brassica* variety EJ 13 (Pusa Tarak)**

1.5.1.2 Varieties identified

LES 1-27 (Pusa Mustard 21). A low erucic strain (single zero), LES 1-27 (Pusa Mahima) yielded 30%, 12.9% and 4.3% higher than the checks, Varuna (NC), Kranti (NC) and RL 1359 (ZC), respectively, in Zone II (Punjab, Haryana, Western UP, Rajasthan and Uttranchal) based on 9 locations' yield data of Coordinated Trials (IVT, AVT-1 and AVT-2). The yield potential of this strain was recorded up to 2.7 t/ha and was identified for NCR, Delhi, by the IARI Variety Identification Committee. It was also identified for Zone II and Zone III by the Varietal Identification Committee in the Annual Group Meet of Rapeseed and Mustard.

LET 17 (Pusa Mustard 22). The variety LET 17 having low erucic acid content (2.0%) yields higher than the conventional checks, Varuna, Kranti and RL 1359 by 32.4%, 6.1%, 9.4%, respectively. Its mean seed yield is 2.10 t/ha, whereas the potential seed yield is 2.75 t/ha. Oil yield (0.73 t/ ha) is almost on a par with that of the conventional checks. The average 1000-seed weight is 3.6 g. It has high siliqua density per unit area. It matures in 142 days**.** The variety was identified during the Annual Group Meet of Rapeseed and Mustard for Zone II with the condition of verification of erucic acid data.

NPJ 93 (Pusa Vijay). It exhibited yield superiority over all the existing popular varieties, *viz*., Varuna (46.94%), Kranti (29.23%), RL 1359 (42.69%), PBR 91 (41.14%), Pusa Bold (19.63%), Pusa Jai Kisan (23.50%) and Pusa Jagannath (27.05%) at Delhi location. In farmers' fields of the NCR, Delhi, it yielded 10.91% and 14.23% higher than the seed yields of the checks, Pusa Jagannath and Pusa Bold. The average seed yield of this variety under optimum conditions was 2.4 t/ ha. It has shown high tolerance to high temperature at seedling stage. The variety was identified for NCR, Delhi under timely sown irrigated conditions.

EJ 14. A short duration variety of Indian mustard, EJ 14 was identified by the IARI Variety Identification Committee for the NCR, Delhi. The variety gives an average yield of 2.0 t/ ha, matures in 100 days and is a good substitute to *toria*.

1.5.1.3 Entries in pipeline

The following advanced mustard entries are in pipeline :

IVT-Timely sown mustard (Irrigated)	PBG 1607, HYT 12
AVT-I Timely sown mustard (Rainfed)	PBG 1188
IVT - Late sown mustard	NPJ 113
IVT- Mustard quality	LET 16, LET 19
AVT-I Mustard quality	LET 20
AVT- II Mustard quality	LET 18
Screening nursery for saline/ alkaline conditions	NPJ 114
IVT-Karan Rai	BCS 1, BCS 2
IVT-*Toria*	EJ 17, NPJ 112
Common Varietal Trial (Mustard)	NPJ 115, PBG 116, PBG 14, PBG 18

1.5.1.4 Breeding material

One hundred -ten fresh inter varietal crosses involving various donors for specific objectives, viz., high seed and oil yield, quality (low erucic acid and low and high glucosinolate) early maturity, drought tolerance, high temperature tolerance, terminal heat tolerance and disease resistance (white rust and Alternaria blight) were attempted. A large number of segregating generations from F_1 to F_6 were handled and more than 1300 single plants/bulks were advanced from segregating generations for different objectives. In *Brassica carinata*, the crosses were made using tall and late maturing released varieties with short duration and dwarf somaclones. In addition to the improved high yielding selections, which resulted in 60 selections bulked for yield trials in advanced generations, 54 selections were effected for double low plant types (low erucic acid and glucosinolates).

1.5.1.5 Screening of material for high temperature tolerance at seedling stage

The timely as well as early sown material was screened for its tolerance to high temperature at seedling stage. Forty-five F_5 and twenty-six F_6 progenies were screened for high temperature tolerance at seedling stage, of which, more than 32 progenies were found highly tolerant to high temperatures under field conditions. Ten cultures were bulked on the basis of their high tolerance to high temperature at seedling stage; likewise, about ten bulks were made for testing under late sown conditions on the basis of their medium maturity and high tolerance to high temperature at seedling stage.

1.5.1.6 Screening of breeding material of mustard for high temperature tolerance at maturity

The timely as well as early sown material was screened for its tolerance to high temperature at maturity. All the 171 white rust resistant plant progenies and 183 breeding lines of F_6/F_7 generations were sown for identifying the genotypes resistant to high temperature at the time of maturity to have equally good seed yield even under late sown conditions. The fresh crosses, back crosses, F_2, F_3 and F_4 were sown for evaluation.

1.5.2 Soybean

1.5.2.1 Variety released

Pusa 9814. The Central Sub-committee on Crop Standards, Notification and Release of Varieties for Agricultural crops released and notified Pusa 9814 for cultivation in Northern Plains Zone. It has given significantly higher yields compared to those of the checks, PK 416 and PK 1042 (20.95% and 25.89%) and qualifying genotype SL 518 (11.89%) with better stability. Pusa 9814 has resistance against yellow mosaic, soybean mosaic virus, pod blight, charcoal rot and moderate resistance to stem fly. The average yield of Pusa 9814 is 2.25 t/ha and the yield potential is 3.4 t/ha.

1.5.2.2 Entries in pipeline

The following soybean entries are in pipeline:

Trial	Zone	Entry
AVT II	NPZ	Pusa 2207
AVT I	NPZ	Pusa 2309
IVT	All zones	Pusa 2204, Pusa 2210

1.6 FIBRE CROP

1.6.1 Cotton

1.6.1.1 Variety released

Pusa Arvindam (PSS 2). The *Gossypium hirsutum* variety Pusa Arvindam was released for West Bengal. It has compact plant type, resistance to cotton leaf curl virus disease and tolerance to jassid. It is very early in maturity (130-135 days) and is recommended for rice fallows in coastal region of West Bengal (Sunderbans) during *rabi* season. It gave an average seed cotton yield of 1.18 t/ha as compared to 0.86 t/ha of the check variety LRA 5166 and recorded a yield superiority of 37% over the yield of the check. The fiber quality of PSS 2 was on a par with that of the check LRA 5166.

1.6.1.2 Entries in pipeline

P72-9-37 was promoted from AICCIP trial Br 02 (a) to Br 03 (a) for multi-location testing in South and Central Zones. P 514 and P 6263 were sponsored for national trials, Br02 (a) and Br02 (b), respectively, for multi-location testing under irrigated and rainfed conditions.

1.6.1.3 Lint characteristics studies

Genotypic variability for cotton (*G. hirsutum)* lint characteristics like 2.5% span length, uniformity ratio, strength, extensibility, colour grade, maturity and short fibre index was analyzed using high volume instrument (HVI). An examination of 308 different samples revealed an average 2.5% span length of 26.00 ± 0.01 mm with 21.05 mm and 30.31 mm as minimum and maximum values, respectively, good uniformity per cent, and micronaire of 4.85 ± 0.02 with 0.85 maturity ratio.

Majority of samples showed high maturity and low short fibre index. The average strength at break (1/8) was 22.80 ± 0.13 g/tex with a range of 16.6 g/tex to 30.8 g/tex. High fibre strength was recorded for the varieties, P 14-2, P 56-6, P 30-1, and LH 1940-1 (30.8, 28.4, 28.5, 28.4 g/tex, respectively). Length and strength are positively related. The colour grade light spotted middling with Rd 67.6 and +b 8.66, was observed.

1.7 VEGETABLE CROPS

1.7.1 Cole Crops

1.7.1.1 Cauliflower

In early maturity group (I), DC 23000 was found to be the most promising line followed by Sel.7. Six new SI based hybrid combinations, CH 140, CH 141, CH 142, CH 144, CH 146 and CH 148, were found promising. In the mid-maturity group (II), Sel. 1-2, DC 476, DC 353, DC 308, DC 431, DC 428, Palam Uphar and IVRMC 11 gave the best performance with respect to curd quality and yield. The CMS based hybrid combinations, H 176, H 909, H 910, H 912 and H 951, were found promising.

For resistance to diseases, namely, downy mildew, black rot and Sclerotinia rot, the promising plants from segregating F_2 and back-cross generations were advanced to make recombinant inbred lines (RILs) and near isogenic lines (NILs).

In late (snowball) group of cauliflower, 42 new CMS based hybrids were developed. Hybrid KTH 44 (34 t/ha) KTH 20 (32 t/ha) and KTH 40 (33 t/ha) gave 36%, 30% and 32% higher yield compared to that of check, besides showing superiority for other horticultural traits. Two hybrids KTH 1 and KTH 2 entered for multilocational trial under AICRP exhibited 23% and 24% superiority for yield over check. Crosses were made to transfer Ogu CMS system into 10 promising genotypes. A line having high level of self-incompatibility was isolated from EC 162587, whereas, all the other 36 genotypes were either partial or fully compatible. Selection SR 05 was found to possess multiple resistance against Sclerotinia rot, black rot and downy mildew, and KT 2 against black rot and downy mildew. Single plant selection was made in advanced generations involving resistant sources against black rot and Sclerotinia rot for quality traits and resistance level under artificial inoculated conditions. Fifty-four genotypes, including 3 CMS lines along with their maintainer, were maintained. In mid group of cauliflower, DC 5 and DC 76 gave consistent superior performance with an average yield of 43.5 t/ha and 36.3 t/ha, respectively.

1.7.1.2 Cabbage

Cabbage hybrid KCH 5 was advanced to AVT-1 based on its superior performance. It has given 38% higher yield compared to that of the studied check at the station in AVT-I.

Fifty F_1 hybrids of cabbage (31 SI based, 15 CMS based and 4 from private sector) were evaluated for qualitative and quantitative traits. Hybrid combination of CMS 3 (improved CMS source) with C 1, POA and Golden Acre produced better yields (1.75 kg/plant, 1.73 kg/plant and 1.67 kg/plant, respectively).

Nine promising selections of cabbage were compared with Golden Acre. Selections C 6 and C 8 were found the most promising with respect to yield (42.8 t/ha and 40.8 t/ha, respectively). Frame size was found minimum in C 1 (43.3 cm) followed by that in C 5 (43.6 cm), C 10 (44.1 cm) and C 6 (44.6 cm). Selections C 1, C 10 and C 6 exhibited early head formation.

Twenty-two germplasm and 12 F_1 hybrids were screened for their resistance/tolerance to black rot and DBM. Among the hybrids, KGMR 1, KCH 5 and KCH 204 and among the varieties/ germplasm AC 204 and Pusa Ageti showed field resistance to black rot (<15%), MR 1, Pride of India and Pusa Ageti showed tolerance to DBM (< 20%).

1.7.2 Cucurbits

1.7.2.1 Ash gourd

Promising selections DAG 4 (P_2) and DAG 6 (P_5) gave yields of 41.0 t/ha and 44.0 t/ha, respectively, during *kharif* season. Ten parents along with their 45 F_1 hybrids developed through Diallel fashion (without reciprocal) were utilized for studying heterosis with respect to 20 quantitative characters. The best F_1 hybrid P_1 (DAG 1) × P_4 (DAG 5), which gave a yield of 35.3 kg/plant and showed top parent heterosis of 48.2%, can be exploited for commercial cultivation.

The Ash gourd inbreds were subjected to molecular characterization for estimating their genetic diversity. They were analyzed with RAPD and ISSR primers in order to detect the molecular variation among these parents. A total of 282 RAPD markers were generated, of which 130 (46.1%) were polymorphic with an average of 3.1% polymorphic band per primer. Twenty-two RAPD markers showed relatively high level (>50%) of polymorphism. Out of 4 ISSR primers used in this study, 2 generated 26 bands, of which 11 were polymorphic. Based on RAPD and ISSR analyses, the parents DAG 2 (P_1) and DAG 9 (P_4) were found to be most diverse. However, these were more closer based on quantitative analysis.

1.7.2.2 Bitter gourd

Nine inbreds, including gynoecious line DBTG 201, were crossed in a half diallel fashion to develop 36 F_1 hybrids of bitter gourd for studying heterosis, combining ability and

gene action. Four F_1 hybrids developed through crossing of gynoecious lines DBTG 201 and DBTG 202 and monoecious lines Pusa Do Mausami and Pusa Vishesh were advanced to develop F_2 generation for studying the genetics of gynoecious sex expression in bitter gourd.

Twenty genotypes of bitter gourd were screened against soil salinity under 4 salt concentrations (1, 2, 4 and 6 EC). Pusa Do Mausami, Sel.1 and Green Long were found to be tolerant to soil salinity up to only 4 EC.

1.7.2.3 Cucumber

Three promising selections DC 54, DC 6 and DC 1 yielded 19.2 t/ha, 18.7 t/ha and 18.2 t/ha showing an increase of 21.5%, 18.3% and 15.1%, respectively, over that of the check Pusa Uday. Monoecious F_1 hybrid DCH 3 and gynoecious F_1 hybrid DCHG 4 gave yields of 19.8 t/ha and 19.3 t/ha which were 25.3% and 22% higher than that of the check Pusa Uday, respectively.

Thirty-one genotypes of *Cucumis sativus* var. *hardwickii* and four cultivated lines of cucumber were evaluated for yield and cucumber mosaic virus (CMV) resistance under artificial inoculation. The germplasm IC 331628 and IC 331616 were most promising as they showed yields of 1.8 kg/plant and 1.4 kg/plant, respectively. The lowest mean PDI for CMV was shown by IC 277048 (6.33%). All four cultivated varieties (DC 1, Pusa Uday, CHC 1 and CHC 2) showed very high PDI and susceptible disease reaction (83% to 92%). Ten promising genotypes were crossed with four cultivated lines of cucumber in Line × Tester method and the observations with respect to 14 parents and 40 F_1's were recorded for eight yield related characters. Six promising F_1's were further advanced to F_2 and B_1 and B_2 generations. The frequency distribution of F_2 and test cross progenies based on mean PDI showed that CMV resistance in *Cucumis sativus* var. *hardwickii* was controlled by a single recessive gene.

Twenty genotypes of cucumber were screened artificially for salinity stress under 5 concentrations (0, 1, 2, 4 and 6 Dsm^{-1}) of salts NaCl, Na_2CO_3 and K_2SO_4 (1:1:1). The genotypes CRC 8, G 338 and Poinsette were found moderately tolerant.

1.7.2.4 Luffa

Sixty-five germplasm of sponge gourd and 32 germplasm of ridge gourd including some *Satputia* types (hermaphrodite) were evaluated and promising lines were maintained. The *Satputia* lines were crossed with monoecious parent DRG 2 and Pusa Nasdar which will be evaluated for yield and other desirable characters. Sponge gourd Selections DSG 6 and DSG 7 gave yields of 15.2 t/ha and 14.3 t/ha, which were 26.5% and 19.0% higher than that of the check Pusa Sneha. They showed a highly tolerant reaction to Luffa leaf distortion mosaic virus (Gemini virus) during rainy season which was further confirmed through molecular analysis of coat protein viral DNA at the Unit of Plant Virology of the Institute. Ridge gourd selection DRG 2 (13.8 t/ha) was found promising against the check Pusa Nasdar (8.0 t/ha).

1.7.3 Solanaceous Crops

1.7.3.1 Brinjal

A long fruited brinjal selection DBL 02 having a yield of 35.2 t/ha was found promising with 22.6% higher yield than the check Punjab Sadabahar and promising long fruited F_1 hybrids DBHL 20 and DBHL 150 produced yields of 47.5 t/ha and 44.9 t/ha, respectively, which were 13.6% and 7.4% higher than that of the check Pusa Hybrid 5 (41.8 t/ha). Round fruited hybrids DBHR 38 and DBHR 164 were most promising with yields of 45.34 t/ha and 43.8 t/ha, respectively, which were 15.1% and 11.0% higher than that of the check Pusa Hybrid 6 (39.4 t/ha). Small round fruited hybrids DBHSR 66 and DBHSR 68 yielded 35.4 t/ha and 32.8 t/ha, respectively, which were 36.2% and 26.2% higher than that of the check MHB 39 (26.0 t/ha).

In resistance breeding programme, forty-five germplasm were screened against Phomopsis blight. Out of these, Pusa Bhairav was confirmed for resistance. Forty-four lines and 8 wild related species were screened against shoot and fruit borer. Comparative tolerance was observed in DBL 02, Annamalai, Kt 4, Punjab Moti, *Solanum incanum, S. insanum, S. indicum* and *S. gilo*.

1.7.3.2 Tomato

In determinate type, tomato selection DT 1and DT 2 showed yield superiority over the check in AVT-II and IET, respectively. In indeterminate trial, Sel. DT 11 gave 8.5% higher yield than that of the check DT 10 (47.0 t/ha). Hybrid BSS 368 gave a yield of 58.0 t/ha which was higher than that of the check ARTH 4. In station trial, F_1 combination DT 39 × CH and 3900 × Pusa Sheetal were most promising with a yield of 76.0 t/ha and 69.5 t/ha, respectively. In TLCV resistant varietal trial, H 86, N 5, Nun 5005, N 1, TH 348, 6-11-a and 6-11-b were found to be highly tolerant against leaf curl virus with high fruit yield. Sel. FEB-2, Megha, and Super Market were found resistant to early blight while NF 31, CB 28 and Pusa 120 showed resistant reaction against root-knot nematode.

Among the thirty-five varieties/lines evaluated under abiotic stress conditions, Booster, New Wonder and Sel.3 were found promising for fruit setting, both under low temperature regime (LTR) and high temperature regime (HTR). Hybrid combinations Sel.3 × Booster, Booster × Sel.3, Pusa

Sheetal × Booster and Pusa Sheetal × Chikoo were found promising for setting fruits under LTR conditions during December-January (night temperature below 8 ºC). Genotypes BS, NW and Sel. 3 were found promising for fruit set at high night temperature (28 ºC).

1.7.3.3 Capsicum

Fourteen F_1 hybrids of Capsicum (bell pepper) were evaluated. Double cross hybrid KTCPH 35 was found most promising for yield (21.5 t/ha), pericarp thickness (5.1 mm) and fruit diameter (0.3 cm).

1.7.4 Root and Bulbous Crops

1.7.4.1 Carrot

Among breeding lines developed for high humidity and high temperature conditions, IPC Ht_2 (19.65 t/ha) and IPC Ht_1 (15.8 t/ha) continued to give good performance in July first fortnight sowing for the second consecutive year while the Check Pusa Kesar produced flowering stalk without producing marketable roots. One hundred new breeding lines with diverse horticultural traits, especially colour, were evaluated in replicated trials and assessed for various horticultural characters. Twelve promising lines were assessed in replicated Randomized Block Design (RBD) at two sites along with checks. Based on yield and other horticultural characters, IPC 122 (37.6 t/ha) and IPC 126 (32.5 t/ha) gave best performance. Cytoplasmic male sterility is being established into most promising new tropical genetic backgrounds through back crossing for the purpose of its exploitation in F_1 hybrid development. About 50 such lines were assessed for desirable traits and selected roots were planted for furthering this genetic material.

In temperate carrot, 62 experimental F_1 hybrid combinations involving nine CMS (A) lines and seven pollinator (C) lines, were evaluated along with the standard variety Pusa Yamdagni as check in station trials. Sixty-one per cent hybrids yielded more than the check. The two highest yielding hybrids, viz., KTCTH 7 (44. 6 t/ha) and KTCTH 8 (41.8 t/ha), with desirable root traits showed 78.4% and 67.2% standard heterosis for yield, respectively.

1.7.4.2 Onion

Promising selections Sel. 383 and Sel. 402 yielded 28.8 t/ha and 26.6 t/ha, respectively, which were 18.5% and 9.5% higher than that of the check Pusa Red (24.3 t/ha). Both the selections are under test at AVT-II of All India Coordinated Research Project (AICRP). Another selection, Sel. 126 (yield 32.3 t/ha), was found superior with 17.59% TSS and yellow skinned bulbs with very good storage quality. Among 26 F_1 hybrids (developed by using CMS system), hybrids H 42 and H 22 yielded 42.7 t/ha and 41.8 t/ha, respectively, and showed 8.6% and 6.2% increased yields over that of the hybrid H 44 (39.3 t/ha). Cytoplasmic male sterile line A and its maintainer B showed stable performance and their seed multiplication is in progress.

1.7.5 Leguminous Crop

1.7.5.1 Garden pea

A total of 196 genotypes were evaluated for off-season cultivation. These were purified and maintained. In all 9 F_2 and 58 F_3 populations of different crosses were evaluated and single plant selections were made on the basis of maturity, disease reaction and pod characters for progeny testing and advancement to further generation. GP 1, GP 2, GP 3, GP 17, GP 27, GP 51, GP 124 (stiff stem), GP 125 (stiff stem), GP 212 (dwarf late), GP 391 (dwarf-late) and GP 8 (dwarf-late afila) were found promising in different maturity groups. Twenty-four entries including checks were tested in two All India Coordinated trials and one station trial. GP 4 gave the highest yield of 6.8 t/ha of green pods which was 116.5%, 121.5% and 78.9% higher than those of the checks VL 3 (3.2 t/ha), VL 8 (3.1 t/ha) and NDVP 8 (3.8 t/ha), respectively.

Twenty-one different genotypes/breeding lines were sown in the *Fusarium* sick plot for screening against *Fusarium* wilt resistance and for assessing their suitability for early sowings. Of these, 5 genotypes, namely, GP 17, GP 207, GP 447, GP 468 and GP 471 were found to possess moderate resistance. A total of 190 genotypes, 9 F_2 and 58 F_3 populations of different crosses were also screened and evaluated for resistance to powdery mildew. Of these, GP 8 (afila), GP 463 (afila), GP 470 (afila) and GP 6 (completely leafless type) showed resistance to powdery mildew. In F_3 generation, single plant selections in very late, and long pods types were made which possessed resistance to powdery mildew.

1.7.6 Malvaceous Crop

1.7.6.1 Okra

Maintenance breeding of variety Pusa A 4 and pre-release seed multiplication of Sel. 22-4 (proposed name Pusa Bhindi 5) were done during spring-summer season. Sel. 22-4 gave outstanding performance during spring-summer as well as *kharif* seasons and is being proposed for release for commercial cultivation. During *kharif*, hybrid derivative selections 1-2-3, C 316, C 317, C 36-1 and Pusa Sawani Selections gave extra early harvest within 42-45 days. Selections C 328, C 289 and A 9 produce short, dark green fruits, suitable for fresh fruit export. In the station trials of varieties and hybrids, NOH 303, Saloni, Barkha, AOL 03-1, Arya 351 and Arya Dhanlakshmi were found to be early and virus resistant while Ever Green, Kamini, AOH 04-3, SOH 1016,

EG 5008 and NBH 225 showed low virus incidence, improved vigour and tolerance to slightly lower temperatures (20 °C), and were slightly late to fruit. Selections DOV 1 and DOV 2 performed well at most of the centres under All India Coordinated Research Project (Vegetable Crops), though with moderate virus resistance.

1.8 FRUIT CROPS

1.8.1 Mango

Two new promising mango hybrids, namely, H 1-1 and H 1-6, were identified for release by the Institute Variety Release Committee in July 2006. Both these hybrids are regular bearing with red peeled fruits having good shelf-life, suited for export market. Other hybrids, which are performing consistently well are H 2-6, H 4-12 and H 8-11. All these hybrids are regular bearing with red peeled fruits having optimum size (200 g to 250 g), pulp content >70%, moderate to good TSS (18.5% to 20%), moderate acidity, and high β-carotene contents.

Fruits of new mango hybrid H 4-12

Fresh crosses were made in two combinations of Amrapali and Mallika as female parents and Sensation, Lal Sundari, Janardan Pasand and Pusa Surya as male parents. Twenty-seven mango hybrids were evaluated for their field performance as well as fruit characteristics.

1.8.1.1 Planting of new mango hybrids in evaluation block

Fifty-nine new mango hybrids were transplanted during the year, of which seven were evolved by crossing Amrapali with Lal Sundari, one each in combination of Amrapali × Janardan Pasand and Amrapali × Pusa Arunima and the rest were from the combination Amrapali × Sensation.

1.8.2 Grape

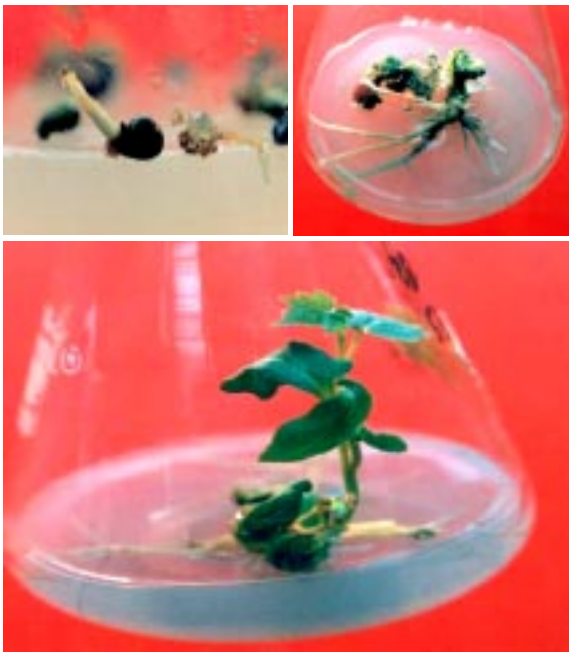
Twenty-five grape varieties and 15 promising/potential hybrids were multiplied for gap planting in the breeding block and for further evaluation. Hybrid seeds produced in 2006 were grown for evaluation. Eight grape varieties were evaluated on Head system and Kniffen system of training.

Bunch of grape var. Tas-A-Ganesh

Bunch of grape var. Centennial Seedless

Out of these, Tas-A-Ganesh and Centennial Seedless varieties showed uniform and timely ripening with good fruit quality.

Ninety-two grape hybrids were assessed and evaluated for their different fruit characters. Out of these, selection 2005-5-1 and selection 2005-6-17 were found to perform well. Three new grape hybrids, viz., Selection 2006-9-11, Selection 2005-11-8 and Selection 2006-12-1 were identified as potential hybrids; of these, one is red in colour and the other two are green coloured, and early ripening having good quality of seedless grape.



Stages of embryo rescue in seedless grape breeding

1.8.3 Citrus

1.8.3.1 Performance of grapefruit cultivars

Four grapefruit varieties, viz., Foster, Imperial, Triumph

and Walter, were evaluated for yield and quality attributes under Delhi conditions. The highest yield (113.97 kg/plant) was recorded in Imperial, followed by Foster (101.90 kg/plant). Maximum fruit weight (378.96 g) and juice recovery (56.73%) were found in Walter. The highest TSS (11.68%), reducing sugar (3.66%) and total sugars (6.70%) with lowest acidity (1.14 %) were recorded in cultivar Triumph and the highest ascorbic acid (38.14 mg/100 ml) was found in Foster.

1.8.4 Papaya

Evaluation of 18 genotypes indicated that the mean performance of dioecious types was superior to that of gynodioecious types for number of fruits, fruit weight and pulp thickness, whereas, the TSS was higher in gynodioecious types. Variety Pant Papaya 1 produced maximum number of fruits (62), followed by Pusa Dwarf (58). The yield was maximum in variety Pant Papaya 1 (76 kg), followed by variety Pusa Dwarf (68 kg). Variety Pusa Nanha recorded the least number of nodes to first flower (21) and it was maximum in variety Pusa Giant (58). The height to first fruit was the least (48 cm) in Pusa Nanha. Variety Pusa Delicious recorded the highest TSS (12^0 Brix).

1.8.5 Pomegranate

Performance of 10 pomegranate cultivars in fruiting was evaluated under Delhi conditions for different physico-chemical traits. Among different cultivars, Jyoti and Ganesh showed better performance while Achick Dana, and Kali Shirin were shy in bearing, and Dholka, Alandi and P 23 were intermediate. Cultivars Jyoti and Ganesh performed better in respect of pink aril colour, high juice recovery and TSS contents and low acidity.

Evaluation of pomegranate cultivars for physico-chemical characteristics

Cultivar	Fruit colour	Aril colour	Fruit wt (g)	Juice/ recovery (%)	TSS (%)	Acidity (%)
Alandi	Pink	Pinkish white	231.0	63.8	11.9	0.31
Dholka	Red with yellow patches	Faint pink	218.9	5.32	13.0	0.27
Bedana	Yellowish green	Pinkish white	208.3	59.4	12.6	0.34
Jyoti	Yellow with pink	Deep pink	248.2	67.3	17.1	0.22
Achick Dana	Brownish yellow	White	180.4	60.3	13.0	0.34
Ganesh	Deep red with yellow patches	Faint pink	243.7	61.8	16.2	0.25
Bedana	Yellowish green	Pinkish white	218.6	63.0	13.6	0.36
Jalore Seedless	Pinkish yellow	Pinkish white	243.0	55.8	12.9	0.30
P23	Greenish yellow	White	168.5	60.0	14.1	0.39
Kali Shirin	Yellow	Pinkish white	162.8	55.2	12.8	0.34

1.8.6 *Aonla*

Four cultivars, namely, Krishna, Chakaiya, Kanchan and NA 7, were evaluated under Delhi conditions. Maximum weight of fruit was recorded in Krishna (40.67 g) and minimum in Kanchan (30.12 g). A new genotype having red fruit surface with high tannin content (1.12 mg/100g pulp) was identified. It had an average fruit weight of 18.34 g. The maximum yield (64.3 kg/plant) was recorded in NA 7 followed by Chakaiya (55.4 kg/plant). The highest seed weight was recorded in Krishna (2.17 g). Fibre content was maximum in Chakaiya (1.8%). TSS (10.9%), acidity (1.75%), and ascorbic acid (500.2 mg/ 100 g pulp), were maximum in Krishna.

1.8.7 Temperate Fruits

1.8.7.1 Apple

A promising apple rootstock identified at the Institute's regional station at Tutikandi (Shimla), was made available to progressive growers to obtain the response of the orchardists to this new rootstock. This rootstock was observed to produce semi dwarf, semi vigorous apple tree and is resistant to woolly aphid, powdery mildew and apple scab. It is a selection from *Malus baccata* Shillong and has been christened as PSM 1 (Pusa Seb Moolvrinth) for use as rootstock for apple. It is easy to propagate by mound layering. Its chilling hour requirement is less than that of M 9 and MM 106. It can be utilized for high density orcharding in apple.

1.8.7.2 Apricot

Apricot cultivars Charmagz, St. Ambriose and Suffaida were most acceptable as dried fruits.

1.8.7.3 Kiwifruit

Cross pollination studies between kiwifruit cultivars revealed that the requirement for male plants in a kiwifruit planting may not be absolute. Cross pollination between pistillate cultivars has given satisfactory fruit set. However, not all cultivars are suitable for pollination in a kiwifruit planting. Cultivar Allison cannot set fruits on pollination with cultivars, Bruno, Abbot and Hayward; although cultivar Allison can satisfactorily pollinate the cultivars, Bruno, Abbot and Hayward.

1.8.7.4 Pear

A trial is in progress for the evaluation of four species of *Pyrus* as rootstocks for pear cultivar Bartlett. One of the species, viz., *Py. calleryana* is exhibiting signs of graft incompatibility. The influence of this graft incompatibility on tree performance is under evaluation. Among various indigenous *Pyrus* species, *Py. pashia* var.

Kumaonii has been found resistant to white root rot.

1.8.7.5 Strawberry

During the period under report, the collection of strawberry cultivars was augmented from sixteen to ninety-six. These cultivars were evaluated for their various horticultural traits and incidence of leaf spot disease. Cultural practices were worked out. Higher yields have been demonstrated by the use of black polyethylene mulch, drip irrigation and plastic tunnels (in winter) and anti-hail nets (in summer). Two strawberry varieties, Shimla Delicious and Jutogh Special were selected for bright colour, high TSS, medium size and distinctive flavour and sent for multi-location trial in different agro-climatic conditions in India.

1.8.7.6 Walnut

A unique walnut clone christened Pusa Khor was identified and evaluated. Its fruits appear to be borne in lateral position as well as terminally. The nut is thin shelled with 50% kernel recovery. The kernel colour is light yellow with 55% oil percentage and good taste.

A unique walnut clone christened Pusa Khor

1.9 ORNAMENTAL CROPS

1.9.1 Rose

Ten new promising hybrids were evaluated based on morphological traits. Out of these, two hybrids numbered as IFL-B14-R10 and FL-B12-R12 were identified for release. The characteristic features of these are given below.

IFL-B14-R10 (White hybrid). Evolved by crossing an indigenous floribunda variety Chandrama with an exotic hybrid tea type variety First Prize, IFL-B14-R10 produces very attractive big flower buds, which are pinkish in colour initially and turn pure white as they open. The flowers have a long vase life and the plants are vigorous and tolerant to powdery mildew and leaf spot diseases.

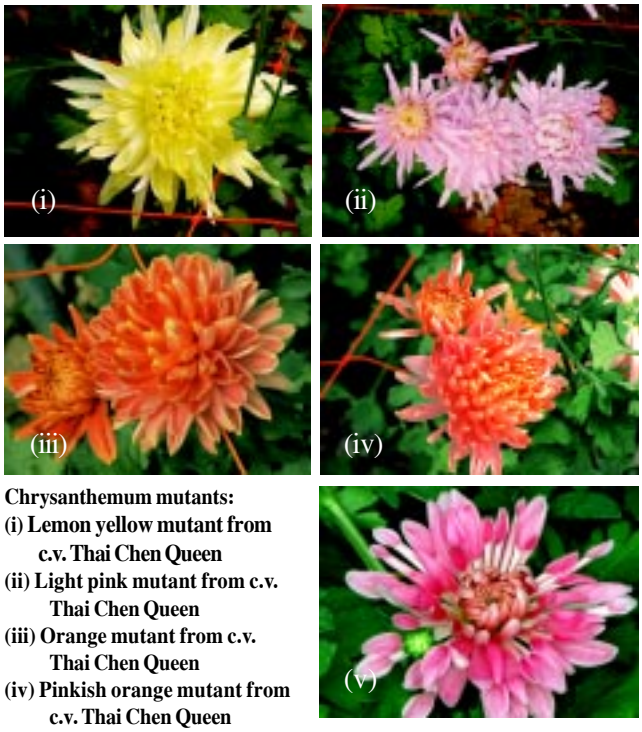
FL-B12-R12. A selection from an open pollinated population of a popular variety Sadabhar, which is a perpetual flowering type with large sized bunches, FL-B12-R12 has vigorous bushes that produce 10-20 bunches consisting of 10-30 flowers per bunch depending on the season. The identified hybrids were characterized morphologically based on the Distinctness, Uniformity and Stability (DUS) testing.

1.9.2 Gladiolus

From a trial consisting of 22 hybrid gladiolus strains, eight were found promising with respect to number of florets. Three of these hybrids were late flowering while two were early. Two hybrids were promosing for spike length, and eight for rachis length.

1.9.3 Chrysanthemum

A range of mutations was obtained from eight cultivars of chrysanthemum through irradiation with 15 Gy. In order to purify the mutants obtained under *in vitro* conditions, attempts were made to regenerate the mutants by the use of petals as explants. High frequency regeneration from petal explants of yellow mutant (from Pusa Century) and pink mutant (from cv. Thai Chen Queen) was achieved on MS medium fortified with Kinetin 10 mg/1+ 2.0 mg/1 NAA followed by Kintetin 10 mg/1 + 0.5 mg/l NAA, whereas in the case of



Chrysanthemum mutants:
(i) Lemon yellow mutant from c.v. Thai Chen Queen
(ii) Light pink mutant from c.v. Thai Chen Queen
(iii) Orange mutant from c.v. Thai Chen Queen
(iv) Pinkish orange mutant from c.v. Thai Chen Queen
(v) Spoon mutant from c.v. Ajay

light purple mutant, Kinetin 10 mg/1+1.50 mg/1 NAA followed by Kinetin 10 mg/1+0.75 mg/1 NAA was found to be ideal. For the regeneration of white chimeral petals from cv. Tata Century, a combination of Kinetin 10 mg/1+2.0 mg/1 NAA followed by Kinetin 10 mg/l+0.5 mg/l NAA was found to be most ideal.

1.9.4 Marigold

In order to develop F_1 hybrids in African marigold (*Tagetes erecta*), GMS system consisting of three male sterile lines (MS 5, MS 7 and MS 8) was utilized. These MS lines (*Tagetes erecta*) were crossed with male parents such as French Selection 1, French Selection 2, French Selection 3, French Selection 4 and French Selection 5 belonging to *Tagetes patula* species. Various selections made in previous years were evaluated. Among them, French Selection 1 and French Selection 2 performed very well as rainy season crop. Both of them produce medium sized, compact flowers, suitable for loose flower production. Sel. 101, Sel.102 and Sel. 20 were found promising as winter season crop. The F_1 hybrid consisting of parentage MS 8 × PNG also performed well during winter season.

1.9.5 Tuberose

Among seven varieties of single petalled tuberose, namely, Mexican Single, Shringar, Prajwal, Rajat Rekha, Sikkim Selection, Hyderabad Single and Calcutta Single evaluated, Shringar and Prajwal, performed better than others under Delhi conditions. Similarly, six varieties of double petalled tuberose, namely, Pearl Double, Suvasini, Vaibhav, Hyderabad Double,

A field view of tuberose c.v. Prajwal

Calcutta Double and Swarn Rekha were evaluated. Vaibhav performed better than other cultivars. March-April planting was found to be the best for planting tuberose bulbs in Prajwal and Vaibhav. A study was conducted to induce earlier flowering in tuberose cvs. Shringar and Mexican Single under Delhi conditions. Three types of growing conditions were tested, viz., plastic tunnel (planted on 02-12-2005), open field conditions (planted on 02-12-2005) and open field conditions in recommended planting time. Shringar bulbs planted under low plastic tunnel produced first flowering during the last week of May 26, 2006 which was 44 days earlier (July 09, 2006) than the flowering observed in the bulbs planted without tunnel and 38 day earlier (July 03, 2006) than the flowering observed in open field conditions in the recommended planting time. However, in cv. Mexican Single, growing of crop under low plastic tunnel could not induce early flowering.

1.9.6 Bougainvillea

The rooting medium having 1000 ppm each of IAA and IBA was standardized for five difficult to root cultivars of bougainvillea, namely, Mahara, Shubhra, Cheery blossom, Lady Marry Baring and Dr. R.R. Pal. Significant differences were observed among the five cultivars in respect of rooting percentage, number and length of primary roots, plant height, number of branches per plant and length of branches. Maximum rooting percentage (67.00%), was recorded in cv. Mahara followed by Dr. R.R. Pal (65.00%) whereas minimum rooting percentage (63.00%) was found in Shubhra.

Bougainvillea c.v. Mahara

1.9.7 Gerbera

Eight varieties of gerbera (viz., Liza, Vinne, Devil, Benami, Ditty, Micky Mouse, Suzi and Renata), were evaluated under polyhouse conditions. The maximum stalk length (68 cm) was recorded in Benami, followed by Ditty (58 cm), whereas flower diameter was maximum in Vinnie (13.50 cm), followed by Liza (13.0 cm). Out of various potting media, cocopeat + vermiculite + perlite in ratio of 2:1:1 was found promising for propagating new suckers as well as growth and flowering of gerbera.

1.9.8 Lilium

Seven new Asiatic lilium hybrids were collected and evaluated for various floral traits. Cultivar Elite performed well with respect to plant height (72.0 cm), number of flowers per spike (7.3), days to bud formation (46.7) and flower diameter (14.2 cm).

2. GENETIC RESOURCES

2.1 CROP GENETIC RESOURCES

2.1.1 Wheat

2.1.1.1 Novel genetic stocks deposited with NBPGR

About 500 g seeds along with passport data of each of the following identified stocks were deposited for medium term storage with NBPGR: WR 1392, WR 1421 and WR 1387 for tillers per meter**;** WR 1408, RD 1018, RD 1008, RD 1009, RD 1063 and RD 1095 for 1000-grain weight.

2.1.1.2 Evaluation of new plant type (NPT)

Fifty-one advance generation lines of NPT were evaluated in yield trials and compared with two national checks, viz., PBW 343 and HD 2329. Fourteen lines showed more than 20% yield increase over the best check PBW 343.

Performance of top ranking NPTs in field evaluation trial

Strain	Parentage	Yield (t/ha)	1000-grain weight (g)	% increase over PBW 343
H 1764-4-4-1	DL 1266-1 x WR957	6.96	40	45.61
H 1767-48-2-1	DL 1266-1 x H 1329-80-4	6.09	44	27.41
H 1767-48-9-1	DL 1266-1 x H 1329-80-4	5.87	43	22.80
H 1767-48-10-1	DL 1266-1 x H 1329-80-4	6.30	54	31.80
H 1767-48-11-1	DL 1266-1 x H 1329-80-4	6.74	45	41.00
H 1767-50-3-1	DL 1266-1 x H 1329-80-4	6.09	47	27.41
H 1808-54-1-1	H 1337-25-4 x PBW 373	6.52	50	36.40
H 1812-109-2-1	H 1337-25-4 x H 1329-36-5	6.09	51	27.41
H 1813-21-12-1	H 1337-25-4 x CYT 1129-5	6.30	44	31.80
H 1813-28-4-1	H 1337-25-4 x CYT 1129-5	5.87	47	22.80
H 1813-28-5-1	H 1337-25-4 x CYT 1129-5	6.09	46	27.41
H 1813-28-9-1	H 1337-25-4 x CYT 1129-5	6.96	44	45.61
H 1813-76-5-1	H 1337-25-4 x CYT 1129-5	5.87	41	22.80
H 1859-50-3-1	H 1337-25-4 x H 1329-80-4	5.74	55	20.08
PBW 343		4.78	38	—
HD 2329		4.35	37	—

2.1.1.3 Development of high protein lines

Four genotypes (PQW 13, PQW 42, PQW 45 and PQW 47) consistently showed superior performance over the last four years during the multiplication-testing programme conducted by DWR. Their average protein ranged from 13.5% to 14.5% and were among the top ranking entries. Two more entries PQW 78 and PQW 80 were identified for multi-location testing based on their superior performance at DWR, Karnal.

2.1.1.4 New sources of resistance against rust

Five winter genotypes, viz., Flinor, Festival, Jingdongi, Mega and Maris-Huntsman, were identified as new sources of resistance against two virulent pathotypes (46S119 & 78S84) of stripe rust. Two new genotypes, HS 424 and HS 431, were identified and confirmed as resistant source for leaf and stem rusts as these two genotypes were found to be resistant against all the pathotypes of leaf and stem rusts. Thirty-three *aestivum* x *durum* derived F_4 lines were evaluated at Dalang–Maidan. Six lines showing resistance against a wide array of yellow rust pathotypes were selected for developing diverse rust resistance genetic stocks.

2.1.1.5 Evaluation of local germplasm from North-Western Himalayas

Eighteen local wheat accessions collected from North-Western Himalayas were characterized for the presence of necrotic genes. Out of these, 5 were found to be carrier of Ne2 gene. Leaf pubescence, a peculiar character present in local germplasm line (WLG79), showed the presence of duplicatory genes for its control.

2.1.2 Rice

2.1.2.1 Promising *basmati* rice lines developed through MAS

Pusa 1527-04-56. Developed from the cross Pusa 2511 × IRBB60 through marker assisted backcross breeding, Pusa 1527-04-56 combines four bacterial blight resistance genes (*Xa4, xa5, xa13* and *Xa21*) in homozygous condition. It has excellent grain and cooking quality attributes, and gives yield on a par with that of the recurrent parent Pusa 2511(Pusa Sugandh 5).

Pusa 1526-04-25. Developed from the cross Pusa 1121 × IRBB 60 by the use of MAS in order to combine bacterial blight resistance in Pusa 1121, Pusa 1526-04-25 carries all four genes (Xa4, xa5, xa13 and Xa21) in homozygous condition. It has lower plant height compared to the plant height of Pusa 1121 and gives higher yield with comparable quality.

2.1.2.2 Test cross evaluation

A total of 94 test crosses were evaluated during *kharif* 2006. Five perfect maintainers and 15 perfect restorers were identified. The maintainer lines will be used for conversion into CMS, and restorers will be used for development of new hybrids.

2.1.2.3 Development of genotypes with extra long kernel

Keeping in view the emerging trend for longer grain in the domestic and international markets, the *basmati* breeding programme was reoriented giving focus on development of genotypes with extra long kernel. Three genotypes, namely, Pusa 1484-03-1-3-2-1 (pedigree: Pusa 1302/Haryana Sugandh, grain length: 11.0 mm), Pusa 1484-03-1-3-2-2 (grain length: 10.5 mm) and Pusa 1554-06-6 (Shahpasand/Pusa 1121, Grain Length: 10.5 mm) were developed. These genotypes have more kernel length than that of the checks, Pusa Basmati (7.60 mm) and Taraori Basmati (7.57 mm).

2.1.3 Maize for Diverse Uses

In an effort to develop varieties for diversified uses, new initiatives were taken up to develop sweet corn, popcorn, baby corn and maize lines with starch specific components.

Two hundred sweet corn lines were selected from the crosses (field corn × sweet corn) on the basis of productivity and morphological features at dry seed stage (plump vs. shriveled) to develop sweet corn varieties.

In popcorn, singe cross hybrid popcorn is not available. Therefore, a 10×10 diallele cross combinations involving popcorn was made for assessing heterotic potentiality.

Seventeen early maturing cultivars consisting of released and newly developed hybrids for their suitability for usage as baby corn were evaluated. New germplasm stocks with extreme earliness, about 10 days earlier than the extra early maturing genotypes, for their promising and potential utility in developing baby corn were developed.

Maize lines with specific starch components (high amylose & amylopectin) from different source populations were involved in specific crosses for realizing high productivity and unique starch properties, relevant for industrial applications.

2.1.4 Pearl Millet

2.1.4.1 Diversification and genetic enhancement of CMS lines and restorers

Two hundred sixty-eight new hybrid combinations were made using 60 restorer lines. These hybrids were produced using five newly developed male sterile lines, viz., MS 411A, MS 630A, MS 540A, MS 589A and MS 549A along with three checks MS 841A, MS 189A and MS 576A for getting an idea about the combining ability and disease reaction of the parental lines and hybrids. During *kharif* 2006, two hundred forty-eight pairs of A & B lines of forty-two advanced stage male sterile lines were grown along with three checks MS 841A, MS 5141A and MS 576A. One hundred sixty pairs of eleven newly developed, stable and downy mildew resistant male sterile lines MS 298A, MS 351A, MS 379A, MS 411A, MS 419A, MS 431A, MS 436A, MS 549A, MS 589A, MS 540A and MS 773A were also grown. Four to six crosses were made in each pair to maintain these lines.

2.1.4.2 Development of biotic and abiotic stress resistance inbreds

Two hundred thirty-eight inbred lines suitable for moisture stress conditions and resistant to downy mildew, which were derived from multiple crosses of diverse lines of Indian elite inbreds, African materials and downy mildew resistant sources, were grown and maintained during *kharif* 2006.

2.1.5 Chickpea

2.1.5.1 Development of extra-large seeded *Kabuli* genotypes

In the national and international markets there is a preference for extra large seeded cultivars of *Kabuli* type chickpea. Keeping this in view, extra large seeded cultivars of *Kabuli* type chickpea were developed and evaluated for their yield performance. Thirty six promising genotypes were identified with more than 40 g/100-seed weight. In addition to high 100-seed weight, all these genotypes have high yield potential ranging from 2.0 t/ha to 3.25 t/ha. The boldest entry, BG 5023, has a 100-seed weight of more than 49 g.

2.1.5.2 Development of extra-large seeded *desi* genotypes

Twenty-seven extra bold-seeded desi chickpea with high yield potential were developed. The 100-seed weight of these lines ranged from 39.2 g to 52.1 g and seed yield ranged from 14.60 t/ha to 27.10 t/ha.

2.1.6 Pea, Lentil, and Cowpea

2.1.6.1 Evaluation of germplasm

Pea. The following pea genetic stocks having morphologically distinct genetic markers, developed through extensive crossing programme ($F_{8/9}$), were sown at IARI farm, New Delhi during *rabi* 2006-2007.

Pea entries with morphological markers

Rec 1	(*le, apu, tac, st, er*)	Rec 2	(*I, r, wel, tac, er*)
Rec 3	(*le, er, st, tl, af, ad, Pl, wb*)	Rec 4	(*iR, def, er, le, tac*)
Rec 5	(*le, er, St, tl, af, wb,Pl*)	Rec 6	(*le, er. St, tl, af, wb*)
Rec 7	(*iR, bold seeded*)		

These genetically stable lines will serve as multi-marker genetic stock for further genetic/ molecular studies. In addition to this, 750 germplasm lines were evaluated for qualitative and quantitative traits.

Lentil. Twenty-three accessions of four wild species were sown in National Phytotron Facility for multiplication. In addition to this, 350 germplasm lines were evaluated for yield contributing traits.

Cowpea. Two hundred fifty germplasm lines were maintained, 259 germplasm lines from Jodhpur were evaluated and 50 new germplasm lines received from NBPGR were multiplied.

The cowpea land races collected from coastal and other parts of Karnataka were evaluated at the Institute's Centre for Pulses improvement, Dharwad and identified for various traits.

Cowpea land races identified for various traits

Genotype	Traits identified	Species
DWDCC 001	high seed index	*Vigna unguiculata*
DWDCC 015	drought and heat tolerance	*Vigna unguiculata*
DWDCC 016	more pods/cluster, high seed index	*Vigna unguiculata*
DWDCC 018	vegetable type	*Vigna unguiculata*
DWDCC 021	vegetable type, extra-long pods	*Vigna sesquipedalis*

2.1.7 Pigeonpea

2.1.7.1 Development of disease resistant material

In the pre-*rabi* season, 17 wilt resistant lines, 2 wilt susceptible lines and 7 released varieties were grown for genetic purification of wilt resistant genotypes and also for incorporation of wilt resistance into the released varieties, i.e., Pusa 992, Pusa 991, Pusa 2001, Pusa 855 and Pusa 9. Besides, 240 F_4 progenies of *C. scarabaeoides* X Pusa 33 cross were also grown for advancing the generation.

2.1.8 *Brassicas*

2.1.8.1 Germplasm evaluated and maintained

More than 600 germplasm lines including *Brassica juncea* (500), *B. napus* (28), *B. carinata* (50), *B. compestris* (25), *B. nigra* (8), *B. oleracea* (1), *B. tournifortii* (4), *Sinapis alba* (2), *Raphanus sativa* (1), *R. caudatus* (3), *B. caudatus* (1), *Eruca sativa* (6) and other species (4) were evaluated and maintained. Natural screening against white rust, Alternaria blight, stem rot and aphids was done. Data on 14 characters were recorded on 243 germplasm lines of *Brassica juncea*, 50 of *Brassica carinata* and 25 lines of *Brassica compestris*. More than 80 quality germplasm lines were also maintained. About 150 somaclones of *Brassica carinata* were also evaluated and maintained. The different donors thus, identified are used in the hybridization programme.

2.1.8.2 Breeding for white rust resistant *Brassica juncea*

Nineteen white rust resistant cultures of yellow and brown seeded *B. juncea* were evaluated to white rust and Alternaria blight resistance. Single plants were selfed on the basis of resistance to white rust. A total of 171 single plant seeds obtained were sown under late sown conditions during *rabi* 2006-2007 and were evaluated under artificial screening conditions for Alternaria blight and white rust. Some of the plant progenies were free from white rust and were phenotypicaly uniform with desirable plant types.

2.1.8.3 Breeding for high erucic strain of mustard

A trial consisting of 21 strains with extra high erucic acid was conducted along with two checks. Nine test strains out yielded the best check. The highest yielder was HET 16 followed by HET 3.

2.1.9 Soybean

Five hundred twelve germplasm accessions were grown. Out of these, 270 accessions were characterized for 11 morphological characters.

2.1.10 Fruits

Indigenous and exotic citrus species/strains were collected and evaluated under Delhi conditions. There are two accessions of *Attani* (*Citrus rugulosa)*, 10 accessions of rough lemon (*C. jambhiri*), three accessions of Rangpur lime (*C. limonia*), one each of Szinkom (*C. reticulata*), Sadaphal (*C. semeflorence*), Sacaton citrumelo, three strains of *Poncirus trifoliata*, (Rubidaux, trifoliate orange, and Pomeray), *C. taiwanica*, and four exotic collections. Among the accessions, the highest percentage increase in canopy volume was observed for *Attani* 2, RLC 4 and Rangpurlime No. 2 in their respective groups. Among the exotic types, maximum plant height and trunk diameter were observed for *Citrus obovoid.*

Fifty-four germplasm of pomegranate maintained in the field were multiplied through cuttings. During the year, two genotypes of papaya were added in germplasm block.

Papaya genotypes added in the germplasm block

Fruit crop	Name of genotype	Centre of collection
Papaya	Surya	I.I.H.R., Bangalore
	Red Lady	Known You Seed (India) Pvt. Ltd., Pune

The Institute's regional station at Tutikandi (Shimla), has a wide ranging collection of germplasm of temperate pome and stone fruits. It comprises 38 *Malus* species, 14 *Prunus* species, 7 *Pyrus* species and 16 miscellaneous genera, viz.,

Cotoneaster, Cydonia, Docynia, Diospyrus, Crataegus, Sorbus and *Myrica*. Besides, it has a collection of 69 apple cultivars, 23 of apricot, 96 of strawberry, 12 of cherry and 6 cultivars of Chinese gooseberry (Kiwi).

2.1.11 Flowers

In rose, 900 varieties were maintained and 40 new cultivars were added in collection. In chrysanthemum, 100 varieties were maintained.

2.1.12 National Off-season Nursery Facility

The Institute's regional station at Wellington provided national off-season nursery facility for wheat, *Brassica*, maize, winter pulses, etc., for nearly 34 research stations, and facility for 10 national and international pathological, and genetic stock nurseries.

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, housing a large number of cyanobacterial isolates maintained in unialgal condition. During the reported period, twelve new isolates from the soils of Chhattisgarh were added to the culture collection. More than eighty blue green algal strains were isolated from paddy fields of India including sixteen isolates from low fertilizer input *basmati* rice soils. These have been identified and utilized for further study.

2.3 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

2.3.1 *Herbarium Cryptogamae Indiae Orientalis* (HCIO)

Enrichment of biodiversity. Five hundred ninety-seven fungal specimens were accessioned in HCIO during 2006 raising the total number of specimens to 46,619. Out of these, 165 were of "Type", 300 were of "Meliolaceae", and 100 were of "North American Ustilaginales" received on exchange basis.

New genera created. *Ectendomeliola walsurae* gen. et. sp. nov. of the family Meliolaceae was described on *Walsura trifolia; Vanibandha sundara* gen. et. sp. nov., a new anamorphic hyphomycetous fungus was described on fallen twigs; and *Corynecercospora teraiensis* gen. et. sp. nov., a new hyphomycetous fungus, was described on *Eleodendron glaucum* L.

New species proposed. Thirteen new species of anamorphic powdery mildews, viz., *Oidium alysicarpe, O. buddleiae, O. cocculus, O. launeae, O. ocimi-sanctum, O. sesame, O. sesbaniae, O. sidae, O. spiraeae, O. brassicae, Oidiopsis solani, Ovulariopsis malloti* and *Cystotheca quercina* were proposed. A perfect state of powdery mildew was also described on *Quercus incana***.** Seven new species of hyphomycetous fungi, viz., *Trichocladium sigmoidea, T. palmae, Acrodictys elliptica, A. lignicola, Cheiromyces ananthgiriensis, Memnoniella mohanramii* and *Zygosporium anupamvarmae* were created. Eight new species of Meliolaceous fungi, viz., *Meliola cynanchi, M. pterigotae, M. strombosiae, M. emespatilii, Asterina loranthigena, A. toddaliicola, Asterostomella otonephelii* and *A. strombosiae* were proposed. *Meliola desmodii-laxiflore* var. *indica, M. tabernaemontanae* var. *wrightiae* are new varieties described from India. Four new species of dematiaceous hyphomycetous fungi, viz., *Sporidesmium mehrotrai, S. curvula, S. lageniforme* and *S. uncinatus* were proposed.

2.3.2 Indian Type Culture Collection (ITCC)

Maintenance and preservation. About 3420 fungal cultures belonging to Mastigomycotina, Zygomycotina, Ascomycotina and Deuteromycotina were maintained by periodic transfer to suitable media. Of these, 200 cultures were preserved under mineral oil (liquid paraffin).

New additions. The collection was enriched by a new addition of 55 different fungal cultures. Some noteworthy plant pathogens accessioned include *Aspergillus amstelodermi* from *Lentinus edodes*; *Pleurotus flasida, P.cryngii, P.ostreatus, Hyphazyius ulmarius, Fusarium equisitii, Alternaria alternata* and *Nigrospora oryzae* from Jatropha; *Xylochia oryzae* sp. nov. from rice seed; *Byssochlamys nivea, Gilmaniella humicola* from *Aloe vera; Fecundostilbum sacchari* gen. nov. from sugarcane; *Phomopsis delbergia* from *Delbergia sissoo; Phoma albizziae* from Albizia causing dieback; *Pencillium aurentiogriseum* from gladiolus bulb; *Rhizoctonia solani* from garlic and tobacco seedlings, and *Glomerella singulata* along with its anamorph *Colletotrichum gloeosporoides* from passion fruit.

Culture supply. Two hundred thirty authentic fungal cultures, viz., Zygomycetes (25), Hyphomycetes (67), Ascomycetes (17), Penicilli (16), Aspergilli (16), Coelomycetes (15) and Fusaria (74) were supplied on payment to various scientific and industrial institutions on their request.

Identification services. One hundred fifty-one fungal cultures/specimens were identified up to species level. Some of the important fungi identified during the period were:

Geotrichum candidum from kinnow; *Beavaria bassiana* from stone weevils; *Pestalotia palmarum* from guava fruit; *Fusarium equisetii* and *F. pallidoroseum* from Jatropha; and *Drechslera* and state of *Cochiliobolus nodulosus* from *ragi* grain.

A new fungus of Stilbellaceae, *Fecundostilbum saccharum* sp. nov., *was* described from the leaves of *Saccharum officinarum.*

2.3.3 Insect Biosystematics

As integral to the studies on biosystematics, 1064 insect specimens were identified under the insect identification service. Detailed taxonomic studies were made on coleopterous pests of red kidney bean, namely, *Alcidodes signatus* (Curculionidae) and *Cyaneolytta coerulea* (Meloidae), along with their field biology. Further efforts were made to compile and consolidate information on the Coleoptera involved in plant galls as gall inducers or gall dwellers, or biological control agents. A perusal of information revealed that there were 105 species belonging to eleven families involved. Majority of these are Curculionidae (62 species under 33 genera) followed by Buprestidae and Cerambycidae. Coleoptera, namely, Carabidae, Coccinellidae, Elateridae and Mordellidae are exclusively non gall inducers but interact as biological control agents, inquilines, etc.

Twenty-seven Indian species under 16 genera of subfamily Formicinae were redescribed. The descriptions were strengthened by the incorporation of additional characters, suitable illustrations, SEM photographs and morphometric ratios. The National Pusa Collection was augmented by addition of three species, viz., *Apanteles phytometrae*, *Cotesia plutellae* and *Distatrix papilionis.*

Monitoring of Formicids indicated that the species composition comprised 8 species under 3 subfamilies, viz., *Camponotus compressus* Fab., *Camponotus sericeus* Fab., *Cataglyphis setipes* Forel and *Acantholepis frauenfeldi* Mayr under subfamily Formicinae; *Pheidole spathifera* Forel, *Melanoplus bicolor* Guer. and *Monomorium scabriceps* Mayr under subfamily Myrmicinae; and *Anochetus madraszi* Mayr under subfamily Ponerinae.

Systematic studies on economically important Hemiptera resulted in the copmpilation of checklists of two subfamilies, viz., Dinodoridae and Peiratinae (Reduviidae). A new bug species *Megymenum khasiensis* was established and described. Three type-species, *Coridius janus* (Fabricius), *Cyclopelta obscura* (Lepeltier & Serville) and *Catamiarus brevipennis* (Serville) and six other species of Hemiptera, namely, *Coridius brunneus* (Thunberg), *Megymenum parallelum* Vollenhoven, *Gellia nigripennis* (Dallas), *Ectomocoris atrox* (Stal), *Peirates affinis* (Serville) and *P. lepturoides* (Wolff), were redescribed along with morphometrics and illustrations of their important taxonomic characters for the first time from India.

A new dinodorid species, *Megymenum khasiensis*

2.3.4 Nematode Biosystematics and Identification Services

2.3.4.1 New nematode species

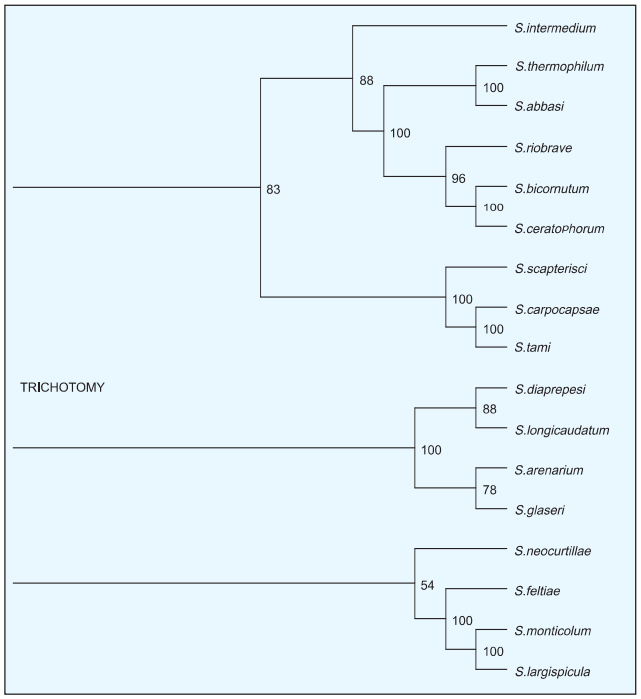
Three new species of agriculturally beneficial predaceous nematodes of the order Mononchida, namely, *Parahadronchus mangiferi, Miconchus sardhanensis,* and *Prionchulus prasadi,* from the rhizoshere of mango being grown in Meerut, Uttar Pradesh were described. The type specimens were deposited in the National Nematode Collection of India (NNCI).

2.3.4.2 New bacterial species

A symbiont (*Xenorhabdus indica*) and a non-symbiont (*Providencia vermicola*) associated with entomopathogenic nematode *Steinernema thermophilum,* which are the first new species of these genera from India, were described. The species were erected based on their morphological, cultural, biochemical and molecular characteristics.

2.3.4.3 Phylogeny of *Steinernema thermophilum* based on molecular characteristics

The complete ITS region of rDNA of *S. thermophilum* of 997 bp was amplified and sequenced. The sequence was deposited in the GenBank, NCBI vide Accession No. DQ665651. A phylogenetic tree was obtained by maximum parsimony using the default parameters of Clustal X. The phylogenetic relationships among the 18 *Steinernema* species including *S. thermophilum* are presented in the following figure. The tree exhibited trichotomy, which could be correlated with the morphological features of these species. The species were grouped into three main clusters, wherein *S. thermophilum* along with *S. abbasi, S. riobrave, S. bicornutum* and *S. ceratophorum* comprised a monophyletic group.



Phylogenetic relationship among 18 species of *Steinernema* with bootstrap analysis of ITS regions of rDNA. The five species, *S. thermophilum*, *S. abbasi*, *S. riobrave*, *S. bicornutum* and *S. ceratophorum* comprised a monophyletic group. Numbers at the nodes represent bootstrap proportion

2.3.4.4 Development of species identification aids

Identification aids for 14 species of root-knot nematodes, *Meloidogyne* spp., and 46 species of entomopathogenic nematodes of the genus *Steinernema* were developed in the form of tabular compendia and dichotomous keys, and the distribution of species in India was mapped.

2.3.4.5 National Nematode Collection of India (NNCI)

The NNCI was augmented with 215 wet suspensions, and 18 type slides of 8 newly described nematode species (*Discocriconemella spermata, D. waitha, Actus conoidus, Cobbonchus subcaudatus, Gracilacus vitecus, Parahadronchus mangiferi, Miconchus sardhanensis* and *Prionchulus prasadi*) thus strengthening the collection up to 2201 Type Accessions. Existing database of NNCI was updated and converted into user-friendly Decision Support System (DSS) format.

2.3.4.6 Nematode identification service

Altogether 67 nematode specimens of plant parasitic, free living and entomopathogenic nematodes received from Gujarat, J & K., U.P., Kerala and Karnataka, were identified. The important identified species were: *Meloidogyne javanica*, *Xiphinema insigne, Steinernema bicornutum, S. carpocapsae, S. feltiae, Heterorhabditis indica* and *H. bacteriophora*.

3. CROP AND RESOURCE MANAGEMENT AND ENVIRONMENT

3.1 AGRONOMY

3.1.1 Effect of Preceding Short Duration Forage Crops and Gypsum-enriched Urea on Productivity of Aromatic Rice

A field experiment was conducted during summer and rainy seasons of 2006 on a sandy clay-loam soil to study the effect of short duration forage crops and gypsum enriched urea on the productivity of aromatic rice cv. Pusa Sugandh 4. Four treatments involving maize cv. African Tall, cowpea cv. V 585, maize + cowpea and fallow were taken in main plots and five treatments of gypsum enriched urea to rice, namely, absolute control and 0%, 5%, 10%, and 15% gypsum enriched urea, were allocated to sub-plots in a split plot design.

Maximum grain and straw yields were recorded when rice was grown after summer cowpea and these were significantly higher compared to preceding maize and fallow. Significantly higher harvest index was also recorded with preceding cowpea compared to summer forage maize. Gypsum-enriched urea had a significant effect on the grain and straw yields of aromatic rice up to 10% enrichment only.

3.1.2 Response of Wheat to N Fertilization under Varying Tillage and Crop Establishment Practices in Mungbean-Wheat Cropping System

An experiment was conducted during 2005-2006 to study the performance of mungbean under conventional flat sowing and bed planting, followed by wheat under varying tillage, crop establishment and N fertilizer levels. Mungbean cv. SML 668 was raised during *kharif* under conventional tillage on flat surface (35 cm spacing) and furrow-irrigated raised-bed (FIRB) system (40 cm bed, 30 cm furrow with 2 crop rows on bed at 25 cm spacing). After harvest of mungbean, wheat cv. PBW 343 was sown under varying tillage, viz., conventional (3 ploughings) and zero (no ploughing), and method of establishment, viz., flat sowing (23 cm row spacing) and FIRB system (3 rows on bed at 10-12 cm spacing). The main plots of tillage/crop establishment were further divided into 5 sub-plots to accommodate varying levels of N, viz., 0, 40, 80, 120 and 160 kg N/ha.

Mungbean performed equally well under flat sowing and bed planting systems. Although the crop growth was better under FIRB due to better conservation and utilization of rainwater as well as border effect of wider furrow spacing, the seed yields were similar to that of flat sowing. In the succeeding *rabi* season, wheat gave the highest grain yield under conventional tillage – flat sowing, which was, however, on a par with that of zero tillage – flat sowing. Growing wheat on beds, whether under conventional or zero tillage, gave similar yields but significantly lower than that of conventional tillage – flat sowing. There was some saving of water (3-5 cm), but the mean yields decreased by 7.8% under FIRB system as compared to conventional flat sowing. Interestingly, zero-tilled wheat gave lower yield than that of conventional tillage under flat sowing but not under FIRB system. The grain yield increased significantly up to 120 kg N/ha only under all tillage and crop establishment practices. This indicates that lower yields under zero tillage were not compensated by increasing N dose up to 160 kg N/ha.

3.1.3 Direct and Residual Effect of Applied Nutrients on Mungbean–Mustard Cropping System

A field experiment was conducted during 2005-2006 to study the direct and residual effects of nutrient management and residue incorporation on mungbean-mustard sequence. Three levels of nutrients, viz, control, recommended dose of N and P, and recommended dose of N, P and S were applied to *kharif* crop of mungbean. In the succeeding crop of mustard, two levels of mungbean stover incorporation, viz., no stover incorporation and stover incorporation in the sub-plots, and four fertility levels in the sub-sub-plots, viz., control, 40 kg N + 20 kg P_2O_5, 80 kg N + 40 kg P_2O_5 and 80 kg N + 40 kg P_2O_5 + 30 kg S/ha were evaluated in a three times replicated split plot design.

Seed yield of mustard produced with 18 kg N + 46 kg P_2O_5/ha to preceding crop of mungbean was significantly superior to control. Mungbean stover incorporation increased the seed yield of mustard (14.4%) significantly over stover removal. Mustard fertilized with 80 kg N + 40 kg P_2O_5 + 30 kg S/ha produced 2270 kg seed yield/ha, which was statistically superior to the rest of the treatments.

3.1.4 Comparative Performance of Bt and Non-Bt Genotypes of Cotton under Different Tillage Systems

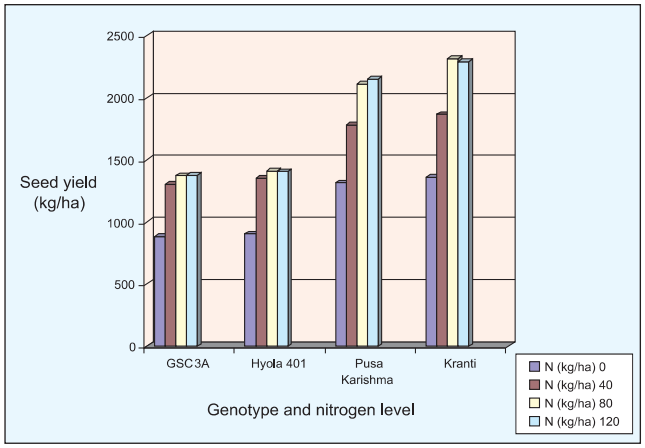
A field experiment was conducted during *kharif* 2006

to evaluate Bt and non-Bt genotypes of cotton under two tillage systems, viz., zero tillage and conventional tillage. The experiment was conducted in a three times replicated split plot design assigning tillage systems to main-plots and genotypes to sub-plots. The crop was sown on 25 May 2006 after harvest of wheat crop.

Performance of cotton under zero tillage was statistically similar to that of conventional tillage practice. Among the genotypes, seed cotton yields of Bt cultivars were significantly higher than those of non-Bt cultivars. Among the Bt cotton cultivars, RCH 134 recorded the maximum cotton yield followed by MRC 6301, RCH 317 and MRC 6304. Among the non-Bt cotton cultivars, RCH 317 gave the highest cotton yield followed by RCH 134, MRC 6301 and MRC 6304. Non-Bt cotton produced higher biomass than that of Bt cotton at boll opening stage. The insect-pest population was relatively higher in non-Bt cotton than in Bt cotton. Populations of aphids, white fly and thrips were marginally higher in zero tillage compared to those of conventional tillage.

3.1.5 Effect of Nitrogen and Sulphur Levels on Canola and Non-canola Type Rapeseed Mustard

Zero erucic acid Indian mustard Pusa Karishma and zero erucic acid as well as glucosinolate Hyola 401 and GSC 3A were evaluated for seed yield and oil content in comparison to non-canola type Indian mustard cv. Kranti at different levels of nitrogen and sulphur during 2005-06.



Interaction effect of genotype and nitrogen levels

The genotype Kranti being on a par with Pusa Karishma recorded significantly higher seed yield (1.95 t/ha) in comparison to that of canola type rapeseed mustard. Among quality genotypes, Pusa Karishma recorded marked increase in seed yield (1.84 t/ha) compared to that of Hyola 401 (1.27 t/ha) and GSC 3A (1.23 t/ha). The genotype Pusa Karishma recorded the lowest oil content compared to Kranti, Hyola 401 and GSC 3A. Genotypes with low erucic acid content recorded lower oil content compared to genotypes with high erucic acid content. The genotypes Hyola 401 and GSC 3A responded to N application only up to 40 kg N/ha, whereas Kranti and zero erucic acid genotype Pusa Karishma responded up to 80 kg N/ha. All genotypes responded to sulphur application but the response was less in canola type compared to that in non-canola type. GSC 3A, Hyola 401, Pusa Karishma and Kranti recorded 11.2%, 10.8%, 14.4% and 18.3% increase in yield due to 40 kg S/ha as compared to that of control.

3.1.6 Response of Soybean to Sulphur and Boron Nutrition

A field experiment was carried out during *kharif* 2006 with four levels of sulphur, viz., 10, 20, 30 and 40 kg S/ha, and three levels of boron, viz., 0.5, 1.0 and 1.5 kg B/ha along with one control to study their effects on the performance of soybean in a factorial randomized block design with three replications.

Application of sulphur to soybean elicited significant response in terms of yield attributes and finally grain yield up to 30 kg S/ha. Boron did not have a significant influence on the growth attributes but had a significant positive effect on yield attributes and grain yield. Application of 1.0 and 1.5 kg B/ha recorded significant increase in yield attributes and seed yield as compared to its influence with the application of 0.5 kg/ha.

3.1.7 Effect of Land Configuration and Method of Irrigation on Productivity, Weed Control and Water Use Efficiency of Sunflower-based Intercropping System

A field experiment was conducted during spring season of 2006 in a split-plot design assigning combinations of land configuration and method of irrigation to main plots and intercropping systems to the sub-plots. The sunflower cv. MSFH 1 as base crop, and mungbean cv. Pusa Vishal and cowpea cv. Pusa Komal as intercrops were sown on 20th February 2006. The crop received five irrigations including irrigation just after sowing for germination.

Methods of irrigation imposed on different land configurations caused significant variation in sunflower seed yield, irrigation water requirement and water use efficiency. Furrow irrigated raised bed (two rows of sunflower on 75 cm raised bed followed by furrow of 45 cm width) recorded 23.7% saving in irrigation water, improvement in irrigation water use efficiency and reduction in weed dry weight over flat bed planting without significant variation in seed yield. In

comparison to this, regular and alternate furrow irrigated ridge planting at 60 cm inter-row spacing recorded 8.4% and 43.9% saving in irrigation water over flat bed planting, respectively. However, this saving in irrigation water caused significant reduction in seed yield (6.9% and 15.8%) over flat bed planting. Cowpea and mungbean as intercrops recorded the highest seed yields under flat bed paired row planting at 45/75 cm. Mungbean and cowpea caused no reduction in the seed yield of sunflower as compared to that in sole stand. Contrary to this, sunflower seed equivalent yield was significantly higher in intercropped stand than that of sole stand. Intercropping system significantly reduced weed dry weight over that of sole stand. Alternate furrow irrigation recorded the highest irrigation water use efficiency, closely followed by furrow-irrigated raised bed.

Effect of land configuration and method of irrigation on productivity, weed control and irrigation water use efficiency of sunflower-based intercropping system

Treatment	Sunflower seed yield (kg/ha)	Intercrop yield (kg/ha)	Sunflower seed equivalent (kg/ha)	Weed dry wt. (kg/ha)	Irrigation water use efficiency (kg/m^3)	Per cent irrigation water saving compared to flat bed planting
Land configuration and method of irrigation						
Flat bed planting at 60 cm spacing with bed irrigation	2997	184	3234	97.6	1.08	-
Flat bed paired row planting at 45/75 cm with bed irrigation	2838	212	3113	91.5	1.03	-
Ridge planting at 60 cm with furrow irrigation	2792	180	3024	124.9	1.11	8.4
Ridge planting at 60 cm with alternate furrow irrigation	2524	153	2721	103.5	1.61	43.9
Furrow irrigated raised Bed (FIRB) (two rows of sunflower on 75cm raised bed followed by furrow of 45cm width)	2968	136	3142	78.5	1.37	23.7
CD (P=0.05)	156	-	198	14.1	-	-
Intercropping						
Sole sunflower	2882	-	2882	109.5	-	-
Sunflower + mungbean*	2872	152	3086	96.3	-	-
Sunflower + cowpea*	2836	185	3058	97.5	-	-
CD (P=0.05)	NS	-	126	10.7	-	-

In case of ridge and raised bed plantings, intercrop was sown in the furrow

3.1.8 Performance of Indian Mustard as Influenced by Date of Sowing and Level of Aqua-Fertilization under Rainfed Conditions

A field experiment was conducted during *rabi* season of 2005-2006 to find out optimum quantity of water for aqua-fertilization through aqua-ferti-seed drill under different dates of sowing and fertility levels for proper germination and growth of Indian mustard under dryland conditions. Two dates of sowing, viz., 25th October and 5th November; four levels of water, viz., control, 5000 litres, 10000 litres and 15000 litres water/ha; and three fertility levels, viz., control, half of recommended dose of NPK, and recommended dose of NPK were evaluated.

Sowing of mustard on 25th October gave significantly higher yield compared to that of 5th November sowing. Application of 15000 litres of water/ha through aqua-fertilization recorded significantly higher germination percentage, growth and yield attributes and seed yield (1.87 t/ha) compared to those obtained with other levels of water. Among fertility levels, recommended dose of NPK gave significantly higher yield compared to that of control, and 50% of recommended dose of NPK.

3.1.9 Agronomic Evaluation of Urea Coated with Neem Oil Components at Varying Doses in Aromatic Rice

A field experiment was conducted during *kharif* 2006 to study the effect of urea coated with varying doses of major neem oil components on grain yield and nitrogen use efficiency of scented rice cv. Pusa Sugandh 2 at a fixed rate of nitrogen, i.e. 100 kg N/ha. The treatments (17) comprised combinations of 5 major neem oil components (free fatty acid, pure oil, meliacins, saturated and unsaturated) coated prilled urea with their 3 doses (500, 1000 and 5000 ppm). An additional treatment of prilled urea alone (control) without any coating was also taken.

Highest grain yield was recorded with meliacins coated urea, which was significantly higher than all the other neem oil components coated urea. Unsaturated fractions coated urea produced significantly more grain than saturated fractions coated urea. Varying doses of neem oil components being on a par recorded higher grain yield over prilled urea

Effect of prilled urea coated with major neem oil components at varying concentrations on yield and nitrogen use efficiency of scented rice

Treatment	Grain yield (t/ha)	Total N uptake (kg/ha)	Agronomic efficiency (kg grain/ kg N)	Apparent N recovery (%)
Sources (Oil component)				
FFA	5.52	108.4	21.5	31.1
Pure oil	5.75	118.0	23.9	36.0
Meliacins	5.98	126.1	26.1	42.5
Saturated	5.65	111.7	23.0	37.2
Unsaturated	5.85	115.3	24.9	39.1
CD (P=0.05)	0.11	16.7	2.8	10.3
Oil component dose (ppm)				
0 (Prilled urea)	5.13	90.0	18.0	26.6
500	5.58	113.6	22.1	35.7
1000	5.83	118.6	24.6	38.7
5000	5.84	115.4	24.8	37.2
CD (P=0.05) (0 vs. rest)	0.08	12.5	2.1	7.7
CD(P=0.05)(Bet. doses)	NS	NS	NS	NS

alone. Highest total N uptake (grain+ straw) was also recorded with meliacins coated urea, which was significantly higher than free fatty acid coated urea. Irrespective of the source, all the doses (500, 1000 or 5000 ppm) of different neem oil components recorded significantly higher N uptake (grain + straw) than prilled urea alone. Meliacins coated urea recorded significantly higher agronomic efficiency (AE) and apparent nitrogen recovery (ANR) of applied N than free fatty acid. Coating of prilled urea with any of the major neem oil components at 500 ppm dose is as good as its higher doses in respect of AE and ANR.

3.1.10 Nutrient Management through Organic Sources in Cauliflower-based Cropping Systems

In a field trial, cauliflower-based cropping systems were evaluated under different sources of organic nutrients in a three times replicated split-plot design, assigning cropping systems to main-plots and nutrient sources to sub-plots. *Sesbania* was grown for green manuring during the *kharif* season. FYM, vermicompost and biofertilizers were integrated in different combinations to supply plant nutrients.

Among the different systems, cauliflower-tomato-*Sesbania* produced the maximum cauliflower equivalent yield (53.3 t/ha), which was 164.4% and 19.7% higher than those of cauliflower–bottlegourd-*Sesbania* and cauliflower-fenugreek-*Sesbania* cropping systems, respectively. Application of FYM @ 5 t/ha with vermicompost @ 2 t/ha and biofertilizers proved to be the best organic sources of nutrients producing the highest yield of all the crops in the system.

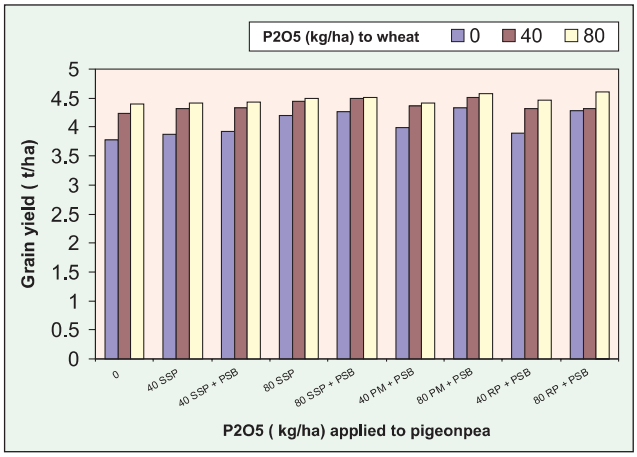
Productivity of various cauliflower-based cropping systems under different nutrient sources

Treatment	Curd yield of cauliflower (t/ha)	Cauliflower yield equivalents of succeeding crops (t/ha)			Total equivalent yield (t/ha)
		Bottlegourd	Fenugreek	Tomato	
Cropping system					
Cauliflower-bottlegourd-*Sesbania*	11.8	8.4			20.3
Cauliflower-tomato-*Sesbania*	10.7			42.7	53.3
Cauliflower-fenugreek-*Sesbania*	12.2		32.4		44.7
CD (P=0.05)	1.4				-
Fertility levels					
Control	8.5	7.0	23.7	31.7	29.3
Biofertilizers (PSB +VAM)	9.3	8.1	30.7	35.1	33.9
FYM @ 10 t/ha	11.3	8.2	33.7	43.9	39.9
FYM @ 10t/ha +biofertilizers	12.0	8.8	34.8	45.0	41.5
Vermicompost @ 4 t/ha	12.2	8.5	34.0	46.4	41.7
Vermicompost @ 4 t/ha+biofertilizer	13.9	9.0	34.4	47.4	44.2
FYM @5 t/ha + vermicompost @ 2 t/ha + biofertilizer	14.8	9.1	35.9	48.8	46.1
CD(P=0.05)	0.9	-	-	-	-

3.1.11 Phosphorus Management in Pigeonpea-Wheat Cropping System

A field experiment was conducted during 2005-2006 to study the phosphorus requirement of pigeonpea-wheat cropping system. The treatments comprised 3 sources of P {Single superphosphate (SSP), press mud (PM) and rock phosphate (RP)} and 2 levels of P_2O_5 (40 and 80 kg/ha) with phosphate solubilizing bacteria (PSB) along with a control (no phosphorus) applied to pigeonpea as main plots and 3 levels of P_2O_5 (0, 40 and 80 kg/ha) applied to succeeding wheat crop as sub plots replicated thrice in a split plot design.

Application of phosphorus to pigeonpea irrespective of sources and levels significantly increased the grain yield. Application of 40 and 80 kg P_2O_5/ha through press mud with PSB being on a par produced similar grain yield to the corresponding levels of P_2O_5 through single superphosphate + PSB. Rock phosphate showed poor performance among



Direct and residual effect of P fertilization on wheat in pigeonpea-wheat system

the 3 sources of P. In succeeding wheat, significant positive residual effect of higher level of P_2O_5 (80 kg/ha) with PSB was observed, where wheat did not receive P or received 40 kg P_2O_5/ha only, except in rock phosphate applied to pigeonpea. Rock phosphate at 40 and 80 kg P_2O_5/ha with PSB in pigeonpea produced similar yields of wheat at 40 kg P_2O_5/ha applied in wheat crop. There was, however, no residual effect of P applied to pigeonpea, when wheat was fertilized with 80 kg P_2O_5/ha.

3.1.12 Performance of a New Wheat Genotype at Different Dates of Sowing under Irrigated Condition

Wheat genotype K 0307 was evaluated against three established checks of normal sown varieties and one check of late sown variety under normal as well as later dates of sowing. Under normal date of sowing it did not yield better than cultivars HD 2824 and PBW 343 but under late sown conditions, the genotype K 0307 out yielded established late sown check DBW 14.

3.1.13 Comparative Evaluation of Well Performing and Established Normal Sown and Late Sown Varieties of North Eastern Plains Zone under Different Dates of Sowing

Three well performing and established varieties each of normal and late sown groups of North Eastern Plains Zone were evaluated for their performance under different dates of sowing for giving a preference of adoption to farmers.

The overall performance of normal sown varieties was superior to overall performance of late sown varieties at all dates of sowing at this location indicating that even under forced condition of late sowings, one can prefer to go for sowing of normal sown high yielding variety of that area.

The performance of HD 2733 (3.39 t/ha) was the best in this area under different dates of sowing followed by PBW 343 (3.22 t/ha), NW 2036 (2.98 t/ha), DBW 14 (2.90 t/ha), HUW 468 (2.78 t/ha) and HD 2643 (2.66 t/ha), respectively.

3.1.14 Evaluation of Suitable Wheat Varieties under Conventional Tillage and Zero-Tillage Conditions

The performance of six recognized varieties of each group, i.e., normal sown and late sown groups, was evaluated under conventional as well as zero tilled sowing conditions.

Results revealed that under conventional tillage condition, the order of preference is for HD 2733 (4.5 t/ha) followed by HUW 468 (4.24 t/ha) and HW 2045 (4.21 t/ha) under high yielding group. PBW 373 (3.96 t/ha) performed best, followed by K 9107 (3.92 t/ha) and HD 2824 (3.73 t/ha) in normal yielding group. Under zero-tillage condition, HD 2733 (4.26 t/ha) followed by HD 2824 (4.18 t/ha) and HUW 468 (3.95 t/ha) from the high yielding group, and PBW 373 (3.90 t/ha) followed by HP 1731 (3.88 t/ha) and HW 2045 (3.78 t/ha) from the normal producing group performed best.

3.1.15 Effect of Seed Treatment with *Azatobactor* and PSB Culture in Wheat

Seed treatment with bio-fertilizers (PSB culture and *Azatobactor*) in plots with half N and half P of recommended dose yielded 3.2 t/ha and 1.62 t/ha, respectively, in conventional and zero-tilled wheat as against to 3.42 t/ha and 1.88 t/ha in plots with full dose of N and P with application of *Azatobactor* or PSP singly. This indicates that application of these bio-fertilizers can compensate for about 50% of recommended nitrogen as well as phosphatic chemical fertilizers, with only a marginal loss in yield but major gain in economy of conventional as well as zero-tilled wheat production.

3.2 SEED SCIENCE AND TECHNOLOGY

3.2.1 Seed Production Technology

3.2.1.1 Pollination studies in hybrid rice seed production

Pollination studies in hybrid rice seed production in Pusa Rice Hybrid 10 were undertaken to understand the various factors contributing to hybrid seed yield. Spikelets of male line always opened later than those in female line growing under similar condition. Late transplanting with lower seedling

age of male line reduced days to flowering by 3 days. Effective accumulated temperature (EAT) of female line was higher than that in male line by about 17-26 ºC. Maximum air borne pollen/ cm^2 was 523.5 with two times (at 10:30 h and 11.30 h) rope pulling under low R.H. condition. The number of pollen deposited on the stigma was the highest in the treatment of GA_3 @ 180 g/ha and two times pollination at 10:30 h and 11.30 h, which gave a seed yield of more than 4.0 t/ha.

3.2.1.2 Quality seed production of vegetable crops under drip and surface irrigation

The comparative studies on seed yield and quality of vegetable crops under drip and surface irrigation revealed significant differences in seed yield and quality characters under two methods of irrigation (i.e., drip and surface) in carrot cv. Pusa Kesar, cauliflower cv. Pusa Sharad, onion cv. RO 1 and turnip cv. Pusa Sweti. Higher seed yield (41.27 g/plant), 1000-seed weight (4.94 g), germination percentage in primary (99), secondary (98) and tertiary (79) umbels, vigour index in primary (1019.7), secondary (924.14) and tertiary (645.43) were recorded under the drip irrigation system in carrot cv. Pusa Kesar. Higher seed yield (34.00 g), 1000-seed weight (5.55 g), germination (99%) and seed vigour (1001.88) were obtained under drip irrigation system compared to those under surface irrigation in cauliflower cv. Pusa Sharad. Vegetable seeds stored under ambient conditions up to next planting season showed better quality attributes like germination percentage, seedling length, seedling dry weight, vigour index-I and index-II and electric conductivity of seed leachates in seeds produced by low-pressure drip irrigation as compared to those produced by surface irrigation. Therefore, the studies recommend seed production of carrot (cv. Pusa Kesar) and cauliflower (cv. Pusa Sharad) with drip irrigation.

3.2.1.3 Hybrid seed production technology in tomato

Hybrid seed production under poly house condition in tomato vars. Pusa Hybrid 4 and Pusa Divya revealed that maximum fruit set, and seed set were achieved with pollination on the 3rd day after emasculation, and repeated pollination had no added advantage over single pollination. Higher seed number/fruit was obtained by pollinating the emasculated bud with pollen stored for two days even though seed set was normal up to 5-day stored pollen. The effective days available for pollination under polyhouse were found to be 55 days for var. Sel 120 (female parent of Pusa Hybrid 4). Low night temperature below 12 ºC results in no fruit set because of flower drop of the emasculated buds. A comparison of quality attributes in seeds (both self and F1) produced under poly house and open field revealed that seeds produced under polyhouse were of better quality though these seeds showed higher percentage of initial seed dormancy, especially in the parental lines of Pusa Hybrid 4.

3.2.1.4 Hybrid seed production technology in cauliflower

The parental lines of cauliflower hybrid Pusa Karthik Shanker (early group) were planted on 23rd July, 17th August, and 27th September, 2005. There was a difference in flowering time for different transplanting dates. A difference of 6-14 days of flowering between the parental lines was recorded (the female parent being late).

GA_3 and IAA were sprayed for manipulation of flowering time in the parental lines at different growth stages. The results indicated that GA_3 @ 250 mg/l and IAA @ 100 mg/l sprayed at curd initiation stage reduced the days to flowering of the female parent synchronizing with that of the male parent. It also enhanced the duration of flowering of the seed parent.

3.2.1.5 Hybrid seed production in bottle gourd (*Lagenaria siceraria* (Mol) Standl)

Hybrid seed production in bottle gourd (*Lagenaria siceraria* (Mol) Standl) was undertaken in open field and poly house conditions following natural (honeybee) and artificial pollination. Hand pollination resulted in significant increase in the number of fruit set/plant, number of filled seed/ fruit, seed yield/fruit and per plant as well as 1000- seed weight as compared to those in natural pollination. Seed yield/fruit (21.33 g), seed yield/plant (31.40 g) and 1000-seed weight (114.00 g) were relatively lower in poly house than those in open field conditions. Highly significant differences for seed length and seed width were noted between the poly house (14.50 mm and 7.20 mm) and the open field (14.68 mm and 7.38 mm). The study suggests that seed production of hybrid bottle gourd should be taken up in the open field conditions and with the use of artificial pollination.

3.2.1.6 Effect of sowing time and cutting management on seed yield and quality of berseem seed

Seed yield of the crops sown on 25th October, 10th November and 25th November remained on a par with each other. However, further delay in sowing reduced the seed yield significantly. Seed yield also remained on a par when one to three cuts were taken before leaving the crop for seed production. However, there was a significant reduction in seed yield when the crop was left for seed production after taking four to five cuts across the sowing dates. Seed quality in terms of germination and seedling vigour was significantly superior in the crops sown on 25th October and 10th November compared to that of the crops sown on 25th November and

10th December. Good quality seed can be obtained after taking two to three cuts of fodder before leaving the crop for seed.

Effect of sowing dates and cutting on seed production in berseem

Treatment	Seed yield (kg/ha)	Per cent germination	Vigor index I	Vigor index II
Sowing Dates				
25th October	331.0	86.2	549.8	191.6
10th November	326.0	84.9	537.3	179.6
25th November	339.6	73.7	446.0	152.7
10th December	229.4	72.0	427.4	138.4
Left for seed after				
One cut	361.5	82.0	500.1	182.7
Two cuts	387.5	81.1	529.8	177.1
Three cuts	340.9	80.5	503.4	161.5
Four cuts	245.6	76.7	476.6	158.4
Five cuts	190.9	75.7	440.6	148.6
CD (P=0.05)				
Sowing dates	26.9	2.70	41.00	17.9
Cutting management	73.8	2.59	34.6	20.8

3.2.1.7 Effect of bulb size and integrated nutrient management in onion seed crop

Seed yield attributes were significantly affected by different nutrient systems. Recommended dose of fertilizer (RDF) (NPK 125:50:25), RDF 75% + Wellgro soil manure (300 kg/ha) and RDF 75% + FYM 5 t/ha remained on a par with each other. Significantly lower seed yield was observed with RDF 75% + Ecohume (25 kg/ha). Seed quality in terms of germination, seedling length and seedling dry weight was not affected by bulb size or nutrient management.

Effect of bulb size and integrated nutrient management on growth and seed yield of onion

Treatment	Number of functional leaves (75DAS)	Number of umbels/ plant	Seed yield (t/ha)
Bulb Size			
Large (>60g)	29	5.68	1.12
Medium (30-60)	27	4.37	0.96
Small size (<30g)	14	2.93	0.68
CD (P=0.05)	3.6	0.92	0.088
Nutrient management			
RDF (NPK 125:50:25)	22	4.40	0.99
75% RDF+Wellgro manure 300 kg/ha	24	4.45	0.96
75% RDF + FYM 5t/ha	28	4.95	1.01
75% RDF+ Ecohume (25 kg/ha)	21	3.40	0.72
CD (P=0.05)	4.1	1.07	0.10

RDF: Recommended dose of fertilizer

3.2.1.8 Integrated nutrient management in onion bulb production

Bulb yield increased significantly at 100% recommended dose (RD) compared to that of 50% RD of NPK. There was a reduction of 23.6% and 38.0% in bulb yield at 75% and 50% RD, respectively compared to that of 100% RD of NPK. The bulb yield obtained from 75% RD of NPK along with FYM, was on a par with that of 100% RD indicating a saving of 25% of NPK. However, yields in 75% RD of NPK + Wellgro soil manure and Ecohume remained lower than that of 75% RD of NPK + FYM.

Effect of integrated nutrient management in bulb production

Treatment	Bulb weight (g)	Bulb yield (t/ha)
100% RD	51.4	26.24
75% RD	45.7	20.07
50% RD	36.3	16.28
75% RD+Ecohume	43.8	22.98
50% RD +Ecohume	41.1	16.38
75% RD + Wellgro manure	42.3	25.59
50 % RD +Wellgro manure	40.1	20.52
75% RD + FYM	50.8	28.71
50% RD + FYM	42.6	20.16
Control	29.9	12.89
CD at 5%	7.6	7.66

(RD: Recommended dose of NPK 100:50:25)

3.2.1.9 Nicking behavior of parental lines (Pusa 6A and PRR 78) of PRH 10 for hybrid seed production

Investigations undertaken for the second year to assess the nicking behavior of parental lines (Pusa 6A and PRR78) of PRH 10 for hybrid rice seed production indicated that among the different gaps (2, 4, 6, 8, 10, 12 days) studied, the nicking was appropriate at around eight days' gap between female parent (Pusa 6A) and male parent (PRR 78) under Karnal conditions.

3.2.2 Effect of Production Seasons on Seed Quality of Quality Protein Maize

Parental lines and hybrids of quality protein maize produced in *rabi* and *kharif* seasons were evaluated for morphological characters, flowering behaviour, seed quality attributes and seed storability. Molecular markers were used for establishing hybridity and assessing genetic purity of hybrid seed. Seed production was better in *kharif* season in terms of yield as well as quality both at Delhi and Kolhapur. Storability of seeds was high, and germination remained above the certification standard for more than one year under ambient storage conditions. Under low temperature conditions (<20°C), the storability could be extended up to two years in

all the genotypes. Accelerated ageing and cold test were good indicators of seed vigour, though for low vigour seeds, cold test could also be used. Among the various isoenzymes, and RAPD and SSR markers tested, dup SSR 34 could successfully establish the hybridity of Shaktiman 1 and also distinguish the hybrid from its seed parent (single cross).

3.2.3 Morphological and Molecular Characteristics for DUS Testing in Maize (*Zea mays* L.)

As per UPOV and Indian test guidelines, 23 morphological characteristics of 10 inbred lines and varieties of maize (*Zea mays* L.) were evaluated for establishing distinctness and uniformity. Additionally, assessment of distinctness and level of homogeneity of four maize genotypes was also tested using 10 SSR markers. Among these characteristics, two qualitative, characteristics i.e., anthocyanin coloration of leaf sheath and angle between blade and stem showed uniformity in its expression for all genotypes studied. Among ten inbreds and varieties, inbred line 193-1 and single cross hybrid Prakash showed the highest uniformity and the least variation within the populations for almost all characteristics. Low uniformity in the case of other hybrids and varieties indicated the inherent problems associated with breeding and maintenance of maize varieties. Application of 10 SSR markers in single plant analysis revealed the highest intra-varietal uniformity (75-100%) in single cross hybrid Prakash. In contrast, inbred line CM 137 showed significant intra-varietal variation at various SSR loci with pair-wise genetic similarity of 45-90%.

3.2.4 Seed Vigour and Its Enhancement

Assessment of various vigour parameters in relation to field emergence and storability was done in 76 soybean seed lots, which included 54 genotypes with differences in storability, seed size and testa colour; fresh and old seed lots of five cultivars each and 12 seed lots of cv. JS 335. The germination (%) after accelerated ageing was found to be the best predictor (r = 0.84) of field emergence in soybean. It was followed by electrical conductivity of seed leachates (r = -0.79). One hundred seed weight had a significant and negative correlation with field emergence (r = - 0.37) as well as storability (r = - 0.29). Out of five seed treatments, viz., Thiram @ 2.5 g/kg, Polykote @ 4ml/kg, Polykote (4ml/kg) + Thiram (2.5g/kg), Thiamethoxam @ 4g/kg and Royal Flo @ 3 ml/kg seed, attempted to improve field emergence in soybean, Royal Flo @ 3 ml/kg was found most effective. Seed vigour played a major role in field emergence under moisture stress conditions with field emergence index of 54.2 in the case of good storer genotype (one out of two viable seeds emerged) as compared to 33.5 (one out of three viable seeds emerged) for poor storer genotypes.

3.2.5 Physical, Physiological and Biochemical Factors for Seed Longevity in Soybean (*Glycine max*. L. Merill.)

Poor seed longevity of soybean is a serious problem, which is influenced by several physical, physiological and biochemical attributes. A significant genotypic variability was observed with respect to storability among different soybean varieties. Accelerated ageing for four days at 40 °C temperature and 90% RH could be used to predict potential longevity of seed after 9 months of storage.

Different physical characteristics, viz., seed colour, seed size, seed density, proportion of seed coat, pores on seed coat surface and 'hourglass' cells in seed coat had direct impact on storability of soybean seeds. These properties influenced the strength of the seed coat and provided protection from mechanical damage due to natural wetting and drying and pre- and post harvest operations. Good storer varieties had lower rates of imbibition and electrolyte leakage, which were associated with the number of pores on the seed coat surface and lignin and calcium contents of seed coat. Black seeded varieties had low number of pores on seed coat surface and higher lignin content in seed coat. Seed deterioration was hastened by retention of high moisture at higher relative humidity and higher rate of imbibition by the poor storer varieties. Higher activities of lipoxygenase (LOX I and II) aggravated the peroxidation of PUFAs in the cell membrane and production of malondialdehyde (MDA) and other volatile aldehydes in soybean seeds. High activity of LOX I and II and production of MDA and other volatile aldehydes were more in the bold and yellow seeded poor storer varieties than in the black and small seeded good storer varieties. Good storer varieties also showed higher activity of radical scavenging enzymes, viz., superoxide dismutase and catalase activity.

3.2.6 Effect of Different Priming Treatments on Germination and Vigour in Capsicum

Preliminary studies carried out at the Institute's regional station at Karnal indicated that osmopriming and solid matrix priming improved seed germination in Capsicum under optimal and sub - optimal temperatures. The effect of priming in improving seed germination was more pronounced at low temperatures. Both solid matrix priming and osmopriming treatments resulted in higher seedling dry weight. Osmoprimed seeds showed low values for electrical conductivity (EC) of leachates, water soluble sugars (WSS) and free amino acids (FAA) thereby indicating better stability of membranes during osmopriming.

Effect of different priming treatments on seed germination and quality under optimal and sub optimal temperatures in Capsicum

Treatment	Germination (%)			Seedling dry wt. (mg)	Seed leachates		
	15^0 C	20^0 C	25^0 C		EC µs	FAA µg/ml	WSS µg/ml
Osmopriming	79	89	83	49.0	42.4	6.834	7.122
Solid matrix priming	78	84	84	53.0	56.0	5.167	16.300
Halo priming	78	83	79	46.0	59.4	8.967	16.580
Hydro priming	73	80	75	46.0	66.5	10.10	20.509
Control	42	74	71	44.0	201.0	35.09	46.804

3.2.7 Effect of Seed Treatment on Seed Quality and Yield Components of Rice (*Oryzae sativa*) Infected with *Bipolaris oryzae*

Studies were conducted to screen diverse groups of seed treatment materials against *Bipolaris oryzae* and the effect of seed treatment on storability and field performance of *Bipolaris oryzae* infected rice seed. Among the 10 seed treatments that were tested both *in vitro* and *in vivo*, Thiram, Mancozeb, Tricyclazole, Kalisena, Salicylic acid and *Trichoderma viridae* were found to be effective against the pathogen. Among the 20 fungicidal combinations (involving 7 chemicals, viz., Mancozeb, Thiram, Carboxin, Tricyclazole, Captan, Bitertanol and Carbendazim) that were tested @ 2 g/kg seed having 97% artificial inoculum of *Bipolaris oryzae,* all the combinations, except those containing Bitertanol or Carboxin, were found to be effective by way of completely eradicating the pathogen. In the 18 months' long storage experiment, seeds of three rice varieties having different levels of natural infection of *Bipolaris oryzae,* i.e., IET 1001 (22.50%), Sona Mehsuri (69.00%) and Jyothi (27.50%), collected from Mandya region (Karnataka), were separately treated with Mancozeb, Tricyclazole, Salicylic acid, *Aspergillus niger* and Azadirachtin before storage. Mancozeb, Tricyclazole and *Aspergillus niger* were found to be effective in improving different seed quality parameters, viz., seed health, germination and vigour. *Bipolaris oryzae* inoculated rice seed treated separately with Thiram, Carboxin, Mancozeb and Captan were found to be on a par with each other in improving field emergence, seedling survival, seedling vigour and seed yield. The second best treatment for controlling *Bipolaris oryzae* was seed treatment with Tricyclazole or Kalisena.

3.2.8 Effect of Magnetic Field Treatment of Seeds on Root and Shoot Characteristics of Maize Seedling

Seeds of maize variety Ganga Safed 2 exposed to different levels of static magnetic field were evaluated for its effect on growth characteristics. Exposure of 1000 and 2000 Gauss magnetic fields for 1 h resulted in significantly higher leaf area, root length, root surface area and root shoot ratio in 45 days' old potted plants. Therefore, this technique can be exploited to improve crop stand in rainfed agriculture by providing high vigour seeds.

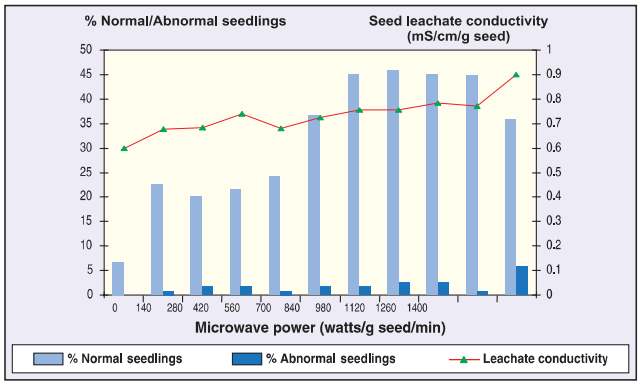
Root growth of 45 days' old maize plants from seeds treated with magnetic field

Effect of magnetic field treatment of seeds on root and shoot characters of maize

Parameter	Total root length (cm)	Root surface area (cm^2)	Root/ shoot ratio	Leaf area
Control	112	22.8	0.13	131
1000 Gauss	634	91.8	0.26	462
2000 Gauss	408	51.6	0.26	345
CD (5%)	88	12.8	0.05	87.4

3.2.9 Microwave Energy for Reducing Hard Coat Dormancy in Fodder Legume *Stylosanthes seabrana*

Hard coat dormancy was reduced and germination per cent increased from 7% in control to 46% in treated seeds. Microwave energy increased leachate conductivity and induced micro-cracks on seed coat that facilitated increased rates of imbibition.



Changes in seed water content with hours of imbibition in water for microwave treated seeds of *Stylosanthes seabrana*

3.2.10 Seed Testing Protocols for Medicinal Crops

3.2.10.1 *Plantago ovata* (isabgol)

Seed germination was examined in 18 seed samples of

isabgol (*Plantago ovata*)(cvs. Niharika and GI 2. Germination in 12 samples of isabgol varied from 87% to 93 %. Niharika took shorter time for germination, as final count was possible on 4th day on Top of Paper (TP) method at 20°C with no pre-treatment or additives.

3.2.10.2 Ocimum *basilicum* (marwa)

Studies on germination requirement and storability of seeds of *Ocimum basilicum* revealed that photodormancy (positively photoblastic) was reduced with increasing storage period. Seeds required pre-treatment (pre-chilling for 24 h) or additives (GA_3, 250 ppm co-applied) for maximum germination in the absence of light or poor light condition in TP at 30 °C. Seeds with 10% moisture content exhibited high germination (84 –90%) after one-year of storage.

3.2.10.3 *Abelmoschus moschatus* (muskdana)

Abelmoschus moschatus (muskdana) seed samples exhibited physical dormancy with 50% to 70% hard seeds, and pre-treatment of seeds with hot water or sulfuric acid was essential for obtaining enhanced germination in Between the Paper (BP) method at 25 °C with final count on the 10th day. Seeds of muskdana exhibited poor storability under ambient storage condition.

3.2.11 Seed Production in Farmers' Field - A Participatory Approach

Under the ICAR mega project on "Seed Production in Agricultural Crops and Fisheries" the Division of Seed Science & Technology of the Institute initiated a programme with the support of CATAT of the Institute on production of quality seed in farmers' fields and transfer of technology through participatory approach in collaboration with the farmers' cooperatives. A memorandum of understanding (MOU) was signed between the Farmers/Farmers Cooperatives in Jhunjhunu district (Raj.) and Bullandshahr district (U.P.) and the IARI for encouraging farmers to produce quality seed and to enhance the seed replacement rate.

3.2.12 Seed Production

At the Seed Production Unit of the Institute (Delhi) and at the Institute's regional stations at Karnal, Pusa, Indore and Katrain, nucleus, breeder and IARI seeds of different varieties of cereals, pulses, oilseeds, vegetables and ornamental crops were produced during the year under strict quality control. Apart from seed production, 845 saplings of fruits and flowers were produced at the Seed Production Unit (Delhi). At the Regional Station, Karnal, about 5500 horticultural plants were produced. At Regional Station, Pusa (Bihar) about 3372 seedlings of papaya (cv. Pusa Dwarf) were produced.

Seed production (t)

Crop	Nucleus seed	Breeder seed	IARI seed	Total seed
Seed Production Unit (Delhi)				
Cereals	-	13.61	52.79	66.40
Oilseeds	-	0.1	3.51	3.61
Pulses	-	5.83	2.83	8.66
Vegetables	0.003	0.324	1.147	1.474
Flower	0.30(kg)	-	1.70(kg)	200(kg)
Regional Station, Karnal				
Cereals	2.77	82.44	71.84	157.05
Forage	0.07	-	5.93	6.00
Oilseeds	0.03	4.00	2.18	6.21
Pulses	0.07	8.13	3.62	11.82
Vegetables	0.04	4.02	1.14	5.20
Regional Station, Indore (Breeder seed produced under farmers participatory programme)				
Cereals	-	164.8	-	164.8
Oilseed (Soybean)	-	1.5	-	1.5
Fruit (Papaya)	-	15(kg)	-	15(kg)
Regional Station, Pusa				
Fruit (Papaya)	-	-	12.55(kg)	12.55(kg)
Regional Station, Katrain				
Vegetables	0.189	0.552	2.26	3.001
Regional Station, Wellington				
Cereal	-	4.00	-	4.00

3.3 SOIL MANAGEMENT

3.3.1 Dynamics of Soil Organic Carbon under Different Agricultural Management Practices and Land Uses

There is a growing interest in assessing the role of carbon sequestration not only in sustaining the agricultural productivity, but also in maintaining the overall environmental quality as soil contains a significant part of global carbon stock. The influence of different nutrient and tillage management practices and land uses on various soil organic carbon pools, and their contribution to the soil fertility was assessed. Results indicated that by and large, there was significant improvement in Walkley and Black (WBC) and labile fractions ($KMnO_4$–oxidizable, LBC and microbial biomass carbon, MBC) of carbon as a result of supplementation of nitrogen through organic and integrated sources after completion of four cropping cycles under soybean-wheat, rice-wheat, and maize-wheat cropping systems. Nutrient management practices have larger effect on the labile fractions of soil organic carbon compared to

Walkley and Black carbon, whereas soil under natural vegetation/forest and receiving sewage sludge or industrial effluents showed improvement in both total and labile pools of organic carbon. Under different cropping systems and native forest, by and large, labile fractions of soil organic carbon exerted more consistent positive effect on the availability of nitrogen, phosphorus and sulphur compared to agricultural lands receiving sewage and sludge on long-term basis. Carbon management index computed based on total and labile fractions of soil organic carbon was sensitive and useful for assessing and monitoring the carbon dynamics under different agricultural management practices and land uses on even short-term basis.

3.3.2 Estimation of Crystallite Size and Crystal Strain of Micaceous Minerals of Different Soils

Crystallite size and crystal strain of micaceous minerals of different soils were estimated from the broadening of mica peak by using the Lorentzian (L) and Gaussian (G) profile shape function. Results show that crystallite size of micaceous minerals was largest in coarse clay fractions of Entisols (13.2 nm to 85.7 nm) and it was followed by clay fractions of Alfisols and Vertisols in that sequence. In almost all the profiles of Alfisols, Vertisols and Entisols, the crystallite size of micaceous minerals exhibited an increase along the depth of the profile. The micaceous minerals present in the lower layers were highly crystalline.

3.3.3 Stability of Clay – Humus Complexes

To study the stability of clay-humus complexes, humic and fulvic acids isolated from three sources, viz, bio-gas slurry, farmyard manure and green manure compost were applied to original coarse clay and fine clay and their residue remaining after removal of amorphous aluminaosilicate, separated from four soils viz., Inceptisol, Mollisol, Vertisol and Alfisol. These were incubated one at 55 °C for thermal decomposition and the other with fungus inoculation (mixed culture of *Trichoderma receeii* and *Aspergillus awamori*) at 25 °C for microbial degradation. Sampling was done at 10 days' interval and organic carbon content was analysed. The data were fitted to find out the decompostition rate constant. The stability of the clay–humus complex was assessed from the rate constant of decomposition obtained from the data fitted in the first order equation. Results showed that the sequence with respect to stability against thermal decomposition was: Alfisol (A) clay.> Inceptisol (I) clay = Vertisol (V) clay = Mollisol (M) clay; Fine clay > coarse clay > coarse clay minus amorphous aluminosilicate > Fine clay minus amorphousaluminosilicate; Biogas slurry > FYM > green manure compost; and humic acid > fulvic acid.

3.3.4 Long-term Effect of Rice Cropping on Clay Mineral Composition of Soil

The most striking difference in clay composition of two profiles, one under rice crop and the other under crops other than rice, was that in the case of continuous non-rice cropping no mica peak (1.0 nm) was observed throughout the profile; instead there was an evidence of extensive inter-stratification or mixed layering. In a profile, where rice has been cultivated for the last 37 years, micaceous minerals ranging from 7% to 25% have been recorded throughout the profile. This shows that weathering of minerals, particularly of mica is slower in soils growing rice under water-logged condition as compared to that in soils growing upland crops.

3.3.5 Stability of Clay Minerals in Relation to Pedogenic Progression in Different Agro-ecosystems

Horizon-wise soil profile samples were collected from adjacent sites of farm-cultivated and forest areas of Kalimpong (West Bengal), belonging to hill and mountainous ecosystem of Eastern Himalayan agro-ecosystem, and Nagpur (Maharashtra), belonging to hot semi-arid eco-region of the Deccan Plateau. Data on the initial characteristics of the soil samples collected from both the sites showed that the forest

Characteristics of arable and forest soils

Site	Horizon	pH	O.C. (%)	Texture	Exch.K (kg/ha)	Exch.Na (kg/ha)	Exch.Ca meq/100g	Exch.Mg meq/100g
Kalimpong (Forest)	Upper	4.1	2.30	Loam	161.0	146.0	0.10	0.44
	Lower	4.7	1.24	Sandy Clay loam	77.0	138.0	0.70	0.37
Kalimpong (Cultivated)	Upper	5.2	1.60	Clay loam	220-362	405-421	1.54-4.40	2.1-3.2
	Lower	5.9	1.20	Clay loam	181-190	456-465	3.60-4.80	2.7-3.0
Nagpur (Forest)	Upper	6.7-8.4	1.12-1.31	Sandy Clay loam-clay loam	117-187	405-486	20.4-25.7	27.5-33.7
	Lower	6.5-8.5	0.57-0.73	Sandy loam-clay loam	74-125	459-548	14.9-34.6	14.4-19.0
Nagpur (Cultivated)	Upper	8.2	0.60	Clay loam	448.0	729.0	41.3	25.0
	Lower	8.4	0.39	Sandy Clay loam	270.0	780.0	39.5	30.4

soils in general have lower pH compared to the pH of nearby cultivated plots. Similarly organic carbon is high in the forest soils but exchangeable Na and K are lower in these soils compared to those of nearby cultivated plots.

3.3.6 Inter-relationship between Boron and Sulphur as Measured by Crop Response and Soil Analysis

To study the adsorption and desorption of boron in the presence of sulphur and *vice versa,* surface soil (0- 15 cm) samples of an Alfisol from Ranchi (Jharkhand) were collected. The adsorption of boron was studied by equilibrating the soil with varying concentrations of boron at each level of applied sulphur at room temperature. Similarly, the adsorption of sulphur was studied by equilibrating the soil with varying concentrations of sulphur at each level of applied boron. The results indicated that the adsorption of boron in the presence

Langmuir constants of boron adsorption in the presence of various level of sulphur

S levels (ppm)	Adsorption maximum (b) mg kg $^{-1}$	Bonding energy constant (k) L mg^{-1}	R^2 Value between c/x and c
10	38.80	0.076	0.960
20	37.64	0.072	0.943
30	39.36	0.067	0.962
40	39.18	0.074	0.948
50	40.67	0.073	0.959
70	41.81	0.073	0.941
90	41.41	0.072	0.924
120	42.36	0.070	0.952

of sulphur conformed to the Langmuir adsorption equation with the correlation coefficients ranging from 0.924 to 0.962 being highly significant. The adsorption maximum (b) ranged from 37.64 to 41.81 mg kg^{-1}. Absence of variation in the values of adsorption maximum with increasing levels of applied sulphur indicated that the B-adsorbing sites are generally specific to boron and act independently of other competing anions. As in the case of boron, the Langmuir model was the best in describing the sulphate adsorption in the presence of increasing levels of applied boron, with R^2 values ranging from 0.843 to 0.920. The values of adsorption maximum (b) ranged from 54.76 to 59.88 mg kg^{-1}, and the constant related to the bonding energy (k) varied from 0.071 to 0.084. The results of the present study clearly show that the adsorption of boron in the Alfisol of Ranchi is not affected by the application of sulphur. Similarly, the competitive effect of boron on the adsorption of sulphur is also not observed.

Desorption of boron in the presence of sulphur and *vice versa* conformed to the Freundlich equation; R^2 values between log c and log x ranging from 0.981 to 0.994 and from 0.947 to 0.992, respectively. The value of Freundlich constant '1/n' varied from 0.422 to 0.606 in the case of boron desorption, and from 0.530 to 0.701 in the case of sulphur desorption, indicating no interaction effect between boron and sulphur.

3.3.7 Effectiveness of Adsorption Isotherms for Determining the Sulphur Requirements of Mustard

Fertilizer sulphur requirement of soils widely varying in available (0.15% $CaCl_2.2H_2O$) soil S content (3.21 to 30.20 mg S/kg) was estimated from the sorption curve, for equilibrium S concentrations ranging from 0.53 to 12 mg S/L. The mean dry matter yield of 60 days old mustard increased significantly with the increase in S level up to 4.0 mg S/L; thereafter non-significant increase was observed. However, 40% of the soil samples having available soil sulphur content above critical limit of 10 mg S/kg by 0.15% $CaCl_2.2H_2O$ responded to sulphur application. These were the soils, which had comparatively high value of sulphur adsorptive capacity. It indicates the soundness of the recommendation of sulphur doses on the basis of equilibrium concentrations over the critical limit basis. This approach may also economize sulphur doses.

3.3.8 Biological Mobilization of Potassium from Waste Mica

Data emanating from the incubation experiment, carried out to evaluate the mobilization of potassium from waste mica using biological potassium fertilizer (BPF), viz., *Bacillus mucilaginous* revealed that with this simple microbial intervention of BPF inoculation, significant mobilization of K occurred from waste mica. The release of potassium was higher when waste mica was added @ 4% K as compared to that obtained with 2% K. Compared to the control, addition of BPF broth culture to both the soils (Alfisol and Inceptisol) having divergent physicochemical properties significantly enhanced the exchangeable as well as non-exchangeable K throughout the incubation period of 30 days. Amongst the two soils, higher amount of exchangeable K was observed with Alfisol than with Inceptisol. On the other hand, non-exchangeable K was significantly higher in Inceptisol than in Alfisol. These results indicate that by introducing this biological intervention, waste mica reserves could be used as the potassic fertilizers, particularly when India is relying wholly on imports to meet the potassium demand of the crops.

3.3.9 Soil Biodiversity Assessment for Enhancing Carbon Sequestration and Nitrogen Cycling

3.3.9.1 Biological soil health under Bt- and non-Bt-cotton

Investigations on microbial activity, biochemical

Impact of *Bt*-cotton on soil biochemical and biological characteristics (Information is based on the comparison between *Bt* and non-*Bt* cotton cultivars).

Biological and biochemical characteristics	Positive effect (+)	Negative effect (-)	Percent
Microbial biomass C	+*		39
Microbial biomass N	+*		47
Microbial biomass P	+*		96
Total organic carbon	NS		-
Microbial quotient	+*		33
Dehydrogenase		-*	- 17
Soil respiration		-*	- 3.5
Potential nitrogen mineralization	+*		17
Nitrification	+*		9
Nitrate reductase	+*		27
Alkaline phosphatase	+*		13
Acid phosphatase	+*		22

processes and dynamics of C, N and P in the rhizosphere of transgenic Bt (cv. MRC 6301Bt) and non-Bt cotton (cv. MRC 6301) crops revealed significant increase (+ 9% to 96%) in microbial biomass carbon, microbial biomass N, microbial biomass P, microbial quotient, and various enzyme activities (potential N mineralization, nitrification, nitrate reductase, acid and alkaline phosphatases) in soils under Bt-cotton over those in non-Bt. The total organic carbon in Bt and non-Bt systems was not different ($p > 0.05$). However, dehydrogenase activity and soil respiration were significantly decreased (-3.5% to -23 %) under Bt and non-Bt systems. Total mineral N (NH_4^+-N + NO_3^--N) in soils was reduced (-14 %), whereas Olsen-P was increased (+ 8 %) in the rhizosphere of Bt-cotton. Time of sampling during plant growth also strongly ($p < 0.05$) affected the above parameters.

3.3.9.2 Influence of land use and crop management on nitrogen dynamics

Assessment of long-term land use and crop management (>15 years, at IARI farm) on N dynamics and microbial groups revealed that the N mineralization potential (NMP), which is an indicator of organic matter quality, varied from 0.5 mg N $kg^{-1}d^{-1}$ in the surface layer of tube-well-irrigated rice-wheat system to about 2.5 mg N $kg^{-1}d^{-1}$ in vegetable nursery system. In agroforestry and vegetable fields the NMP was more in subsurface than in the surface layer. The potential nitrate reductase activity (NRA), an indicator of potential denitrification, was highest in both the layers of agro-forestry system and was minimum in the vegetable nursery. With respect to microbial diversities, three distinct patterns were observed. Soil bacteria, fungi and actinomycetes dominated in sewage irrigated vegetable fields and agroforesty systems.

3.3.10 Fertilizer Nitrogen Use Efficiency by Wheat Grown under Elevated Levels of Atmospheric Carbon Dioxide

In order to test the hypothesis whether stimulation in growth under elevated CO_2 alters fertilizer-N use efficiency by wheat and organic-N fraction pools in its rhizosphere, and whether widening of C: N ratio in plant parts can be arrested through enhanced N application rates; a pot experiment was conducted in an Inceptisol at ambient (370 mmol mol^{-1}) and elevated (600±50 mmol mol^{-1}) levels of atmospheric CO_2 superimposed with 100%, 150% and 200% of STCR recommended N. Data showed that all the plant parts showed significant gain in yield on exposure to elevated CO_2. The C:N ratio widened in both straw and grain due to higher CO_2. Tracer studies showed that both grain and straw samples recorded moderate enhancement of % Ndff values under elevated CO_2, prompting increase in total fertilizer-N uptake by 19%, and fertilizer-N use efficiency by 16%. Apparent fertilizer-N efficiency values were 15%-20% higher than actual efficiency, indicating strong priming effect, especially under elevated CO_2. All the three possible mechanisms of (i) enhanced fertilizer-N use efficiency, (ii) greater exploitation of native-N, and (iii) adjustments in N requirements within plant seemed to work together; and helped to meet the increased N demand.

Among inorganic-N fractions, nitrate-N decreased and ammonium-N increased in crop rhizosphere under elevated CO_2, compared to ambient situation. Among various fractions of acid hydrolysable-N, amino sugar-N decreased by 30%, and ammonia-N enriched by 21%; while amino acid-N remained unchanged owing to elevation in atmospheric CO_2. Strong evidence has emerged from this study that the ammonia-N, both in organic or inorganic form, is protected in crop rhizosphere better under elevated CO_2.

3.3.11 Phosphatase Activity and Organic Phosphorus Mobilization in Rhizospheres of Rice and Wheat Grown under Elevated Atmospheric Carbon Dioxide

In order to test the hypothesis whether the increased P demand by the C_3 crops grown under elevated atmospheric carbon dioxide is met through enhanced mobilization of organic P, a pot-culture study was carried out in open top chambers with ambient (approx. 370 ppm) and elevated (600±50 ppm) levels of atmospheric CO_2 with rice and wheat as test crops. Both the crops were grown with 150% of the

recommended doses of fertilizer (for N, P and K) along with crop residues @ 9 g/kg soil. Crops were grown up to maturity. Data emanating from the experiments showed that there was a greater assimilation of P by the crops under elevated atmospheric CO_2.

In spite of significant increase in microbial mass (around 41% in rice and 17% in wheat rhizosphere, values averaged over all the stages of crop growth) under elevated CO_2, there was no effect of types of phosphomonoesterase except alkaline phosphatase in rice rhizosphere. This apparently disapproves the contention that the additional demand of P might have been partially met through mineralization of organic P. There was a significant build-up of organic P in rice rhizosphere at higher atmospheric CO_2 concentration, thus confirming the earlier trend with phosphomonoesterase activities. This prevented a net reduction in total P in spite of significant reduction in inorganic P.

3.3.12 Management of Agricultural Wastes as a Source of Plant Nutrients - Monitoring of Nutrient Transformation during Enriched Composting

Enriched composts were prepared by chopped rice straw mixed with various combinations of urea, rock phosphate (RP) with and without *Aspergillus awamori*, single superphosphate (SSP) and mica. Periodic samplings were done and analyzed for organic C, total and available N, P and K. Results showed that the mineralization of organic C increased with the progress of composting in all the treatments. Total N as well as NH_4^+-N and NO_3^--N increased significantly with the progress of composting. Among the sources of P, RP + *A. awamori* showed the highest amount of total N, NH_4^+-N and NO_3^--N as compared to RP alone and SSP. The NO_3^--N decreased up to 120 days of composting with the increase in levels of P, but it significantly increased with 2% P level at 180 days of composting. While the increase in the rate of N increased the total N, NH_4^+-N and NO_3^--N, the C/N ratio narrowed down with the increase in composting period. Mobilization of P from RP increased significantly during composting. It increased further when *Aspergillus awamori* was introduced along with the RP. With the increase in the rates of P, the available P content also exhibited a significant increase. However, with the increase in the rate of K through mica, the availability of P decreased. Increasing the levels of P increased the total P content gradually. As far as available K is concerned, among the sources of P, RP was associated with the highest available K at 60 to 180 days of composting. Inoculation with *A. awamori* did not show any further improvement. With rising rates of P, the available K content decreased significantly.

3.4 WATER MANAGEMENT

3.4.1 Surface Irrigation Studies

The experimental data on the advance and recession of water in border checks were collected during irrigation of wheat crop over its entire growth period. The analysis of data indicated that the water front advance was largely influenced by the inflow rate and its variations during each irrigation. The quantification of this influence was, however, very complex in view of temporal and spatial variations of other parameters like, infiltration, surface roughness and slope.

Surface Irrigation Simulation Software (SRFR): Simulation of application efficiency was found to be in close agreement with the observed values. The performance of SRFR was, however, found more satisfactory when the variation in the inflow rate was less.

Water application efficiency in the border checks increased with the growth of the crop. This trend in water application efficiency was attributed to the development of the effective root zone depth of the crop resulting in reduced percolation losses with subsequent irrigation.

3.4.2 Meteorological Studies

The rainfall data for the last 35 years in Gurgaon region were analysed and the runoff in all the years during monsoon season was computed to prepare the estimate for earthwork to increase the storage capacity of the pond at the KVK entrance. An estimate was prepared for storing an additional quantity of water of 1.325 ha-m in the pond.

Rainfall pattern of Water Technology Centre (WTC) farm site (1972-2006) was anlaysed and studied in the form of standard precipitation index (SPI) in different time scales. This is a useful index to assess drought situation in semi-dry and dry regions. Two time scales of the SPI were studied, namely, annual and seasonal. There were 17 drought years and about 19 drought seasons during the period. On a longer time scale, annual drought like situation is less frequent but lasts longer. On the other hand on seasonal basis, SPI indicates more frequent droughts but lasts for a shorter period. This index is particularly useful in planning and assessment of hydrological drought.

3.4.3 Watershed Based Studies

An exponentially distributed geomorphologic instantaneous unit hydrograph (ED-GIUH) model was developed for prediction of surface runoff from ungauged watersheds and its performance was compared with the curve number (CN) based runoff estimations. It was revealed that, the developed ED-GIUH model performed better than the CN

techniques in predicting surface runoff for rainfall events for duration less than or equal to 6 hours.

The digital elevation models (DEMs) of watersheds for different resolutions were generated using the available contours and by adopting geostatistical techniques within ArcGIS environment. Further, an interface in ArcGIS, named as watershed morphology estimation tool (WMET), developed in visual basic for application (VBA) programming language as a built-in macro was operated under different sub-watershed threshold aerial units to generate the drainage network. The WMET interface used the D-8 flow routing concept in generating of the watershed drainage pattern. Finally, the effect of the up scaling issues on the generated drainage network was investigated by comparing the generated network with the observed drainage network of topological maps. The drainage density was estimated for different scales of threshold areas to account for the effect of upscaling. It was revealed that the effect of upscaling in finer resolution DEMs' was more prominent than that of coarser resolution DEMs'. Also, the higher value of threshold area resulted in drainage networks with missing links of first order and smaller channels and the smaller threshold values resulted in more clustered and dendritic networks with abrupt links. Nonetheless, it was observed from this study that the upscaling and downscaling of the threshold unit for generation of the drainage network plays a significant role in its accurate mapping. Further, the relationship between the drainage density and the upscaled area can be used as a parameter in quantification of surface runoff and sediment yield from watershed systems.

Modified curve number estimation techniques were coded in VBA built in macro programming tool and linked with arcobjects protocol of ArcGIS to develop an interface for estimation of surface runoff. This developed interface performed a series of activities starting from storing of the GIS feature class attribute tables to the estimation of surface runoff depths using four different CN techniques. The interface was validated using the recorded data for the periods from 1993 to 2001 of a gauged watershed Banha in the Upper Damodar Valley in Jharkhand. The observed runoff depths for different rainfall events in this watershed were compared with the predicted values of NRCS- CN methods and its three derivatives using statistical significance. The developed interface in ArcGIS is user friendly and can be applied over any watershed systems by inputting the desired information as required for CN based surface runoff estimation techniques.

The seasonal water requirement of a range of crops grown in the Moolbari watershed near Shimla in Sub-Himalayan region were worked out on decadal (10 daily basis) using CROPWAT model. The objectives of the study were to find the best alternative cropping pattern for most efficient utilization of available water resources in the watershed. The general crops grown in the watershed as well as the few cash crops preferred by the farmers (depending on the market response) were selected for the present study. While the *kharif* season crops such as pulses, French beans, maize, pumpkin, tomato (Kh) and potato (Kh) did not require any irrigation water to be applied, the cucumber required 24.33 mm of water. The summer season crops depicted higher water requirements in general: green beans (146.17 mm), tomato (114.17 mm) and winter wheat (122.63 mm). *Rabi* season crops could be grouped into three groups (low, medium and high water requiring crops) based on their water requirements. The estimated water requirements of chickpea, small vegetables, barley, sesame and linseeds were 45.71, 23.31, 35.86, 44.13 and 26.07 mm, respectively. The medium water requiring crops were green peas, mustard, maize (up to baby corn stage) and sunflower with their water requirements of 51.42, 57.01, 61.43 and 53.17 mm, respectively. The vegetable crops such as cabbage, cauliflower, potato (R), and Capsicum though were highly preferred group of crops, yet required high amount of water during the complete growing season, i.e., 78.15, 78.15, 82.37 and 75. 38 mm, respectively, as compared to other two groups. The climatic, soil and market availability conditions being more suitable to growing of a large number of vegetable crops that could fetch more cash to farmers, yet the availability of water restricts their growing with flooding irrigation. However, the adoption of highly efficient methods of irrigation and optimization of crops based on their water requirement and profits will result in the development of the best cropping pattern.

3.4.4 Application of Modern Tools (Remote Sensing)

A methodology was developed to identify different land degradation problems in an irrigation command using remote sensing and GIS. The methodology includes characterization of land degradation problems, its distribution and extent and simulation of surface waterlogging for a given effective rainfall. It was found that normal soil, saline soil, waterlogged-saline soil, and waterlogged area can be best represented by NDVI, Salinity Index and normalized Salinity Index, Brightness Index and Normalized Difference Water Index, respectively. It was observed that January month remote sensing imagery gives the best result for distinguishing different land degradation problems.

3.4.5 Irrigation Agronomy

In the second year of field experimentation, the trend of grain yield productivity of Ethiopian mustard *(B. carinata)*

was almost similar to that in the first year. Three irrigations given at seedling (30 DAS) + 50% flowering + pod development stages of the crop produced the maximum and significantly higher seed yield compared to the yield produced with one irrigation (seedling). Similarly, nitrogen applied @ 90 kg/ha produced the highest yield followed by 30 kg N/ha. Application of 40 kg S/ha through multiplex enhanced the seed yield of mustard substantially over that of 20 kg S/ha and no sulphur. Moisture use by mustard in terms of seasonal consumptive water use and moisture use rate was maximum with three irrigations. But nitrogen and sulphur applications did not influence appreciably both the moisture use, i.e., consumptive use (CU) and moisture use rate (MUR). However, crop water use efficiency (CWUE) was more with one irrigation and higher levels of nitrogen and sulphur.

Under rainfed conditions, sowing of wheat by aqua-ferti-seed-drill (AFSD) gave significantly higher grain yield compared to that obtained in conventional method. It was also observed that under one life saving irrigation availability, irrigation may be applied during CRI-tillering stages of the crop growth to induce more tillering and root density which in turn would enhance the productivity of wheat. Aqua-ferti sowing increased the seasonal water use and crop water use efficiency over that of conventional sowing.

Results revealed that there was no significant difference in grain yield of pearl millet because of cropping system. Similar grain yield was obtained when pearl millet was grown as sole crop and intercropped with either cowpea or mungbean. However, additional yields of intercrops were obtained without any adverse effect on the yield of main crop. Irrigated pearl millet (two irrigations given at tillering and grain development) produced significantly higher grain yield compared to that produced under rainfed conditions.

3.4.6 Pressurized Irrigation Studies

Irrigation applied daily as per the ETcrop produced pod yield of summer peanut var. GG20 comparable to that produced under irrigation applied 2 days after and at 30% management allowed deficit (MAD) but higher than that produced under 40% and 50% MAD. However, methods of planting (normal and paired row) did not show significant variation in pod yield of summer peanut.

The response of two crop geometries (consisting of 150 cm^2/plant and 250 cm^2/plant with two distinct irrigation methods, namely, drip and micro sprinkler methods using 340 mm water each) on garlic yield was investigated. The experiment was planned with two plant densities (4 lakh plants/ha and 6.6 lakh plants/ha) having 12 treatments and 3 replications in the randomized block design. The analysis of the data showed that the highest yield was recorded in 10 cm × 15 cm spacing with drip irrigation method. The seasonal average water use rate with drip irrigation was estimated to be 1.6 mm/d for the crop duration of 165 days in the semi-arid region. The crop yield ranged from 5 Mg/ha to 11 Mg/ha, respectively, in micro sprinkler and drip irrigation methods. The variation in yield was attributed to the better water distribution uniformity obtained under drip irrigation method. Economic analysis of the data further suggested that the highest benefit cost ratio of 1.8 was obtained in the case of the drip irrigation method. The study concluded that 6.5 to 7 lakh plants/ha with drip irrigation would be one of the best options for garlic production.

Subsurface drip irrigation systems are more efficient than the surface drip irrigation systems. A subsurface drip irrigation system was installed in onion (Indo-American hybrid var. Creole Red) crop at 0.0, 5.0, 7.5, 10.0, 12.0, 15.0 and 18.0 cm depths, with drippers spaced at 30 cm each with an application rate of 2.75 Lph. It was found that when drip laterals were placed at 12.0, 15.0 and 18.0 cm soil depths there was less upward movement of soil moisture which resulted in water stress to the plants roots. Possible reasons could be the shallow root system of onion and soil type.

The use of coloured photodegradable mulches in potato revealed that clear plastic (translucent white) mulch gives higher soil temperature compared to that gives by blue, green, yellow and black mulches but maximum yield (30.3 t/ha) was obtained in white coloured mulch.

A user-friendly software, namely, MICROS was developed in Visual BASIC 6.0 for the design and evaluation of micro-sprinkler system. A detailed 'Help' menu is provided in the software to facilitate a thorough understanding of the theory and methodology adopted for the design and evaluation of micro-sprinkler systems.

3.4.7 Aerobic Rice Cultivation

Rice production under traditional puddle-transplanted low land uses more than 50% of irrigation water used in agriculture. A change from traditional rice production system to aerobic rice system is imperative to increase the water productivity of rice crop. Twenty-four rice genotypes were evaluated for their yield performance under aerobic conditions with three irrigation regimes, viz., irrigations at zero kPa, 20 kPa and 40 kPa soil moisture tensions. In aerobic rice production system with zero kPa irrigation treatment, rice genotypes IR74371-46-1-1 and Proagro 6111 produced the highest yield of about 5.5 t ha^{-1}. Rice genotypes Pusa Rice Hybrid 10, Proagro 6111 (hybrid), Pusa 834, IR 55423-01, IR 72875-94-3-3-2, and IR 74371-46-1-1 produced a grain yield of ≥ 4 t ha^{-1} under aerobic production system irrigated at 40kPa soil moisture tension, while the upland variety N 22 produced

a grain yield of about 3.0 t ha^{-1} under these conditions. As puddling and nursery raising are not necessary for aerobic rice system, it directly saves about 300 mm of water as compared to the water used by conventional transplanted rice. Further, irrigation at 40 kPa soil moisture tension also saves about 400 mm of irrigation water as compared to the water used under irrigation at near 0 kPa soil moisture in aerobic rice system. Thus, about 50% water requirement for rice can be saved by aerobic rice production system.

3.4.8 Water Quality Studies

A field experiment was conducted to assess the relative reduction in grain yield of gram (chickpea) and pea (field pea) on irrigation with saline water (EC_{iw}) of 0.4, 2.5 and 5.0 dS m^{-1}. Results indicated that, in general, grain yield of all the varieties of chickpea decreased by 10% and 25% on irrigation with EC_{iw} 2.5 and 5.0 dS m^{-1}, respectively. However, varieties did not show much variation among themselves. Based on grain yield with saline water, chickpea varieties were observed to be salt tolerant in the following descending order:

Pusa 72 = Pusa 362 > Pusa 1103 = Pusa 1105 > Pusa 1108

Further grain samples analysis indicated higher uptake of K^+ than Na^+ in all the varieties. Increasing salinity in water, however, did not induce increasing uptake of Na^+ and K^+.

Five varieties of field pea were grown in 2 m x 2 m plots and irrigated with EC_{iw} of 0.4, 2.5 and 5.0 dS m^{-1}. Based on grain yield, the varieties were salt tolerant in the following descending order:

DDR 44 > DMR7 >DDR23 >DDR27 >P 1542

An analysis of grain samples indicated that the uptake of K^+ was more than that of Na^+ in grains of all the varieties and the trend was not affected by increasing EC_{iw} levels.

A field experiment was conducted to study the effect of different EC_{iw} levels (0.4, 2.0, 4.0 and 6.0 dS m^{-1}) on the yield of garlic (*Allium sativum* L.). Results indicated that relative yield reductions were 10.7%, 11.5% and 34.0%, respectively, as compared to that of the control (EC_{iw} = 0.4 dS m^{-1}). However, reduction in vegetative parts, i.e., height and branching was not affected to that extent. It may, therefore, be inferred that garlic crop may be grown with saline water (EC_{iw}) up to 4.0 dS m^{-1} without any appreciable reduction. An analysis of bulb and leaves indicated that the uptake of Na^+ was more in leaves than in bulb, and increasing EC_{iw} levels induced more uptake of Na^+ in leaves than in bulb. The uptake of K^+ was more than that of Na^+ in both leaves and bulb and it remained unaffected with increasing EC_{iw}.

Water quality of groundwater samples from IARI tubewells was determined in terms of EC, pH, cationic and anionic composition. In general, the groundwater was categorised as low to moderate saline (EC_{iw} 1.0 to 2.5 dS m^{-1}) with moderate to higher levels of sodicity HCO_3^- = 7 to 13 meL^{-1}). Most groundwater samples had higher amount of NO_3^- ranging from 28 ppm to 131 ppm. Low NO_3^- content was noted in Indo-Israel project area and the highest in Lohamandi area (including the Seed Production Unit of IARI).

3.4.9 Isotopic and Hydrochemical Models for Vulnerability Assessment of Overexploited Groundwater

Iso-contours and multi-component mixing models of pollutants and isotopic composition of groundwater provided a unique understanding of the pollutants dynamics in groundwater in Delhi area. Over 60% of the wells have become vulnerable to increased chloride and nitrate contamination. The major sources of chloride and nitrate are anthropogenic wastes, landfills, sewage irrigation and sewage treatment plants, turf grass fertilizer and surface water runoff. ^{18}O isotope and major elements that accompany the groundwater may distinguish sources of nitrate with less ambiguity, under different land use. Cl, Na, Mg, Ca, SO_4 and NO_3 show promising results as nitrate tracers on ternary diagram and through element vs. element plots. Over the last two decades, intense urbanization induced several cut slopes of the rugged topography, released additional Ca^{2+} to groundwater by corrosion of subsurface concrete materials such as building foundations. There are indications of pollutants transport from the western, northwestern and southwestern areas to the urbanized and overexploited parts. In the northwestern and western parts, there is evidence of increasing ground water pollution and leachate transport to ground water through surface drainage. Guidance has been provided on the overall approach for protection of groundwater.

3.5 INTEGRATED NUTRIENT MANAGEMENT

3.5.1 Evaluation of Enriched Organo-Mineral Fertilizers on Crop Productivity and Soil Fertility in Soybean-Potato Cropping Sequence

Field experiments were continued to evaluate the fertilizer use efficiencies of enriched organo-mineral fertilizers, viz., (i) compost-A [rice straw (RS) + phosphate solubilizing microorganism (PSM) *Aspergillus awamori*]; (ii) compost-B [RS + RP (Udaipur rockphosphate) @ 2%P + PSM + mica @ 2% K] and (iii) compost-C [RS + RP @ 4% P + mica @ 4% K] on crop productivity and soil fertility in soybean-potato cropping sequence for the second year (2005-2006). Application of fertilizer materials directly to soybean crop resulted in significantly higher yield and uptake of nutrient

by soybean, and higher organic C and available N, P and K status in soil compared to those recorded in the control. Among the various products, the performances were in the order: product-C > product-B > product-A. Treatments receiving 50% N from fertilizer and 50% N from any one of the products performed better than the treatments receiving 75% N from fertilizer and 25% N from respective products. Residual effect on yield and uptake of N, P and K of potato was higher in the enriched organo-mineral fertilizers than in the control. Similar trends in crop productivity as well as build-up in soil fertility were observed by potato grown on residual fertility during the second year (2005-06).

3.5.2 Response of Sulphur on Seed Yield and Quality in Mungbean – Mustard Sequence

Field experiments conducted during *rabi*-2005-2006 on mustard in collaboration with the Seed Production Unit showed that the application of gypsum @ 30 kg S/ha along with recommended dose of NPK + 10 t/ha FYM produced the highest seed yield of, sulphur content in and uptake by mustard compared to those recorded in the rest of the treatments. Application of gypsum, pyrite and elemental sulphur @ 30 kg S/ha along with recommended dose of NPK could not produce significantly higher grain yield compared to that produced under recommended doses of NPK with and without FYM. All the treatments significantly increased the sulphur content of straw of mustard over that of the control except under recommended doses of NPK + FYM. Sulphur content in mustard seeds significantly increased under all the treatments over that of the control with the sole exception of pyrites. This study establishes that gypsum is a superior source of sulphur for mustard over elemental sulphur and pyrites. Integrated use of gypsum as sulphur source along with recommended dose of NPK + FYM sustains production of mustard in alluvial soils of Delhi.

3.5.3 Long-term Effects of Application of Manures and Fertilizers on Soil Environment under Maize-Wheat Cropping System

At the Delhi Centre of the All India Coordinated Research Project on Long-term Fertilizer Experiments (LTFE), a field experiment established during 1971-72 was continued with maize-wheat cropping system, to study the long-term effect of application of fertilizers applied alone or in combination with organic manure on soil characteristics and production sustainability. The experiment consists of 10 treatments, including sub-optimal (50% of recommended) to super-optimal (150% of recommended) NPK, N or NP alone, NPK along with Zn, S or FYM, and an unfertilized-control. The impact of these nutrient management practices on soil physical properties, micronutrient fractions and biological soil health is reported as follows:

3.5.3.1 Soil physical properties

Fertilizer treatments influenced significantly the hydraulic conductivity of the surface (0-15 cm) soil, the values being lowest (0.445 cm h^{-1}) in unfertilized-control plots and highest (0.761 cm h^{-1}) in NPK + FYM treatment, after 35 cropping cycles. The mean weight diameter (MWD) values were also highest (0.504 mm) under NPK + FYM. Soil bulk density did not differ under different treatments, except those receiving FYM.

Some physical parameters of soil as influenced by long-term use of fertilizers and manure

Treatment (kg ha^{-1})	Hydraulic conductivity (cm h^{-1})	Mean weight diameter (mm)	Bulk density (Mg m^{-3})
120-0-0 (NPK)	0.541	0.357	1.480
120-26-0 (NPK)	0.557	0.380	1.483
120-26-33 (NPK)	0.691	0.447	1.483
120-26-33 (NPK)+FYM	0.761	0.504	1.407
120-26-33 (NPK)+S	0.539	0.426	1.467
Control	0.445	0.365	1.503
CD (P = 0.05)	0.154	0.113	0.022

3.5.3.2 Micronutrient fractions

Amount of the various forms of Fe, Mn, Cu and Zn in surface soil fluctuated over a period of eleven years (1993-2004). Out of these, calcium carbonate bound-Fe and Zn as well as the forms of the four elements bound to the organic matter showed a declining trend. The distribution of different fractions of Fe, Mn, Cu and Zn under different fertilizer treatments and soil depths did not follow any specific trend. Different forms of Fe, Mn, Cu and Zn, namely, water soluble, easily reducible Mn-bound, organic matter bound, iron oxide bound, calcium carbonate bound, sorbed, and residual, were correlated with each other, establishing the existence of an equilibrium in the soil system. The contribution of different fractions towards micronutrient availability, crop yield and uptake varied widely amongst the micronutrients. Continuous cropping and fertilizer use decreased the concentrations of micronutrient cations bound to organic matter. If this trend continues, the deficiency especially that of available Fe and Mn may occur in near future. Proper management of organic matter would be needed to maintain and/or enhance the organic matter-bound Fe and Mn in soil.

3.5.3.3 Soil biological properties

There was a significant increase in total organic C (TOC) and microbial biomass C (MBC) contents in 100% NPK + FYM compared with the TOC and MBC of other treatments after harvest of maize 2006. A significant build up of total P as well as its organic and inorganic fractions was recorded under

Total organic C (TOC), microbial biomass C (MBC), fractions of phosphorus and sulphur, and enzymatic activities under long-term fertilizer use

Treatment	TOC	MBC	Total P	Inorganic P	Organic P	Total S	APM	AS
			(g kg^{-1})				(µg PNP g^{-1} h^{-1})	
50% NPK	9.3de	0.21c	1.93c	1.55bc	0.38c	2.5d	104d	1.27d
100% NPK	10.0d	0.25b	2.41ab	1.84ab	0.57abc	3.0d	145c	1.52c
150% NPK	12.9b	0.26b	2.64a	1.90a	0.74a	3.9c	176b	1.68b
100% NP	9.3de	0.23c	2.42ab	1.76ab	0.66ab	5.6ab	102d	1.19d
100% N	8.7d	0.18d	1.82c	1.35c	0.47bc	3.0d	72e	1.07e
100% NPK+ FYM	15.2a	0.33a	2.48ab	1.99a	0.49bc	5.5ab	209a	1.88a
100% NPK+S	11.0c	0.26b	2.29b	1.80ab	0.50bc	6.0a	191ab	1.22d
Control	8.3e	0.18d	1.75c	1.36c	0.39c	5.0b	85de	0.90f

APM: Alkaline phosphomonoesterase; AS: Arylsulphatase. Values in the column followed by different lowercase letters are significantly different at P = 0.05 according to Duncan's

treatments receiving P at recommended or super-optimal rates. Similarly, there was a build up of S in treatment where S was applied along with 100% NPK. The activities of alkaline phosphomonoesterase and arylsulphatase were significantly higher in 100% NPK + FYM treatment. The arylsulphatase activity was lower in 100% NPK+ S treatment as compared to that of 100% NPK treatment. Alkaline phosphomonoesterase activity and arylsulphatase activity significantly correlated with TOC and MBC contents in soil.

3.5.4 Basic Data and Soil Test-based Fertilizer Recommendations for Wheat and Pearl Millet

From the soil-test crop-response correlation field experiments conducted on wheat (PBW 502) and pearl millet (Pusa 383), the basic data were generated on nutrient requirements of these crops; and per cent utilization efficiency of soil, fertilizers and manure nutrients. Studies revealed that the FYM, besides directly contributing nutrients to the soil, also enhanced the efficiency of N, P and K fertilizers by 16.9%, 5.0% and 23.6% in wheat and 8.9%, 4.1% and 48.6% in pearl millet, respectively, over that recorded for N, P, and K under no-FYM treatment. With the application of FYM @ 10 t ha^{-1}, the fertilizer dose of N, P_2O_5 and K_2O could be reduced by 55, 20 and 30 kg ha^{-1} in wheat and 40, 35 and 45 kg ha^{-1} in pearl millet, respectively.

Basic data and soil test based fertilizer adjustment equations for wheat (cv. WR 544)

Nutrient	NR	%CS	%CF	%CFYM	Fertilizer adjustment equations
Wheat (PBW 502)					
Without FYM					
N	27.5	26.1	49.9	-	FN = 55.2 T – 0.52 SN
P_2O_5	8.9	54.7	23.3	-	FP_2O_5 = 38.2 T – 5.38 SP
K_2O	35.9	25.6	109.5	-	F K_2O = 32.8 T – 0.28 SK
With FYM					
N	27.5	26.1	66.7	24.3	FN = 41.2 T – 0.39 SN– 1.82 FYM
P_2O_5	8.9	54.7	28.3	12.4	FP_2O_5 = 31.4 T – 4.43 SP– 0.88 FYM
K_2O	35.9	25.6	133.1	36.3	F K_2O = 27.0 T – 0.23 SK– 0.95 FYM
Pearl Millet (Pusa 383)					
Without FYM					
N	34.9	18.5	48.1	-	FN = 72.6 T – 0.38 SN
P_2O_5	13.1	37.4	20.9	-	FP_2O_5 = 62.7 T – 4.10 SP
K_2O	50.2	18.9	94.3	-	F K_2O = 53.2 T – 0.24 SK
With FYM					
N	34.9	18.5	57.0	28.7	FN = 61.2 T – 0.32 SN– 2.52 FYM
P_2O_5	13.1	37.4	25.0	8.2	FP_2O_5 = 52.4 T – 3.42 SP– 2.25 FYM
K_2O	50.2	18.9	142.9	55.8	F K_2O = 35.1 T – 0.16 SK– 1.64 FYM

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

3.5.5 Integrated Nutrient Management in Pigeonpea-Wheat System

Results from the field experiment on pigeonpea-wheat system during the third consecutive year showed that the application of fertilizer NPK along with FYM or sulphitation pressmud (SPM) significantly increased the yields of pigeonpea and wheat compared with the yields obtained under fertilizer alone. Induced defoliation (ID) imposed through foliar application of 10% urea solution at physiological maturity of pigeonpea (extra-short duration cultivars) led to more than 1.0 t ha^{-1} of additional litter fall compared with natural senescence. This additional litter fall recycled into the soil gave about 40 kg N ha^{-1} along with substantial quantities of other nutrients. The yield of pigeonpea remained unaffected due to ID, but that of subsequent wheat was increased significantly. After completion of two crop cycles, marginal build-up in organic C was noticed under integrated nutrient supply treatments involving fertilizer NPK, FYM or SPM and ID compared with initial organic C content of 0.36%. Distribution of mineral-N (NH_4^+-N + NO_3^--N) in soil profile, investigated up to a depth of 0-90 cm, indicated greater content of NO_3^--N in 0-15 cm soil layer under ID or FYM/ SPM treatments, compared with that under NPK alone.

3.5.6 Sustaining Soil Health for Increasing Productivity and Quality of Crops through Integrated Nutrient Supply and Management

Under the project "Integrated nutrient supply and management in pearlmillet-mustard sequences" the

treatments comprised supply of nutrients through fertilizer alone (N, P_2O_5 and K_2O-75:30:30, 100:50:50, 150:75:75) and N, P_2O_5 and K_2O (100:50:50) along with either FYM @ 10 t ha^{-1} and 20 t ha^{-1} or sulphitation press mud (SPM) @ 5 t ha^{-1} and 10 t ha^{-1}. Among the NPK fertilizer treatments applied with FYM or SPM in pearl millet, the sources of P were DAP, SSP and rockphosphate-enriched biogas slurry (RPEBGS). The results from an ongoing field experiment indicated that application of FYM or SPM (10 t ha^{-1} each) along with N, P_2O_5 and K_2O supply through fertilizers (100:50:50) gave 0.33 to 0.39 t ha^{-1} higher grain yield, significantly higher P and K uptake and P use efficiency in pearl millet over the corresponding data recorded for N, P_2O_5 and K_2O alone application. The per cent contribution of FYM and SPM (10 t ha^{-1} each) towards total N and P uptake by pearl millet was 15.5 and 13.5, and 19.9 and 13.6, respectively. Among the P sources, RPEBGS in combination with FYM (5 t ha^{-1}) and phosphorus solubilizing microorganisms (PSM) was equivalent in effect to the other sources (DAP and SSP) with respect to grain yield, K uptake and P use efficiency in pearl millet. Application of recommended level of N, P_2O_5 and K_2O (100:50:50) along with FYM (20t ha^{-1}) was on a par with the N, P_2O_5 and K_2O level (150:75:75) with respect to grain yield, P and K uptake and P use efficiency in pearl millet.

3.5.7 Release and Uptake of Phosphorus from Some Organic Materials in Wheat-Blackgram Sequence by the use of Tracer

Employing tracer (P-32) in a study on release and uptake of phosphorous from three organic manures, namely, FYM, sulphitation pressmud (SPM) and sewage sludge (applied @ 40, 80 and 120 kg P_2O_5 ha^{-1}) in wheat-blackgram sequence revealed that the grain yield of wheat was the highest with DAP (4.66 t ha^{-1}) followed by SPM (3.97 t ha^{-1}), sewage sludge (3.76 t ha^{-1}) and FYM (3.71 t ha^{-1}). In terms of P uptake by wheat at flowering, the organic P sources used for P application could be arranged in the sequence: SPM (11.9 kg ha^{-1}) > sewage sludge (10.2 kg ha^{-1}) > FYM (9.7 kg ha^{-1}). The actual contribution of P from individual manure towards total P uptake by wheat at flowering was maximum with SPM (17.89 %) followed by FYM (17.29%) and sewage sludge (16.62%) as against DAP (29.0%). The manures used as P sources were arranged in decreasing order of their performance with respect to mean P utilization by wheat at flowering as SPM (6.72 %), sewage sludge (5.61%) and FYM (4.89%). Farmyard manure proved better than those of SPM and sewage sludge in their residual effect on blackgram in terms of grain yield, mean P uptake and mean P utilization. The P utilization by blackgram was maximum with FYM (13.3%) followed by SPM (8.91%) and sewage sludge (8.60%) in that sequence.

3.5.8 Assessment of Oil Content and Oil Yield of Mustard Grown under Pearl Millet –Mustard Cropping Sequence

Oil yield and oil content of mustard seeds, grown in an experiment on integrated nutrient management in pearl-millet–mustard cropping sequence, were evaluated under various treatments for consecutive two years' period (2004-2006), with oil content estimated by the NMR technique. The oil content in the seed samples indicated a variation of about 33% to 36%; the average values being marginally higher in the second year (2005-2006), while the control plots showed relatively higher content of oil but less of oil yield presumably due to lower seed yield. The NPK application decreased the oil content but increased the oil yield due to higher seed yield. The NPK application along with pressmud or BGS generally raised both oil content and oil yield, and also the seed yield. Trend was more pronounced when phosphorus was supplied through single super phosphate (SSP) and was applied in conjunction with FYM. The increase in seed as well as oil yield having increased oil content due to SSP, BGS or press mud clearly hint at the significant role played by sulphur in improving quantity and quality of oil in mustard.

3.5.9 Integrated Nutrient Management in Fruit Crops

In sweet orange cultivar Mosambi, various combinations of fertilizers along with bio-fertilizers and micronutrients (0.4% foliar sprays) were applied to assess their effect on fruit yield and quality parameters. Out of the various treatments, application of N (300 g) + P (250 g) + mixed strain of VAM (5 g) + *Azospirillum* (5 g) along with spray of 0.4% micronutrients (Cu + Fe + B + Zn) gave maximum number of fruits (151 fruits/plant), higher yield (22.6 kg/plant), and higher juice content (57.6 %) with TSS: acid ratio (12:1).

Kinnow bearing on *Troyer citrange* rootstock under INM strategy

In Kinnow mandarin, treatment comprising *Azotobacter* (10g/ plant) + PSB (10 g/plant) and micronutrients (combined spray of Fe, Cu, Mn and Zn at 0.4 % each) was found superior for growth and yield (103 fruits/plant) parameters as compared to those of control (65.0 fruits/plant). The maximum juice recovery (56.5%) and TSS (12.3%) were also recorded in the above treatment.

3.6 NUTRIENT AVAILABILITY

3.6.1 Soil Fertility Status in Different Agro-ecological Regions

In the on-going IARI-PDCSR-PPIC collaborative research project entitled "Appraisal of Soil Fertility Status of Different Agro-ecological Regions of India", 1100 soil samples representing 11 districts and 11 agro-ecological sub-regions (AESRs) were analysed for different soil fertility parameters. Soils of all the districts/AESRs exhibited deficiency of at least 4 nutrients i.e. N, P, K and B, but the magnitude of samples falling in fertilizer responsive category varied.

Nutrient deficiency in the soils of different agro-ecological sub-regions (AESRs)

AESR No.	District	No. of samples	Per cent samples in fertilizer-responsive category for										
			OC(N)	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B
2.3	Hisar	100	99	91	59	-	-	10	1	38	-	3	8
6.1	Ahmadnagar	100	64	60	35	-	-	3	36	55	-	-	22
6.2	Parbhani	150	65	89	3	-	-	1	53	17	-	-	51
7.3	West Godavari	50	14	14	86	24	4	-	-	-	-	-	24
8.1	Coimbatore	100	44	25	1	1	-	10	13	84	-	-	51
8.2	Bangalore	100	37	22	72	1	1	-	-	-	-	-	50
11.0	Raipur	100	72	3	4	-	-	1	-	3	-	-	49
15.4	Jorhat	100	57	66	93	7	4	-	-	-	-	-	60
17.1	Karbi Anglong	104	65	79	91	-	-	-	5	4	-	-	47
19.1	Raigad	100	78	62	96	-	-	-	2	-	-	-	33
19.3	Thiruvanan-thapuram	100	10	4	100	-	-	-	-	-	-	3	46

In 7 out of 11 districts, 57% to 99% samples containing organic C ≤ 0.75% were rated as N-responsive, whereas the magnitude of responsiveness in other 4 districts (namely, West Godavari, Coimbatore, Bangalore and Thiruvananthapuram) varied from 10% to 44%. In general, lower the organic C content greater was the incidence of P deficiency. Hence, the 7 districts having more than 50% samples in N-responsive category, also exhibited P deficiency to the extent of 60% to 91%. Widespread deficiencies of K were recorded, except in the soils of Parbhani, Coimbatore and Raipur. Soils' responsiveness to B was noticed in more than half of the samples of 5 districts, and the magnitude was the highest (60%) in Jorhat. Soils of these areas exhibited sporadic deficiency of S (<10%). Simultaneous deficiency of two or more nutrients, referred to as multi-nutrient inadequacy, occurred in all the districts/AESRs, and the magnitude was as large as 50% to 96% of the samples analysed. As the individual inadequacies of N (based on organic C), P, K and B were most frequent, the inadequacy combinations generally included one or more of these nutrients. On the whole, NPKB, NPK, NPB, NKB and NP were some of the prominent multi-nutrient inadequacy groups across the AESRs.

3.6.2 Zinc and Phytate Contents in Wheat Genotypes

The analyses of 117 wheat genotypes in previous year showed that there are subtle differences in the micronutrient contents particularly iron and zinc. Only two genotypes were found to have zinc content more than 50 mg kg^{-1}. In wheat genotypes, tested high for zinc content (> 40 mg kg^{-1}), the Zn to phytate molar ratio was found to be more than 14, indicating low bio-availability of zinc.

3.6.3 Reversion of Applied Zinc in Soils into Unavailable Forms

In zinc deficient soil, the available zinc, one year after application at normal recommended level of 5 kg Zn ha^{-1}, was found to be similar to that in original soil, and only in soils applied equivalent to 10 years' or more cumulative dose it showed a slight build-up. In a pot study, it was found that there was no significant effect of higher levels of Zn application equivalent to 10 years' or more cumulative dose on wheat yield, although it gave nearly 2 to 3 times higher zinc in wheat straw.

3.7 RICE - WHEAT CROPPING SYSTEM

3.7.1 Carbon Storage and Mineralization under Rice-Wheat System as Influenced by Tillage and Integrated Nutrient Management

Soil C content, labile carbon fractions and water stable aggregates were monitored in Typic Haplustept at IARI farm. Soil samples from five treatment combinations of N and farmyard manure under conventional and conservative agricultural tillage practices [T1: Control; T3: 100%NPK; T6: 150%NPK; T11: 100%NPK (25% N substituted by organics); T12: 100%NPK (100% N substituted by organics)] were collected after the harvest of each crop during the five crop seasons. In the microcosm studies, the CO_2 evolved at different time intervals was measured and the CO_2 data were used for calculation of "k", the first order mineralization rate constant. Compared to control or 100%NPK application, the treatments with either partial or full substitution of N by organics favored organic carbon and its various labile fractions.

The highest cumulative C mineralization was observed in soils from 100%NPK (100%N substituted by organics), the lowest in control, with the rest of the treatments in between. The observations are closely matched to their soil carbon content in these treatments. The amount of C mineralized, i.e.,

fraction of the total soil organic carbon, ranged from 5.78 in control and 7.28 for T12 with the rest having 6.75% (T3), 6.98% (T6) and 7.14% (T11). The first order mineralization rate constant "k" varied from 0.0041 for control and 0.0052 in T11 and T12. T3 and T6 had a "k" of 0.0048. Soils from no-till treatments showed lower rate of C mineralization.

The effect was attributed to better soil aggregation (higher mean weight diameter) and thereby resulting in mineral protection which facilitates the process of C stabilization in soil.

3.7.2 Nitrogen Use Efficiency in Rice under Conventional and Raised Bed-Planting

An experiment conducted in 2005 *kharif* season with rice variety Pusa Sugandh 3 under transplanted un-puddled raised bed condition gave a yield of 6.52 Mg ha^{-1} compared to 5.69 Mg ha^{-1} under transplanted puddled flat bed continuously flooded conditions. Also, the fertilizer N use efficiency as measured using ^{15}N labelled urea under raised bed condition was 46.7% compared to 38.4% under flat bed conditions. The direct dry seeding under raised bed or conventional flat bed conditions gave significantly lower yields as in the previous two years. The saving in irrigation water under raised bed planting was 21.2% compared to that under flat bed conditions. Under conventional condition, there was a higher build-up of ammonium-N in flood water after second split application of fertilizer N, and under bed planting conditions, there was a slight increase in nitrate-N in flood water and of this nearly 56% was derived from fertilizer urea. In rice variety Pusa Sugandh 3, the chlorophyll measurements using SPAD meter at ear emergence showed a linear relationship with rice grain yield.

3.7.3 Evaluation of Below Ground Root Biomass and Nitrogen in Wheat

The stem injection technique using 94.4 atom per cent urea revealed that the below ground biomass was nearly 3365 kg ha^{-1} under bed planting conditions and most of the roots were traced in the bed, and only about 23% of roots could be traced in furrow on both sides of the bed. In flat planting conditions, the roots were between upper 30 cm soil depth and the biomass was 3745 kg ha^{-1}. The below ground biomass accumulated 28.9 to 34.7 kg N ha^{-1}.

3.7.4 Fertilizer N Application Based on Chlorophyll (SPAD) Index in Wheat and Rice

In wheat, the data on chlorophyll measurements using SPAD meter showed direct linear relationship with leaf N content at GS-30 stage, and variable N rate application at GS-37 based on chlorophyll measurements resulted in a saving of nearly 20% fertilizer N. In rice crop, the SPAD index (chlorophyll) measured at ear emergence stage showed a highly significant positive relationship with rice grain yield at harvest ($r^2 = 0.911$).

3.8 ORCHARD MANAGEMENT PRACTICES

3.8.1 Study on Salt Tolerance in Citrus Rootstock

Citrus rootstocks, i.e., Jatti Khatti, Sylhet lime, Attani 1 and RLC 7 were screened for different levels of salinity. None of the rootstock could survive beyond 2.25 dS/m salinity after 90 days of salinization. Per cent reduction in dry mass of shoot (18.75%) and root (5.28%) was found minimum in Attani 1 and Sylhet lime, respectively, at 2.25 dS/m salinity, whereas, the highest reductions in dry mass of shoot and root were recorded in Jatti Khatti (41.07% and 57.33%) at the same salinity levels. Root/shoot ratio increased with increasing salinity levels in all the cultivars except Jatti Khatti. Maximum increase in root to shoot ratio recorded in Sylhet lime (0.65) at higher salinity levels indicates that root of this variety is more tolerant than shoot.

3.8.2 Rootstock Scion Interaction in Citrus

The performance of sweet orange cultivar Mosambi budded on five different rootstocks evaluated under Delhi conditions showed differential effect. Maximum plant height (3.35 m), spread (3.62 m x 3.76 m), heavier fruits (203.66 g), yield (102.50 fruits /plant) and juice recovery (51.75%) were noted on Karna Khatta (*Citrus karna*) rootstock. Minimum plant height (2.11 m) and canopy spread (3.13 m x 3.16 m) were observed on Cleopatra mandarin (*Citrus reshni*) rootstock. Maximum fruit drop (37.25%) was recorded on Jambhiri (*Citrus jambhiri*) rootstock and the lowest was on Karna Khatta rootstock (23.75%). Mosambi fruits with higher total soluble solids (10.30%) and lower acidity (1.00%) were recorded on Cleopatra mandarin rootstock.

3.8.3 Standardization of Micro-Irrigation and Fertigation Schedules for Apple

It has been concluded that micro-irrigation at 60% depletion of field capacity (FC) was necessary to maintain the apple trees in high productive condition. Fertigation with a low dose treatment was optimum to replace conventional fertilizer application. Fertigation curtails the fertilizer requirement of an apple tree to 0.323 kg against the requirement of 6.47 kg by conventional method resulting in annual savings to the extent of Rs 55.36 per tree. The optimum doses are: urea 1.7 g/tree/week for 10 weeks. Application of aureofungin, chlorpyriphos and hexaconazole through micro-irrigation was effective in reducing the incidence of white root rot, wooly aphid and powdery mildew.

3.8.4 Standardization of Fertilizer Dose for High Density Amrapali Mango

Trials were conducted to find out the nutritional requirements of mango cultivar Amrapali, under high density for different age groups of mango plants. Different levels and methods of nitrogen application were made to study its effect on plant growth, yield and fruit quality of cultivar Amrapali. Maximum tree volume (63.93 m^3) with plant height (523 cm), and canopy spread (483 cm x 483 cm) were observed when 800 g nitrogen/plant was applied partially through soil and partially through foliar spray (750 g nitrogen through soil and 50 g nitrogen applied as foliar spray). However, the highest yield per plant (78.20 kg) was observed under 400 g N/plant (basal) with better quality of fruits (20.60% TSS) in comparison to that observed under other nitrogen treatments. Among the foliar treatments, application of 3 per cent urea/plant was found to be the best for fruit yield (51.3 kg/plant) while better quality of fruits (19.1% TSS) was observed in 4 per cent urea as foliar application. The growth was found to be antagonistic to yield, i.e., higher the growth, lower the yield.

Effect of different doses and methods of nitrogen application on growth, yield and fruit quality of mango cultivar Amrapali under high density

Treatment {Nitrogen/ plant (g)}	Plant height/ (cm)	spread/tree (cm)		Tree volume (m^3)	Number of fruits /plant	Fruit wt. (g)	Yield/ tree (kg)	TSS (%)
		East-west	North-south					
Basal								
400g N	487	447	447	50.75	153	170	78.2	20.6
600g N	503	490	447	58.19	130	151	58.9	19.7
800 g N	537	440	477	59.37	107	164	52.4	20.0
Basal+Foliar								
400 (370+30g)N	493	420	427	47.00	97	171	49.6	19.7
600 (560+40g)N	547	443	443	56.41	100	160	48.0	18.4
800 (750+50g)N	523	483	483	63.93	73	168	36.9	17.5
Foliar								
3% urea	503	433	437	49.85	100	171	51.3	16.6
4% urea	513	430	430	49.89	110	152	50.1	19.1
5% urea	537	423	467	55.72	93	160	44.8	17.2
Control	490	440	447	47.34	47	134	18.7	15.0

3.8.5 Organic Cultivaton in Fruit Tree

Mango. A field experiment was conducted to estimate the effect of farmyard manure (FYM), vermicompost (VC), *Azotobacter*, *Azospirillum* and *Azospirillum* mixed strain (nutrilink), and phosphate solublising bacteria (PSB) (Microphos) on plant growth, assimilate partitioning, leaf nutrient status, fruit yield and quality in mango cultivar Amrapali. Increase in plant height and canopy volume was found significant with the application of various treatments compared to control, whereas increase in trunk girth and plant spread (east-west and north-south) was found non-significant. Maximum increase in plant height (8.32%) was observed in treatment with FYM + VC + AM fungi + *Azotobacter* + *Azospirillum.* Assimilate partitioning and other physiological parameters such as total chlorophylls, starch, proline, photosynthesis and leaf nutrient status were also found significant in treated plants as compared to those of control. Leaf nutrient status was found significant for N, P, Ca, Mg, Fe, Cu and Zn. More number of fruits (179 per plant), yield (33.1 kg per plant), TSS (22.8 %) and â-carotene (15,800 ìg/ 100g) and ascorbic acid (36.4 mg/100g pulp) were recorded with treatment comprising FYM (50 kg), vermicompost (16.5 kg), *Azotobacter* (10 g) and PSB (10 g) per plant.

3.9 PROTECTED CULTIVATION TECHNOLOGY

3.9.1 Production Economics of Virus-free Tomato Grown under Insect-proof Net House

A virus-free tomato crop (var. GS 600) was grown successfully under insect proof net house fabricated by using 40 mesh U.V. stabilized nylon net for a period of 6 months (August to January). Fruit yield of 1.5 t/ 300 m^2 was harvested and the crop was 98% virus free. Pesticide application was minimized and mainly used against vector white fly and fruit borer during rainy and post rainy seasons. The cost: benefit ratio of tomato cultivation under insect-proof net house was worked out as 1:2.15 under Delhi conditions.

3.9.2 Effect of Foliar Spray of Micronutrients on Plant Growth and Fruit Yield of Greenhouse Grown Sweet Pepper

All the micronutrients and commercially available products (Multiplex and Agroton) were sprayed at a concentration of 0.5% at flower bud initiation, flowering, and fruiting stage in addition to recommended dose of NPK through fertigation in all the treatments except in the control where only recommended dose of NPK was applied through fertigation. All the plant growth and fruit yield characters were significantly influenced by foliar spray of micronutrients. Maximum plant height (168.0 cm) and fruit weight (156.0g and 160.0 g, respectively) were recorded under multiplex and ferrous sulphate. Maximum fruit size (11.6 cm x 6.9 cm and 11.2 cm x 6.8 cm, respectively)

Effect of micronutrients foliar spray on plant growth and fruit yield of green-house-grown sweet pepper (var. Indira F_1 Hybrid)

Name of micro-nutrients	Plant height (cm)	Days of first picking of colored fruit after trans-planting	Fruit size index (LxG) (cm)	Average fruit weight (g)	Number of fruits/ plant	Av. fruit yield (t/ha)
Multiplex (commercial product)	168.0	96.0	11.6 x 6.9	156.00	11.60	48.0
Agroton (commercial product)	148.0	99.0	11.2 x 6.8	136.00	12.10	45.7
Borax	160.0	108.0	9.6 x 5.6	112.00	11.25	35.3
Manganese sulphate	152.0	104.0	9.6 x 5.4	114.00	15.65	49.2
Ammonium molybdate	150.2	99.0	9.4 x 6.0	112.00	11.15	34.6
Ferrous sulphate	168.0	105.0	10.8 x 7.0	160.00	9.0	32.2
Copper sulphate	147.0	110.0	8.8 x 6.2	105.00	12.25	31.9
Mixture of all	150.0	98.0	8.2 x 6.4	100.00	16.00	40.7
Control	154.0	93.0	9.8 x 6.2	120.00	10.50	33.8

was recorded under multiplex and agroton spray, whereas maximum fruit yield (49.2 t/ha) was recorded under manganese sulphate followed by multiplex (48.0 t/ha) under greenhouse grown sweet pepper.

3.9.3 Effect of Fruit Thinning on Fruit Quality in Greenhouse Tomato

Fruit thinning in greenhouse tomato (var. GS 600) significantly influenced the mean size of fruits mainly during winter season. The highest mean fruit weight (123.0 g) was obtained when only 4 fruits per truss were allowed to develop after removal of the excess number of fruits a few days after fruit set. The lowest mean fruit weight (95.0 g) was recorded when 7 fruits were allowed to develop in the truss without removal of any fruit from the truss.

3.9.4 Comparative Performance of Tomato Grown in Evaporatively-cooled and Naturally Ventilated Greenhouses

A tomato crop (var. GS 600) was transplanted in the first week of August under two kinds of greenhouse i.e., semi-climate controlled having cooling system, and indigenously designed naturally ventilated greenhouse. Under semi-climate controlled greenhouse the tomato crop could be grown up to June next year (11 months duration) with a total fruit yield of 260.0 t/ha, whereas under indigenously designed naturally ventilated greenhouse, the tomato crop terminated at the end of April, (9 months duration) with a total fruit yield of 196.60 t/ha. The break even costs of producing tomato under semi-climate controlled greenhouse and naturally ventilated greenhouse were worked out to be Rs. 21.0/kg, and Rs.8.50/kg, respectively.

3.9.5 Studies on Brassinosteriod Response on Off-season Chrysanthemum in Greenhouse

Chrysanthemum cv. Snowdon White was planted and sprayed with brassinosteroid (0, 1,2,4,6,8 and 10 ppm) at 12th to 14th leaf stage to determine the response to plant growth and induction flowering. It was found that the plants sprayed with brassinosteroid (6 ppm) grew vigorously with maximum plant height (78.7 cm) and stem length (66.7 cm). However, the plants sprayed with brassinosteroid (10 ppm) grew on a par with the plants sprayed with 6 ppm and 8 ppm brassinosteroid and produced maximum stem diameter (0.73 cm), flower size (11.2 cm across) and longest vase life (16 days) at room temperature.

3.9.6 Fertigation Scheduling and Nutrient Dynamics in Cabbage

Effect of different dosages of irrigation (60%, 80% and 100% ET) and nutrients NPK (100-60-60, 100-60-100 and 100-60-140) on the yield, average fruit weight and maximum fruit weight of cabbage (cv. Ambassador) grown under drip fertigation was studied. The maximum yield of 30 t/ha, and the maximum fruit weight of 800 g were obtained at the irrigation level of 80%ET and nutrient dosage of 100:60:140 kg/ha.

3.9.7 Studies on the Effect of Vent Area on the Temperature and Humidity in a Naturally Ventilated Greenhouse

The micro-climate of a naturally ventilated greenhouse is greatly influenced by the vent area provided in the greenhouse. Experiments were conducted on a model quonset construction greenhouse to optimize the vent area in relation to the floor area of the greenhouse. The salient results obtained are: (i) roof vent area more than 15% had negligible influence on increasing the ventilation rate, (ii) a total vent area equal to 50% of the floor area was desirable for effective ventilation, (iii) wind speed was more important for effective ventilation compared to the thermal buoyancy, and (iv) greenhouse length orientation should be north-south to take advantage of wind for ventilation.

3.9.8 Vegetable Production under Green House and White Shade Net-house

Precision farming of tomato, capsicum, cucumber, summer squash and *palak* was done by judicious use of all agricultural inputs. Tomato variety GS 600 yielded 10.1kg/m^2, capsicum variety California Wonder yielded 6.6 kg/m^2, cucumber variety Pusa Sanyog yielded 9.8 kg/m^2, summer squash variety Australian Green yielded 10.90 kg/m^2 under green house condition, and *palak* variety All Green produced 3.2 kg/m^2 under white shade net-house conditions.

3.9.9 Drying of Bio-materials

Aonla with various pretreatments, viz., blanching for 1 min, 2 min, 3 min, 4 min, and 5 min, and unblanched, was dried in a greenhouse type solar dryer and also under ambient conditions. Blanching for all time durations was found to improve the drying rate and product quality in terms of microbial load and vitamin C content. Rate of drying was faster in the greenhouse type solar dryer. The microbial load was found to be within acceptable limits in dried *aonla* after a storage period of 6 months, and more than 45% of the vitamin C (ascorbic acid) content was retained in the dried sample.

3.9.10 Survey of Greenhouses in and Around NCR (Delhi Region)

A survey was conducted in and around NCR for assessment of the use of different plasticulture and protected cultivation applications. The survey sites belonged to farmers' fields, farmhouses and landscaping units, research institutions, etc. Greenhouses, and more prevalently shade nets, were used in these regions for crop cultivation. Multispan and Quonset type greenhouses were mainly used in these regions for the cultivation of high value vegetables, herbs, flowers and nursery raising.

3.10 AGRICULTURAL ENGINEERING

3.10.1 Development of Pulse Polisher for Pigeonpea

A pulse polisher consisting of roller, concave, feed hopper and frame, was developed for polishing of pigeonpea *dal*. The roller is made of 250 mm diameter wood, and is covered with 5 mm leather. The length of concave is 550 mm, 75% of which is covered with leather towards inlet end, and 25% towards exit end is uncovered for separation of powder. It is operated with a 3 HP 3 phase motor. The overall dimension of the machine is 690 mm x 420 mm x 1470 mm.

Pulse polisher

3.10.2 Development of Integrated Rice Mill and Grader

A small capacity rice mill consisting of rubber roll sheller, blower for husk separation and polisher, was developed last year. This year, it was integrated with a grader. The grader consisted of 2 screens having round holes of different sizes and arranged in series. Dimensions of screens were 100 cm x 45 cm (upper screen) and 80 cm x 45 cm (lower screen). A pan is provided in the bottom of these two screens for collection of rice bran. These screens were employed for separating brokens and rice bran. Whole rice comes through the outlet of top screen, brokens through middle screen, and bran through bottom pan. Oscillating motion has been provided to the screens for effective separation. The grader is powered with a 0.5 HP single-phase electric motor. The capacity of the grader is 200 kg/h.

Integrated rice mill and grader

3.10.3 Modified Peristaltic Pump-Aqua Ferti Seed Drill

The earlier developed peristaltic pumping based aqua ferti seed drill (AFSD) was modified based on field tests and suggestions of farmers obtained during the demonstration of the machine in actual field conditions in Haryana and Rajasthan. The modifications were undertaken with respect to lateral and vertical stability. The aqua tank located at the rear of the machine was shifted to the centre to adjust the centre of gravity of the machine. This helped in preventing the toppling over of the tractor machine system during the operations particularly at slopes. To ensure lateral stability, in place of one tank, two tanks of 550 cm diameter and 300 litre capacity each, were placed on both sides of the peristaltic pump. The furrow opener was also modified to avoid clogging particularly at the turns. For better ease of operation and to add aesthetics, the pump was redesigned. The width of the pump was reduced to facilitate placement of the two tanks. The width of the main frame of the AFSD was increased to adjust three rows of staggered furrow openers to ensure lateral stability. Thus, shifting of the aqua tank ensured vertical stability. The changes in frame design, and adjustment in weight distribution provided lateral stability. Special clamps

with spring were mounted to provide proper tension in the tubes of the peristaltic pump. The modified AFSD was test evaluated for its performance with respect to germination and initial growth.

3.10.4 Development of Modified Onion Detopper

An onion detopper developed earlier was modified. The power transmission system was modified. The unit can now be operated by one motor in place of two motors provided earlier. Minor adjustments have also been made in belt conveyor, oscillating conveyor and finger unit for better conveyance of onion bulbs. Wheels have been provided for easier transportation.

3.10.5 Development of Self-propelled Inter-cultivator for Row Crops

An inter-cultivator propelled by 2.8 kW engine was developed for row crops. The drive system was designed for the forward speed of about 3.0 kmph. Steel rim wheels of 50 cm diameter with lugs were provided for traction and were mounted on the output shaft of the gear box. The weight of the power unit was 60 kg. It was tested in field with two types of cultivator attachments: (a) fixed tine, and (b) rotary tine.

Self-propelled inter-cultivator with rotary attachment

The average weeding index obtained was 75 at a field capacity of 0.15 ha/h

3.10.6 Development of a Manually Operated Roller Flaker for Cereals and Pulses

A hand operated roller flaker was developed. The flaker has two rollers, which are mounted on an MS frame, and a pair of roller bearings (operated in reverse directions with the help of chain and sprocket arrangement). When a pretreated cereal/pulse sample is introduced between the two rollers in operation, the resultant product is a flake of 1.00 mm thickness, which is, in turn, used in preparing other value added products. The specifications of the developed roller flaker are as follows:

Overall dimension	:	0.375 m x0.2 m x 0.19 m
Capacity	:	4-5 kg/h
Material of construction	:	MS (Aluminum for roller surfaces)
No. of rollers	:	2
Length and diameter of rollers	:	0.32 m and 0.075m
Roller surface	:	Light knurled
Mode of operation	:	Hand operated

3.10.7 Densification Characteristics of Green Gram, Lentil and Corn Cob

Studies were continued on densification characteristics of crop residues. During the year under report, straws of green gram, lentil and corn cob were evaluated at different compaction pressures and straw moisture contents. Bulk densities of loose straws at different moisture contents were determined. Bulk density and resiliency of the compressed blocks were also evaluated. Bulk density of the blocks decreased with increase in moisture content but increased with increase in compression pressure whereas resiliency increased with increase in moisture content but decreased with increase in compression pressure.

3.10.8 Ergonomic Evaluation of Hand Tool Injuries among Indian Farmers and Intervention Development

There are 800 million hand tools used on Indian farms by 240 million farm workers. In India, more than 50% injuries on farm are associated with hand tool as most of the activities are manually performed.

3.10.8.1 Mechanism of injuries

An analysis of farm hand tool injuries indicated different mechanisms of injuries, viz., slippages of tool from hand, hitting a hard surface in impact type soil interactive tools (spade), improper handle diameter and length of handle, improper material and texture of handle, and improper clearance for hand in handles are the major causes of hand tool injuries. Handle angularity resulted in wrist deviations causing musculoskeletal disorders.

3.10.8.2 Ergonomic evaluation of hand tools

An ergonomic evaluation of hand tools was done by measuring the dimensions of handles. Fifty three different hand tools commonly used on farms were evaluated. These included the small handle tools (handle length <25 cm) like sickle, digging forks, axe, small rake, etc; medium hand tools (handle length 25-50 cm) like axe, spade, rakes, etc; and long handle tools (handle length > 100 cm) like hoes, rakes, digging bars, etc. Dimensions like handle diameter at different location, handle length, weight, and angularity were recorded for all the tools.

Critical anthropometrical dimension of hand were investigated for design of handles. Hand dimensions of 40

Hand anthropometrical dimensions (N=40)

Percentile	Grip diameter (cm)	Middle finger-palm diameter (cm)	Palm breadth (cm)	Palm breadth-thumb (cm)
5th	3.7	1.9	7.0	9.0
50th	4.8	2.5	8.0	10.0
95th	5.5	3.3	9.0	11.0

workers were recorded for estimating the handle design. Conical wooden tools were used for measuring inside grip diameter, and middle finger palm diameter.

A comparison of hand tool's handle with relevant anthropometric dimension was done. The handle diameter should lie between inside grip diameter of 5th percentile and 95th percentile of middle finger palm dimension. Similarly handle length should accommodate 95th percentile of palm breadth. The diameter of the handle in large number of tools was smaller than the desired one for Indian population. In the case of handle length, a few small handle tools also had smaller dimension not accommodating 95 per cent of population. With this evaluation, it is suggested that the handle diameter of hand tools should be between 3.3 cm and 3.7 cm and handle length should be more than 9 cm.

3.10.8.3 Intervention development

An ergonomic intervention in the form of finger guard was developed to save upper limb injuries. The finger guard is made of Teflon cloth. This guard covers the little finger of hand, which normally comes in contact with ground or crop stubbles and cutting edge of the tool. This is a cost effective intervention. The finger guard can be made and stitched on an ordinary sewing machine. The cost comes out to be less than Rs 50 (one dollar) for a pair of guard.

Ergonomic intervention for hand tool operation

3.10.9 Laboratory Evaluation of Digging Blades for Shallow Depth

The crops like onion are shallow rooted crop. Studies were, therefore, conducted on five different shapes of blades to assess its suitability for shallow digging. The draft of the blades was measured at different soil moisture content, speed and depth of operation. A convex shape blade was found to be the best and is being incorporated in an onion digger under development.

3.10.10 Drying Studies of Capsicum in Solar Cabinet Dryer and Open Sun

An experiment on drying studies on capsicum was conducted in solar cabinet dryer. Open sun drying was also done to compare the effect of solar cabinet dryer on drying. A one-kg sample of capsicum was used for drying in the cabinet dryer and open sun. The capsicum was blanched with 10% sodium meta-bisulphate (KMS) and heated for 10 minutes. The measurement of temperature of the dryer chamber was done with the help of portable temperature indicator (least count 0.1 ^{0}C) at three central locations in the chamber. The moisture content of capsicum in solar cabinet dryer (SCD) was reduced from 94% to 7.22% in 24.0 h while in open sun drying (OSD) it took about 36.5 h to reduce to 7.35%. The drying rate was lower at low moisture content initially. However, it increased much faster with moisture content in SCD than in OSD. The drying rate was higher in the case of SCD than that in OSD. The quality of produce dried in solar cabinet dryer was found better than that dried in open sun.

3.10.11 Mechanization Pattern and Farm Machinery Use in Uttar Pradesh

Information on general mechanization status in Uttar Pradesh and farm machinery use protocol in Muzaffarnagar district was collected to know the mechanization gaps and steps needed to ensure proper use of agricultural machines to enhance crop productivity in the study area.

During the period 1999-2000 to 2003-2004, Uttar Pradesh recorded the highest average sales of 58102 tractors per year. However, state of mechanization is dismal in the state. Farm mechanization programme under macro management of agriculture started in February 2001 in the state. Under this programme, various equipment are being promoted for sale

through State Agro Corporation Ltd, where assistance in the form of subsidy is provided. During the period 2002-2003 to 2005-2006, a total amount of Rs. 2392 lakh was spent on distribution of 3379 tractors and 104576 implements.

There is ample scope for mechanization keeping in view the vastness of the state and production potential. Lack of infrastructure and poor state of trained manpower availability along with low subsidy are major hindrances in promoting mechanization. There is a need for district level workshop facilities responsible for demonstration of new developments and training, repair and maintenance of agricultural equipment.

3.10.12 Mechanization Pattern of Sugarcane in Muzaffarnagar (U.P.)

A study was conducted on mechanization pattern of sugarcane cultivation and transportation in selected villages of Muzaffarnagar. Use of specific sugarcane machinery, e.g., sugarcane planter, either semi-automatic or automatic, and sugarcane harvester was found negligible. Generally, farmers owned a tractor drawn four-bottom ridger, for planting of sugarcane, and a tiller for interculture operations.

The sugar mills located in the region have the provision of sugarcane collection both at the mill gate and at the collection centers located at several places in the area. On an average, the collections at the gate and center were 30% and 70%, respectively. Sugarcane is transported to the mill by all the three modes, viz., trucks, tractor-trailer system and animal carts. As estimated, the percentage share of the three modes of transportation are 70, 10, and 20 by trucks, tractor-trailers and animal carts, respectively. Sugarcane being a labour intensive crop, a comprehensive mechanization package is required on the pattern as practised in Maharastra and Tamilnadu where a complete networking in sugarcane production, harvesting and haulage is followed with an aim to avoid sugar loss by adhering to timeliness of schedules at different stages and operation, both for improved cultivation and better sugar recovery.

3.10.13 Farm Operation Services

3.10.13.1 Field operations

The Farm Operation Service Unit is a central facility of IARI. It caters to the needs of all, who are undertaking field experiments at IARI. The Unit has several precision machinery and equipment such as precision planter, pneumatic seed drill, rice transplanter, etc.

After harvesting of *rabi* crops, deep ploughing was done, which resulted in breaking of hard pan created by continuous cultivation by shallow harrowing. Deep ploughing also results in absorption of more rain water and increase in recharge of ground water.

Deep ploughing

In order to increase the nutrient status of the Institute farm, a massive green manuring programme was undertaken. About one hundred acres of land was brought under green manuring.

A massive programme of preparation of peripheral road was also undertaken. The road became operational in the month of November, which improved the security cover and mobility of the security personnel along the boundary wall of IARI.

Construction of peripheral road

Another massive programme of cleanliness of the Institute farm was also undertaken with the help of the existing machinery available. It gave a very good look to the field and experiment at plots during the International Rice Congress, Farmers Meet and *Krishi Vigyan Mela*.

About 12 acres of land which was not under cultivation before this year, was reclaimed by FOSU and crops were grown in the area in *rabi* season.

Reclamation of barren land

An experiment laid out some years ago under the Agro-energy Project resulted in overgrown bushes and shrubs causing security problem. The FOSU started cleaning this area, and till date 80% of jungles were cleaned.

Two main *nalahs* are flowing through the Institute farm, where weed control was a problem. This Unit undertook weed control through chemical and manual methods. In the non-experimental areas, weeds were controlled with the help of machine. About 100-acre area, which was under experimental crops, was harvested with the help of available old plot combines before the on-set of monsoon. Very old indigenous machines and tractors, including tube well machinery, were repaired well in advance. In order to achieve 100% efficiency, a large number of fast moving spare parts were purchased well in advance to save time in repairing the machinery.

In order to achieve uniform irrigation water application, about 45 acres of land was laser leveled this year.

3.10.13.2 Irrigation distribution management

In order to provide timely irrigation to experimental crops, the Institute has two reservoirs to store water. This time both the reservoirs were cleaned and the silt accumulated in the bottom was removed. The plantation on the reservoir wall was also removed, which increased the storage capacity and the life of the reservoir.

Both the reservoirs were protected by barbed wire fencing. In order to provide irrigation to experimental crops, 18 tube wells were run throughout the year. Submersible pumps were kept ready to install any time in the event of break down.

To supplement the tube well irrigation, this Unit was also able to draw water from the canal irrigation system from *Bhuli Bhattari*.

3.11 POST-HARVEST TECHNOLOGY AND MANAGEMENT

3.11.1 Maturity Studies in Mango

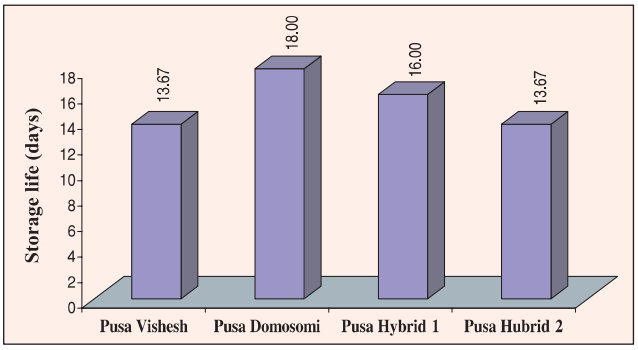
Harvesting dates and phenylalanine ammonia lyases (PAL) enzyme studies in mango ver. Amrapali in relation to jelly seed disorder were conducted. The PAL enzyme activities were found correlated to the maturity levels during July and its activity diminished after 10th of August, i.e., peak jelly seed infestation period in Amrapali.

3.11.2 Tree Age and Fruit Quality Studies in Guava

Rainy and winter guava fruits obtained from plants of different age group were analyzed for total anti-oxidant pectin content and pectin methyl esterase (PME) activity. PME activity was found elevated in rainy season guava while the amount of total anti-oxidant was 1.5 times higher in winter season guava fruits obtained from the trees of all age groups.

3.11.3 Modified Atmosphere Packaging of IARI Developed Bittergourd

Post harvest quality attributes with respect to storage of IARI developed bittergourd varieties and hybrids (viz., Pusa



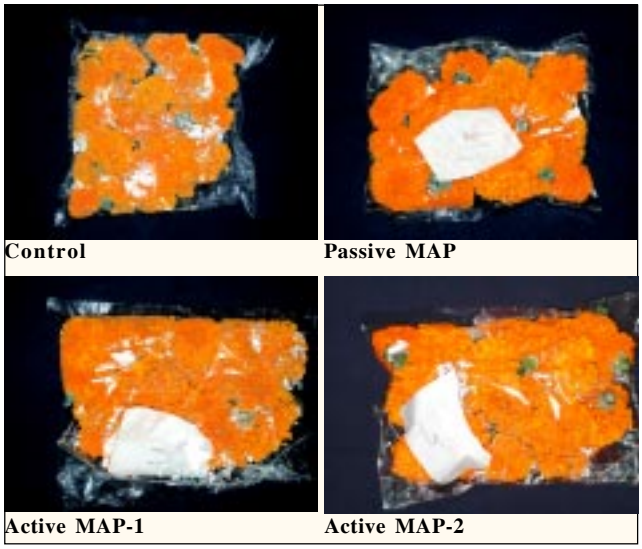
Storage life of IARI bittergourd varieties and hybrids at 8°C

Modified atmosphere packaging of IARI developed bittergourds

Vishesh, Pusa Do-mousmi, Pusa Hybrid 1 and Pusa Hybrid 2) were evaluated using MAP (Modified Atmosphere Packaging) with or without active packaging for a period of 20 days after harvest. Pusa Vishesh had the least respiratory rate, whereas Pusa Hybrid *2* exhibited the highest rate of respiration at harvest. The maximum marketable storage life (18 days) was observed in Pusa Do-mousmi and the least in Pusa Hybrid 2 at 8 ºC with 85% to 90% R.H. High respiratory rate in Pusa Hybrid 2 was also correlated with the least value of firmness at harvest. Until a period of 14 days the weight loss in all the varieties and hybrids remained well below 2.5% but beyond this period both Pusa Hybrid 1 and Pusa Hybrid 2 showed a sharp increasing trend in weight loss compared to Pusa Vishesh and Pusa Do-mousmi. Modified Atmosphere Packaging-1 (active modification with blended gaseous regime of 4.5% O_2 + 7.5% CO_2 + 88% N_2) resulted in 8 days' more storage life than that of control. Pusa Vishesh and Pusa Hybrid 1 gave better response to MAP.

3.11.4 Modified Atmosphere Packaging (MAP) of Marigold Flowers

Marigold flowers are a rich source of lutein which is predominantly used in the preparation of eye ointment, and poultry feed, and has a great potential as food colourant. Pusa Narangi Gainda flowers when packed in active MAP using gaseous blends of 2.5% O_2 + 5% CO_2 + 92.5% N_2 retained excellent quality upto a period of 2 months at 4-5 ºC with 70% to 80% R.H. with the least respiratory activity as compared to that of control and passive MAP. Preliminary analysis indicated the possibility of more retention of lutein in harvested flowers by active MAP.



Modified atmosphere packaging of marigold cv. Pusa Narangi Gainda

3.11.5 Bio-efficacy Trials of Smart Fresh ((1-MCP) in Mango cvs. Dashehari and Chausa

A proposal of a consultancy research project on "Bio-efficacy Trials of Smart Fresh (1-MCP) in Mango" for M/s Global Agri Systems Pvt. Limited, New Delhi was undertaken and an MOU was signed on May 9, 2006. Smart Fresh formulation (1-MCP) could serve as an effective treatment in altering the physiological and biochemical attributes of mango cultivars for better marketability. It delayed the senescence of mango cultivars by inhibiting ethylene liberation and reducing respiratory rates. However, such response lasted only for a very short period primarily due to severe latent infection in fruits particularly in cv. Chausa.

3.11.6 Studies on the Feasibility of Heat Shrinkable Films for Extending Shelf-life of Apple

Shelf-life of shrink-wrapped apples in cryrovac (9m), polyolefin (13m) and LDPE (25 m) at room temperature could be extended to 42 days without much loss in weight (4.4%) and various quality attributes as compared to 21 days of unwrapped apples (control). After 21 days, un-wrapped apples showed higher weight loss (9.6%) and poor quality attributes than those of shrink-wrapped ones (2.1%). Shrink-wrapped apples were better in colour, texture and quality parameters than un-wrapped apples at various intervals of observations, although decay loss occurred at almost equal proportion (8.6%) in wrapped as well as un-wrapped apples. Among different heat shrinkable films, there was no significant difference in weight loss, quality parameters, but cryovac film was the best for maintaining the texture, quality and overall acceptability of apples kept at room temperature for 42 days.

3.11.7 Screening of Onion Genotypes for Dehydration

Ten different genotypes of onion, namely, Sel. 154 XY, PR , Sel. 104, Sel. 383, Sel. 131, Sel. 126, Pusa White Round, Sel. 402, Sel. 102 -1, and Pusa A- Lane, were tested for their dehydration characteristics. The study revealed that the red coloured genotypes Sel. 402 and Sel. 383, and white coloured genotypes Sel. 154 XY and Sel. 131 were better for the preparation of dehydrated onion slices as they retained better dry matter content, nutrients as well as sensory score for the finished product.

3.11.8 Optimization of Sugar Concentration and Temperature for Osmotic Dehydrated Mango Slices

Optimum osmotic concentration of 60º B at 60 ºC for six hours osmotic dehydration of mango slices was found to be

the best. It was found that acidity reduced with increase in sugar concentration while ascorbic acid, sugar content and sensory attributes increased with elevated sugar concentration. However, temperature had negative effect on the retention of ascorbic acid.

3.11.9 *Jamun* Juice Concentrate and Storage Study

Jamun juice could be concentrated to 1/6 of its volume with better nutrient retention, colour and flavour by evaporating method. The concentrate could be stored in plastic and glass bottles for six months at room and low temperatures with better nutrients contents, flavour and anthocyanin pigments. This concentrate can be used for beverage preparations during off season after 20 times' dilution with water and addition of 10% sugar to it. It can also be used for the preparation of other products like jelly, squash, nectar, powder, and ice–cream cocktails.

3.11.10 Evaluation of Carrot Cultivars for Dehydration Purposes and Nutritional Quality

Seven genotypes of carrot, namely, IPC 25, IPC 30, IPC 122, IPC 126, IPC 133 Yellow, IPC 133 Orange and Pusa Kesar, were screened for dehydration purposes and nutritional quality. On the basis of characteristics, like drying and rehydration ratio, β- carotene and lycopene contents, and overall organoleptic quality, the cultivar IPC 122 was found to be the best for the preparation of dehydrated carrot shreds.

3.11.11 Effect of Packaging on Osmotic Dehydrated *Aonla* Segments

Among the various packaging material, 200 g co-extruded film pouches or 260 g ALPE pouches packed with nitrogen followed by storage at low temperature was found to be the best for retention of better quality of dehydrated *aonla* segments during storage. The values for acidity, β-carotene, ascorbic acid, rehydration ratio, sugar content and sensory score were higher in the samples packed in 200 g co-extruded film pouches while the values for moisture and non enzymatic browning (NEB) were less when compared with 200 g HDPE pouches. However, these values decreased with an advancement of storage period.

3.11.12 Phenolics as Natural Ingredients for Enhanced Oxidative Stability in Foods

Fenugreek and mint powder were tested as natural antioxidants to control oxidative deterioration in non-preheated and preheated oils. Preheated oil (with added extract of fenugreek and mint extract) showed remarkable inhibition of 2-thiobarbituric acid reactive substances (TBARS) ranging from 16% to 94% depending on formulation ingredients. Results indicate that dehydrated powders from fenugreek and mint have potential for wide food applications for preventing oxidative rancidity in lipid containing products.

3.11.13 Functionalized Frozen Carrot Slices

A natural extract from turmeric was tested as a natural novel ingredient for stabilizing the β-carotene content in frozen carrot slices. Frozen carrot slices pretreated with turmeric extract (10% for 30 min) recorded enhanced phenolic content and increased antioxidant activity in comparison to those of untreated control. The per cent β-carotene content remained unchanged after six months.

3.11.14 Storage of Irradiated Pulp for Beverage Preparation

Mango pulp (cv. Chausa) was preserved by thermal treatment and addition of preservative after acidification (control) and by irradiating acidified and non-acidified mango pulp at 1 kGy, 2 kGy and 5kGy. The treated samples were stored at refrigeration temperature up to a period of 4 months in glass bottles. During storage it was observed that control samples performed better with respect to shelf-life and non-enzymatic browning (NEB) than irradiated samples. The titratable acidity and NEB showed an increasing trend whereas total carotenoids, pH and ascorbic acid decreased during storage.

3.11.15 Physical Properties of Maize

Physical characteristics of food grains are important in many problems associated with design of a specific machine or analysis of the behaviour of the product in handling and storage of the material and in development of new consumer products. A study was conducted to determine the physical characteristics, namely, bulk density, true density, porosity, angle of repose, coefficient of friction, terminal velocity and hardness of Pusa varieties of maize (PEHM3, PHM4 and PEHM5) at 8 different moisture contents between 7% and 40% (wb).

Sorption characteristics of hybrid maize varieties (PEHM3 and PHM4) were determined at temperatures of 20°C, 30°C and 40°C and at relative humidity between 11% and 80%.

3.11.16 Development of Maize Roasting Machine

A batch type temperature controlled roasting machine was developed. It would be used to evaluate the roasting characteristics of IARI developed varieties of maize. Subsequently, efforts would be made to develop snack type food from maize and *jowar*.

3.11.17 Enzymatic Pre-treatments of Pigeonpea *Dal* for Reducing the Cooking Time

The enzymes, pectinase and amylase, were employed at three different concentrations for the reduction of cooking time of *dal* prepared from three pigeonpea varieties (Pusa 2003-1, Pusa 2004-1 and UPAS 120). The cooking time with enzyme pretreatment was less as compared to the pretreatment with chemicals.

3.11.18 Investigation on the Effect of Chemical Treatments and Flaking on Reduction in Cooking Time of Selected Varieties of Pigeonpea

The effect of chemical treatment and subsequent flaking (in the developed flaker) was investigated on the three pulse varieties UPAS 120, Pusa 2003-1 and Pusa 2004-1. Three GRAS chemicals, namely, NaCl, $NaHCO_3$ and NaTPP (sodium tripolyphosphate) were used in previously optimized 1% concentration level for 4 hours. The treated samples were then flaked to a thickness of 1.0 mm (approx.) and subsequently dried at 60 ºC in a cabinet dryer. Cooking trials were conducted on the samples. It is evident from the results that the flaked samples cooked faster than the unflaked samples. The best chemical treatment was found to be that of $NaHCO_3$ (1%) in the case of all three varieties followed by NaTPP and NaCl. The varieties Pusa 2004-1 and UPAS 120 cooked faster than Pusa 2003-1.

Effect of chemical treatment and subsequent flaking on the cooking time of selected pulse varieties

Chemical	Time of cooking (min)					
	Variety					
	UPAS120		Pusa 2003-1		Pusa 2004-1	
	Flaked	Unflaked	Flaked	Unflaked	Flaked	Unflaked
NaCl (1%)	13	16	21	22	6	14
$NaHCO_3$ (1%)	6	12	10	11	5	14
NaTPP (1%)	11	14	15	18	10	14

3.11.19 Standardization of Drying Techniques for Marigold

Experiments were carried out in Pusa Narangi Gainda to standardize drying techniques for marigold petals for higher retention of carotenoids in dried petals. Under pre-treatment studies, fresh petals were treated before drying with different preservatives. Of these, cysteine (0.1%) gave the best result retaining maximum total carotenoids (359.20 mg/100 g) in petals after drying. To standardize drying methods, three methods, i.e., sun drying, solar drying and cabinet drying, were employed. Cabinet drying was found to be the best method requiring less time for drying and retaining maximum total carotenoids (355.04 mg/100 g) in dried petals.

3.11.20 Biophysical Characterization of Plant Responses and Post Harvest Quality Preservation of Agri-products

Four mungbean genotypes were evaluated for seed quality and vigour in response to gamma irradiation for reducing post harvest losses. Seed hardness decreased with increasing irradiation dosage (0.5 to 5.0KGy) in three mungbean genotypes (Pusa Visal, IPM 99-125 and K851). Seed protein content also declined and followed a pattern as observed for hardness index across mungbean genotypes. Pusa 9531 maintained seed hardness and protein levels in irradiated seeds. Production of free radicals upon irradiation was found to increase with dose while reverse occurred with storage period.

3.12 MICROBIOLOGY

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

3.12.1.1 Evaluation of quality parameters of different composts

A mixed culture of bacterial and fungal strains capable of producing extra-cellular hydrolytic enzyme was evaluated for biodegradation of different agro wastes. Initial C: N ratio of all the substrates, viz., paddy straw, sugarcane bagasse, cotton stover, pigeonpea stover, chickpea stover, mustard stover, *jamun* leaves and grass clippings, was adjusted to 50:1 by adding mustard cake. A mixed fungal inoculum consisting of *Aspergillus nidulans*, *A. awamori, Trichoderma viride* and *Phanerochatae chrysosporium* raised on sorghum seeds was applied @1% (w/w). Bacterial inoculum consisting of pectinolytic strain PC-15, lipolytic strain L-11, amylolytic strain A-6 and cellulolytic actinomycetes C-3 was grown individually in nutrient broth and applied @ 1% (v/v). Moisture of the composting mixture was maintained at 60% (w/w) throughout the experiment. Samples were collected after 60 days of composting and analyzed for C, N, pH, EC, humus and available phosphorus. The results demonstrated the effectiveness of applied inoculum on degradation of diversified agro wastes as evident from C: N ratio. C: N ratio was observed in the range of 9.75-35.97 in different degraded agro-wastes. Grass clippings were most suitable for decomposition followed by paddy straw. Maximum amount of available P (872.32 ppm) and humus content of 15.2 % was observed in pigeonpea compost.

3.12.1.2 Integrated uses of organic inputs in sustainable and organic agriculture

The response of integrated use of organic inputs and microbial inoculants on wheat var. HD 2687 was done in *rabi* 2005-2006, in a split plot design. The main plots included enriched wheat straw compost (EC) and vermi-compost at 6 t ha^{-1}. Five sub plots included T-1, control; T-2, *Azospirillum* + *Azotobacte*r; T-3, PSB +AM fungi; T-4, *Azospirillum* + PSB + AM fungi; and T-5, *Azotobacter* + PSB +AM fungi. Plot size was 34 m^2 and three replicates were maintained for each treatment. Observations on the growth parameters and soil fertility were taken at 60 DAS and at harvest of the crop. Significant differences were observed in the level of soil organic carbon content, available P and dehydrogenase activity. Although soil health improved by the use of organic inputs but similar trend was not observed in grain yield.

Wheat crop was followed by mungbean var. Pusa Ratna to study the response of integrated use of organic inputs and microbial inoculants. Main plots included enriched leaf trash compost and vermi-compost at 2 t ha^{-1}. Three treatments formed subplots and included T1 vermi- compost (VC) and T4 enriched compost (EC), control; T2 and T5, + *Rhizobium*; and T3 and T6, *Rhizobium* + PSB. Plot size was 55m^2 and three replicates were maintained. Soil samples were taken 40 days and 80 days of crop growth and then whole crop was turned in the field for timely transplanting of paddy. Vermi-compost along with *Rhizobium* and PSB was better in terms of soil organic C (0.94%) and N% (1.0%) after 80 days of sowing, whereas enriched compost + *Rhizobium* + PSB was better in terms of available P (83.2kg ha^{-1}) after 80 days of sowing.

In *kharif* season, rice var. Pusa Basmati 1 was raised organically. Vermi-compost and enriched compost were applied at 1.5 t ha^{-1} in main plots and treatments in subplots included T1 and T6, control; T2 and T7, BGA; T3 and T8, BGA + PSB; T4 and T9, BGA + AM; T5 and T10, BGA + PSB + AM fungi. Plot size was 33 m^2 and three replicates were maintained for each treatment. Soil samples were taken at 45 and 80 days of crop growth and grain yield data were recorded at harvest. Grain yield showed differences among the treatments. Among the inoculants, VC+ BGA + PSB gave maximum yield (1.82t ha^{-1}) while in the case of interaction between organic amendment and BGA inoculation treatment, maximum yield of 2.73t ha^{-1} was obtained due to BGA and enriched compost.

3.12.2 Exploitation of Microorganisms for Crop Production

3.12.2.1 Identification of efficient microorganism for mass production of biofertilizer and their protocol development

Co-inoculation effects of microorganisms along with B. japonicum on soybean. Influence of AM fungus *Glomus lamellosum*, and phosphate solubilizing bacterium *Pseudomonas striata* along with *Bradyrhizobium japonicum* were examined on soybean variety Pusa 22 in a field experiment. Results show that the combinations of *Glomus lamellosum* + *P. striata* and *B. japonicum* + *G. lamellosum* increased the yield by 1.7 t/ha and 2.05 t/ha over that of uninoculated control, respectively. Microbial biomass carbon ranged from 69.6 to 179.1 µg/g soil for treatment *B. japonicum* + SSP 40 kg P_2O_5/ha. Total P content (%) in grain at harvest was maximum in treatment *B. japonicum* + SSP 60 kg P_2O_5/ha.

Similarly in another experiment, seven plant growth promoting rhizobacteria singly and in combination with *B. japonicum* on soybean variety PK 416 showed beneficial effects of PGPR on soybean yield. Co-inoculation of *B. japonicum* with bacterial isolates RP-7 and RP-24 gave maximum yields 2000 and 1983 kg/ha, respectively. This inoculation technology is to be recommended to the farmers for soybean cultivation. This combination has worked well in other soybean growing states also when tested under AICRP programme of ICAR.

Evaluation of soybean germplasm lines for nodulation by native rhizobia. Thirty-two germplasm lines of soybean showing resistance to YMV were screened for nodule number, dry weights of nodule, shoot and % N of shoots. Nodule number ranged from 1.2 to 30.0/plant, nodule weight from 7 to 108 mg/plant, shoots weights from 1.0 to 5.44 g/plant; and % shoot N from 1.8 to 4.2.

Development of Azotobacter bio-inoculants for low organic carbon conditions. Azotobacter strains (JL 17, JL

Acetylene reduction ability of *Azotobacter* strains under different conditions

Strains	Sucrose	Benzoic acid	Cinnamic acid	CMC	Gallic acid	Syring-aldehyde	Unsterile soil	Sterile soil
JL 17	217.38 (14.64)	849.29 (28.99)	22.81 (4.15)	36.745 (5.88)	14.21 (3.14)	1.44 (1.39)	0.0254 (0.72)	0.0848 (0.77)
JL 18	166.22 (12.49)	939.87 (30.61)	25.23 (5.02)	42.31 (6.15)	9.10 (3.03)	1.43 (1.39)	0.0436 (0.74)	0.0668 (0.75)
JL 104	899.57 (29.81)	871.64 (29.53)	5.49 (2.26)	12.67 (3.66)	2.58 (1.68)	4.526 (1.78)	0.0155 (0.72)	0.1070 (0.78)
JMS 100b	754.58 (26.05)	195.42 (13.92)	161.19 (10.96)	19.83 (5.51)	0.007 (0.71)	4.210 (1.92)	0.0261 (0.73)	0.0199 (0.73)
A41	704.597 (26.48)	3.24 (1.89)	54.71 (7.04)	9.43 (3.15)	5.802 (2.41)	2.554 (1.55)	0.0475 (0.74)	0.1928 (0.82)

Figures in parentheses are transformed values

18, JL 104, JMS 100b, A 41) capable of utilizing resistant carbon sources were screened for nitrogenase activity. Benzoic acid proved to be the best carbon source to support ARA in *Azotobacter* strains JL 17 and JL 18. The ARA activity under unsterile conditions was higher than that observed under sterile conditions.

Effect of complex carbon source on IAA production ability of *Azotobacter* strains was also investigated. For all strains gallic acid proved to be the best carbon source for IAA production. Cinnamic acid and carboxy methylcellulose (CMC) did not support auxin production by any of the cultures. The P-solubilizing ability of the selected *Azotobacter* strains was analyzed. All the cultures possessed P-solubilizing ability. JL 17 was observed to have the best P_2O_5 solubilizing activity followed by A 41.

Development of liquid inoculants for Azotobacter with longer shelf life. Attempts were made to produce *Azotobacter* liquid inoculants with longer shelf life. Results indicated that bacterial protectant considerably improved the survivability of *Azotobacter.* The effect of different compounds on PHB content of bacterial cell was studied. Butanol was found to exert a positive effect on PHB production by the cultures after the treatment. Methyl crotonate at 0.4% showed an increase in PHB content by 39.03%. Twenty per cent concentration of mineral oil was observed to be significantly better than the control treatment. There was a 82.51% increase in PHB content after treatment with mineral oil.

Cyst population was also estimated in *Azotobacter* after subjecting the well-grown culture to heat shock for 30 min at 50 °C. The cyst formation enhanced with the increase in sugar concentration from 2% (control) to 4%.

Effect of osmotic pressure on the cyst formation in *Azotobacter* strains

Sucrose conc. (%)	*Azotobacter* W-5 strain		*Azotobacter* CBD-15 strain	
	Cfu ($x10^7$ ml^{-1})	Cyst ($x10^7$ ml^{-1})	Cfu ($x10^7$ ml^{-1})	Cyst ($x10^7$ ml^{-1})
2	45.5	1.0	7.5	0.5
3	183.5	1.5	6.5	1.0
4	12.5	0.5	16.5	1.0
5	105.5	2.0	46.5	1.5
6	56.5	1.0	10.5	-

Interaction of sucrose and n-butanol was studied for the enhancement of encystment of *Azotobacter* strains W-5 and CBD-15. It was observed that 3% sucrose without butanol stress improved the cyst formation (30.91%) in W-5 strain, whereas in CBD-15 strain, 3.0% sucrose only, was capable of increasing maximum cyst formation (68.79%).

ARA of selected *Azotobacter* strain for lower carbon conditions *in vitro* was studied. Out of four selected strains (M-4, RJ-1, CBD-15 and JMS-100b) maximum activity was shown by the strain JMS-100b (2073.61 µ moles of C_2H_4/mg protein/h) followed by RJ-1 (1507.76), CBD15 (1199.42) and M4 strain (42.99). This indicates that the strain JMS-100b and RJ-1 may be good nitrogen fixers even at low carbon conditions.

Effect of different Cd concentrations on P solubilizing microbes (*P. striata and P. indica*) was determined under *in vitro* conditions. There was a significant decline in growth of these microbes with increasing doses of Cd.

3.12.2.2 Microorganisms as bio-control agents

Biochemical characterization of antifungal compound against Rhizoctonia bataticola. Isolate HKA-15 was found to control the charcoal rot fungus *R. bataticola* of soybean. EMS mutagenesis was done to develop mutants, which had lost antifungal activity. *In vivo* pot experiment with wild and mutants DM1 and DM2 showed per cent charcoal rot disease incidence of wild to be 27% (HKA-15) and 69% and 67%, respectively for DM1 and DM2 mutants. These results showed that HKA-15 produces an anti metabolite, which is inhibitory to the fungus. The antifungal compound found in the supernatant of HKA-15 was found to be of very resilient nature. It did not lose antifungal activity at high temperature (121^{0}C for 30 min) and when treated with protease enzyme.

Testing biocidal activities of natural products from microbes. Microorganisms were isolated from soils of various habitats for their biocidal activities. These were screened for fungicidal, nematicidal and insecticidal activities. One species of *Schizosaccharomycete* showed antifungal activity against *Sclerotium rolfsii* and *Macrophomina phaseolina*. Fifty per cent growth inhibition of *S. rolfsii* was observed at 25 ppm with ethyl acetate extracted metabolite whereas in *M. phaseolina* this was observed at 3.12 ppm. In the case of butanol extracted culture filtrate, the antifungal activity was low showing 50% growth inhibition of *S. rolfsii* at 250 ppm and that of *M. phaseolina* at 62.5 ppm. This may be considered as a significant antifungal activity of this microorganism.

3.12.3 Molecular Characterization of Agriculturally Important Microorganisms

3.12.3.1 Development of transgenic biofertilizer cyanobacterium *Nostoc muscorum* with cloned mps genes of *P. striata*

Plants take P in the form of soluble orthophosphate ions, i.e., HPO_4^{2-} and $H_2PO_4^-$. But a major portion of the phosphatic fertilizers, which are applied to agricultural fields, get fixed into unavailable forms in soil resulting in only 10-15% becoming available to plants. Various bacteria, actinomycetes,

fungi and cyanobacteria are reported to solubilize different types of insoluble phosphates.

One of the major mechanisms of mineral phosphate solubilization involves the production of organic acids concomitant with/without a significant lowering of pH. *Escherichia coli* cannot produce gluconic acid, as it cannot synthesize PQQ, the cofactor for apo-glucose dehydrogenase enzyme, which *E. coli* strains normally possess.

Two approaches were employed to transfer the *mps* gene in to *E. coli*. Genomic library of *P. striata* (the phosphate solubilizing bacterium) was prepared in *E. coli* and screened on HMM plates. Two EcoRV *E. coli* clones were selected on the basis of P-solubilization (clearing zone formation). These clones PBSEV1 and PBSEV2 showed an increase in P availability and decrease in the pH of the medium over the same growth period confirming that DNA coding for *mps* activity from *P. striata* has been incorporated into *E. coli* clones and is getting expressed.

3.12.3.2 PCR amplification of PQQ synthase gene from bacteria

PCR approach was employed to amplify the *pqq* gene and transformed *E. coli* DH5α with it. Ligation of the gel eluted PCR product with the T-vector and transformation was done according to the instructions given by the manufacturer. The blue-white colony screening was done by incubating plates at 37 °C for 16h. *Nco*I restriction enzyme was used to restrict the plasmid DNA and release the insert.

Sub-cloning of the PCR product. The PCR product in T vector was subcloned in phagemid pBluescript SK (+) after double digestion with restriction enzymes *Apa*I and *Spe*I and eluted. The eluted band was ligated to phagemid pBluescript SK (+) using instant T4 DNA ligase. The recombinant phagemid pBluescript SK (+) was transformed in *E. coli* DH5α and the spread plated on Luria agar plates. White colonies were spotted on Pikovskaya's medium containing ampicillin (100µg/mL). The colonies showing zone of solubilization were picked and checked for the presence of insert. The recombinant clones of *E. coli* were also checked in terms of ZOS, amount of Pi released, change in pH and organic acid profile.

Solubilization zone ranged from 4.5mm to 13.2 mm when TCP was used as P-source and 2.0 mm to 8.7 mm on MRP used as P-source. *P. striata* showed a 6.8 - 10.3 mm zone of solubilization with TCP after 96 h of incubation.

Characterization of recombinant clones of E. coli DH5α. Among the six recombinant clones of *E. coli* DH5α, three clones (named as C4, C5 and C6) were further characterized in terms of their potential for P-solubilization, pH change, quantification of Pi release and their organic acid profiles. In this study, it was shown that the fragment of 400 bp was able to induce the MPS strait in *E. coli*.

3.12.4 Exploration and Exploitation of Cyanobacterial Genetic Resources for Agriculture and Industry

3.12.4.1 Exploitation of cyanobacteria in wheat crop

Cyanobacterial biofertilizers known as blue green algae constitute the most important inputs in rice cultivation. Under the waterlogged conditions of rice fields, blue green algae form one of the most potential sources of biologically fixed nitrogen. Wheat is the next important crop, in which high doses of fertilizers are required for obtaining high yields. However, biofertilizers such as BGA have not been exploited as supplementary inputs in this crop. Cyanobacteria are free living but many of them have the capacity to form specific associations with animals and plants. In symbiotic associations, the cyanobacteria (cyanobionts) become modified while retaining their ability to fix atmospheric nitrogen. Therefore, investigations were aimed at evaluating the role of cyanobacteria isolated from the rhizosphere of wheat plants.

Eight cyanobacterial forms were isolated from rhizosphere soil samples of wheat variety HD 2687. Of these, three belonged to the genus *Calothrix*, and two each to *Hapalosiphon* and *Nostoc*. One was identified as *Westiellopsis* sp. When seeds were soaked in culture filtrates of different cyanobacteria, they showed germination percentage varying from 96% to 99%. The germination % was 99 in the case of *Calothrix ghosei*, *Hapalosiphon intricatus* and *Nostoc* sp., followed by 98% germination in *Calothrix* sp., *Hapalosiphon* sp., *Westiellopsis prolifica* and *Calothrix membranacea*, and 97% in *Nostoc muscorum*. Seeds soaked in sterile water or sterile BG-11 medium showed germination percentage of 90% only.

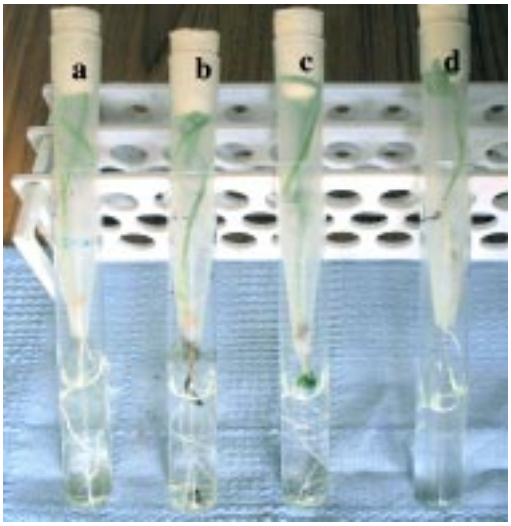
Influence of cyanobacterial extra cellular filtrates on the growth of wheat seedlings. The length of coleoptile was measured in the seedlings after 3 days and the highest values were recorded in the extracellular filtrates of strain *Nostoc* sp. followed by *Calothrix ghosei*. Extracellular filtrates of *Hapalosiphon* sp., *Calothrix* sp., *Nostoc muscorum* and *Westiellopsis prolifica* brought about moderate enhancement on a par with each other, which was, however, greater than that of the control. Culture filtrates of *Calothrix ghosei* (K1), *Hapalosiphon intricatus* (K2) and *Nostoc* sp. (K3) led to the maximum length of radicle of 5.799 cm, 5.173 cm, and 4.831 cm, respectively.

The extra cellular filtrates showed the presence of Indole-3-acetic acid. IAA concentrations in culture filtrates of

Calothrix ghosei (K1); *Hapalosiphon intricatus* (K2) and *Nostoc* sp. (K3) recorded were 3.37, 2.7 and 2.19 µg ml^{-1} respectively. Among these three cultures, *Calothrix ghosei* (K1) was the best. The IAA production in culture filtrates of dark incubated cultures was much lower as compared to that in light incubated cultures. These cultures also exhibited acetylene reduction activity (N-fixation) in light as well as in dark. The acetylene reduction activity (ARA) was shown both in light and dark; the dark activity was 10-12 times lower than the ARA in light with the maximum in *C. ghosei* (41.415 η moles µg $protein^{-1}$ h^{-1}). These cyanobacterial species showed production of IAA and IBA.

3.12.4.2 Co-culturing of wheat with cyanobacteria

The selected cyanobacterial cultures were co-cultured with wheat seedlings in hydroponic set up. After 10 days, the root portion was washed, then cut into small thin sections and observed. Microscopic examination of root sections showed colonization of root surface by the cyanobacterial strains. LM revealed the presence of short filaments in the root hairs, which was further confirmed in TEM. *C. ghosei* penetrated the root hairs.



Cyanobacterial association with roots of wheat seedlings after 10 d of co-culture in BG-11 medium under light: a, sterile BG11 medium + wheat seedling; b, K1 + wheat seedling; c, K2 + wheat seedling; d, K3 + wheat seedling

A significant enhancement in plant chlorophyll was recorded in the wheat seedlings co-cultured with selected cyanobacterial strains over wheat seedlings grown in sterile medium. The fresh biomass showed 25-50% enhancement in the co-cultured wheat seedlings, as compared to un-inoculated wheat seedlings. *Calothrix ghosei* (K1) co-cultured with wheat seedlings recorded highest fresh biomass, followed by *Hapalosiphon intricatus* (K2) and *Nostoc* sp. (K3). ARA activity of total system (plant + associated cyanobacteria) was used as an index of nitrogen fixation. Acetylene reduction activity was the highest in wheat seedlings co-cultured with *Nostoc* sp. (K3) followed by *Calothrix ghosei* (K1).

Co-culturing of selected cyanobacterial strains with wheat (var. HD 2687) in hydroponics and their effect on ARA and fresh biomass

Treatment	Fresh biomass (g)	ARA ηmoles g^{-1}fresh biomass
Wheat seedlings + K1	0.2654	1.0867
Wheat seedlings + K2	0.2140	0.3590
Wheat seedlings + K3	0.2005	1.773
Wheat seedlings + sterile medium	0.1529	-
CD (P=0.05)	0.0175	0.0635
S Ed	0.0076	0.0259

K1, *Calothrix ghosei*; K2, *Hapalosiphon intricatus*; K3, *Nostoc* sp.

3.12.4.3 Influence of cyanobacteria on growth and yield of wheat under pot culture experiments

Pot culture experiments were conducted using unsterile soil in glasshouse and under controlled conditions of the National Phytotron Facility using sterile soil during the period November 2005 - March 2006. Plant growth parameters like plant height; plant dry biomass and grain yield were recorded. The grain yield was 7.576 g pot^{-1} in T10 followed by T7, T1 and T9, recording 6.878 g, 6.716 g and 6.192 g, respectively. In phytotron, the grain yield ranged from 5.271 g to 9.906 g pot^{-1}. The grain yield was the highest in the treatment T9 which was not significantly higher than that of T1. The treatment T9 showed 87.9% higher grain yield compared to that of its control T3. With exceptions (T3 and T8), the other treatments did not exhibit significant differences.

Influence of rhizocyanobacterial strains on grain yield of wheat grown under glasshouse (unsterile soil) and phytotron

Treatment	Grain yield (g pot^{-1})	
	Glasshouse	Phytotron
T1 (Full dose of NPK, un-inoculated)	6.716	9.306
T2 (2/3 N +PK, un-inoculated)	6.009	6.863
T3 (1/3 N +PK, un-inoculated)	4.045	5.271
T4 (1/3 N +PK+K1)	4.729	7.339
T5 (1/3 N +PK+K2)	5.731	6.911
T6 (1/3 N +PK+K3)	5.093	8.760
T7 (1/3 N +PK+K1K2)	6.878	7.214
T8 (1/3 N +PK+K1K3)	5.976	6.463
T9 (1/3 N +PK+K2K3)	6.192	9.906
T10 (1/3 N +PK+K1 K2 K3)	7.576	9.113
CD (P=0.05)	0.9602	2.1069
S Ed	0.4603	1.0100

K1, *Calothrix ghosei*; K2, *Hapalosiphon intricatus;* K3, *Nostoc* sp.

3.12.5 Genetic Evaluation of Cyanobacteria for H_2 Production and N_2 Fixation

The effect of several key environmental factors on the development and control of hydrogen production has been examined in specific cyanobacterial isolates. Cellular biomass capable of evolving hydrogen gas was strongly affected by light intensity, temperature and age of the culture. A comparative study of cyanobacterial isolates from the soils of Andhra Pradesh revealed variability with respect to pigment profile, total soluble proteins, carbohydrates and N assimilatory parameters. Enhancement in the intensity of light (50-200 µEinstein/m^2/s) resulted in increased nitrogenase activity under normal conditions. Hydrogen production increased under argon environment from 50 to 150 µEinstein/m^2/s light intensity. Genetic modifications of cyanobacteria to improve the efficiency of hydrogen production by the use of either nitrogenase or hydrogenase should lead to the development of commercially viable hydrogen producing strains for the future.

The argon flushed vials containing *Nostoc muscorum* and *Anabaena fuellibornii* were incubated at different temperatures under total darkness for 24 hours and the highest hydrogen production was recorded at 30°C temperature.

Effect of temperature on hydrogen production (nmole H_2/mgchl/h)

Temperature °C	*Nostoc muscorum* (CCC529)	*Anabaena fuellibornii* (CCC 527)
25	2.67	1.56
30	2.87	1.89
35	2.32	1.73
40	1.91	1.31

Inclusion of organic carbon sources (10 mM) as supplements in the medium enhanced the hydrogen production over that of the control and the highest hydrogen production was recorded when the medium was supplemented with sucrose. Addition of fructose resulted in a slight decrease in hydrogen production.

Effect of C sources on hydrogen production (nmole H_2/mgchl/h)

Carbon source	*Nostoc muscorum* (CCC 529)	*Anabaena fuellibornii* (CCC 527)
Control	2.18	1.78
Glucose	3.89	2.57
Fructose	1.79	1.13
Maltose	2.79	1.91
Sucrose	4.32	3.11
Malic acid	3.13	2.17
Succinic acid	2.56	2.13
$NaHCO_3$	ND	ND

3.12.6 Development and Contribution of BGA Inoculant in Low Fertilizer Input *Basmati* Rice

Isolation of cyanobacteria from low fertilizer input rice growing areas indicated the dominance of nitrogen fixing heterocystous forms. *Nostoc* was abundant with nine isolates followed by *Anabaena* (4) and *Calothrix* (3). Based on frequency distribution, *Calothrix* showed maximum growth whereas *Nostoc* showed maximum nitrogen fixing ability and extracellular ammonium release. The total carbohydrates and total soluble proteins were the highest in *Nostoc punctiforme.* Based on the preliminary growth and physiological studies, five cultures, viz., *Nostoc punctiforme, Westiellopsis prolifica, Anabaena variabilis, Calothrix marchica* and *Nostoc calcicola* were selected for development as BGA inoculant for low fertilizer input *basmati* rice. Combined application of cyanobacterial isolates resulted in higher soil microbial biomass carbon, soil organic matter, available nitrogen and grain yield in comparison to those obtained with single inoculation.

Effect of BGA inoculation on soil parameters under *basmati* rice cultivation with no fertilizer input

Treatment	Microbial biomass carbon (mgkg^{-1} soil)	Organic carbon (%)	Available nitrogen (kg ha^{-1})
Control	17.28	0.33	142
A1	45.12	0.36	155
A2	41.26	0.37	146
A3	34.70	0.33	153
A4	44.55	0.34	143
A5	55.82	0.36	158

Control – No fertilizer input (N_0) and uninoculated; A1 - *Nostoc punctiforme;* A2 - *Westiellopsis prolifica;* A3 - *Anabaena variabilis,* A4 - *Calothrix marchica,* A5 - *Nostoc calcicola*

3.12.7 Interactive Potential of BGA/*Azolla* and Other Bioinoculants in Rice-Wheat- Mung bean Cropping System

3.12.7.1 Interactive effect of BGA/Azolla and other bioinoculants on soil available P and phosphatases in rice-wheat-mungbean cropping system under organic farming and INM

For the second year in succession, *Azolla* inoculation along with inorganic fertilizers resulted in maximum available soil P under rice-wheat- mungbean cropping system. Alkaline phosphatase activity was also maximum in *Azolla* inoculated plots followed by that in *Azolla*+ BGA treatment.

Under organic farming, all organic amendments, viz., *Azolla* BGA, FYM and vermicompost alone or in combination, gave higher values of available P as compared to those given

by the control ($N_{80}P_{30}K_{30}$). The alkaline phosphatase activity was maximum when *Azolla*+BGA+FYM were used together.

3.12.7.2 Evaluation of bio-inoculants in rice-wheat-mungbean cropping system for organic farming and INM

Rice grain yield increased by 134% over that of absolute control, and grain yield of 4.16 t/ha could be obtained under organic farming by using four amendments *(Azolla*, BGA, FYM and vermicompost) in scented rice (cv. Pusa Basmati 1). This yield was on a par with the grain yield recorded under recommended dose of chemical fertilizer (N_{80} P_{40} K_{40}) application.

Rice grain analysis for Fe, Zn, Mn and Cu showed an increase in Fe and Mn under treatments with two or more organic amendments over that of the control.

Soil microbial population (Actinomycetes, bacteria, fungi and BGA) was enhanced by the application of organic amendments which also accordingly resulted in a notable enhancement in dehydrogenase and phosphatase enzyme activities.

Effect of different organic treatments on grain yield of wheat (cv. HD 2687) and scented rice (cv. Pusa Basmati 1)

Treatments	Grain yield (t/ha)	
	Wheat	Rice
Azolla(A)*	2.02	2.36
BGA (B)	2.05	2.29
FYM (F)	2.31	2.12
Vermicompost(V)	2.39	2.60
A+B	2.34	3.16
A+F	2.62	3.29
A+V	2.72	3.57
B+F	2.65	3.48
B+V	2.78	3.52
F+V	2.69	3.56
A+B+F	2.82	3.68
A+F+V	3.08	3.89
B+F+V	3.01	3.93
A+B+F+V	3.35	4.16
$N_{80}P_{40}K_{40}$	3.56	4.34
$N_0P_0K_0$	1.59	1.78
C D (at 5%)	0.29	0.41

Rate of application/ha: *Azolla*@1.0 t; BGA 15 kg, FYM 5.0 t and vermicompost 5.0 t
* *Azotobacter* replaced *Azolla* in wheat crop

Similar trend was recorded in organic wheat crop production for all the parameters, except the yield, which was significantly lower than that of the yield recorded under recommended dose of chemical fertilizer.

In integrated nutrient management experiment, the grain yield of rice and wheat increased significantly due to organic input alone or in combination with chemical fertilizer. In rice, there was an increase of 64.5% in grain yield due to N_{40}, whereas the increase was 74.2% to 115.4% when organic inputs were provided alone or in combination with N_{40}. At N_{80}, the rice grain yield increased by 117% over that of the control whereas the increase was 100.5% to 154.4% when organic inputs were provided with $N_{80.}$ Similar trend was recorded in wheat.

3.12.8 Bioremediation of Wastewaters by the Use of *Azolla*

Dead biomass of *Azolla* adsorbed and removed Ni and Pb from the medium and there was a higher adsorption of metal ions at low pH (2 and 5) as compared to that of pH 7. The removal of nickel was complete at low initial concentration (10 ppm and 50 ppm), and at higher concentration (100ppm), it was 98-99%.

Analyses of secondary treated sewage effluents collected from Keshopur treatment plant seven days after growing *Azolla microphylla* showed that there was a reduction in organic C, total organic N and total P contents. The growth behaviour of *Azolla* was satisfactory on these effluents and comparable to that observed in standard growth media. However, there was no marked decrease in biological oxygen demand (BOD) and chemical oxygen demand (COD) values and the dissolved oxygen levels did not change.

3.12.9 Development of PCR based Markers for *Anabaena*

Species level identification of 70 *Anabaena* strains (including 24 strains belonging to the CCUBGA germplasm and 46 strains isolated from diverse agroecologies of India) was carried out based on taxonomic keys. Alluvium type of soil samples, besides generating 38 isolates, also harboured representatives of all species, except *A. oscillaroides*. Molecular profiling using HIPTG, $STRR_{mod}$ and STRR 1A sequences generated specific fingerprints for the individual isolates and proved highly effective in discerning genetic relationships among the strains.

A core set of highly promising *Anabaena* strains for use as biofertilizers and source of pigments and bioactive compounds was identified.

3.13 ENVIRONMENTAL SCIENCES

3.13.1 Spatial Mapping of the Global Warming Potential from Rice Paddies

Agro-ecological zone specific emissions of N_2O, CH_4 and CO_2 were simulated for 94 agro-ecological zones of India by the use of Infocrop model. It was established that the total annual CH_4, N_2O and CO_2 emissions from rice growing areas

were 2.1 Tg, 19.8 Gg and 72.98 Tg, respectively. This translates into a global warming potential of 86.5 Tg CO_2-C.

3.13.2 Impact of Tillage Management on Global Warming Potential (GWP) of Soils under Rice-Wheat Cropping

Two consecutive-year field experiments were carried out in rice-wheat agro ecosystem for quantifying the effect of tillage management practices on emission of green house gases (GHGs). The study showed that CO_2 emission decreased by >15% in no tillage (NT) against that recorded by conventional tillage (CT). Though the N_2O emission increased (>10%) in NT, the total GWP of soil under wheat crop decreased in NT. In rice, there was no significant impact of tillage on CH_4 emissions, and, over all, there was no significant impact of NT on GWP of soil under rice cultivation.

3.13.3 Evaluation of Nitrification Inhibition Potential of *Jatropha* Products

Jatropha cake and *Jatropha* oil coated urea were evaluated for their efficiency in inhibiting nitrification of urea-derived NH_4^+–N in lab incubation studies. Both substances partially inhibited nitrification of urea-derived NH_4^+. *Jatropha* cake inhibited NH_4^+ release up to 35% on day 14th and *Jatropha* oil coated urea inhibited NH_4^+ up to 33% on day 17th. *Jatropha* seed cake and *Jatropha* oil were found to be on a par with neem cake and neem oil in nitrification inhibition activity.

3.13.4 Temperature Dependent Response of Soil CO_2 Efflux in Different Physiographic Regions of India

The effect of temperature on soil organic carbon (SOC) minearlization of four different physiographic regions (representing different climatic zones of India) was studied using laboratory incubation studies. The soils of the northern mountains and those of the coastal plains showed an exponential increase in decay constant k with the increase in temperature. However, the soils representing the peninsular plateau and the great plains did not show much variation in the decomposition rate constant.

3.13.5 Effect of Heat Stress on Growth and Yield of Different Crops

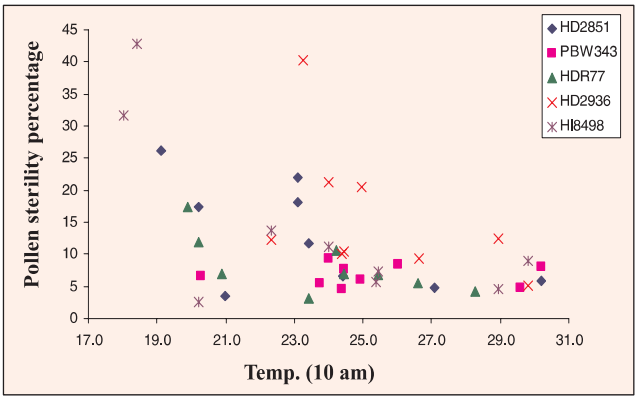
Artificially imposed heat stress (+2.7^{0}C) from transplanting to maturity caused reduction in biological and grain yields of rice cvs. Pusa Sugandh 2 and Pusa 44. Pusa 44 showed less degree of sensitivity to heat stress with respect to spikelet sterility as compared to Pusa Sugandh 2.

Thirty rice germplasm including land races, lines and varieties were assessed for their spikelet sterility under higher thermal regime. Out of thirty genotypes, only seven genotypes showed spikelet sterility less than 30%, whereas most of the local land races collected from different parts of the country showed spikelet sterility between 30% and 65%.

High temperature also altered chemical integrity (nitrogen, total sugar, carbohydrate and starch contents) of crops. Nitrogen and starch contents increased, and the contents of total sugar and carbohydrate reduced both in leaf and stem at different growth stages. The reduction in carbohydrate content in shoots indicated the possibility of loss of carbohydrates in respiration maintenance, thereby, decreasing the carbohydrate/ nitrogen ratio and nitrogen utilization efficiency of wheat plants grown under high thermal regime.

3.13.6 Impact of Temperature on Pollen Sterility in Wheat

A field experiment was conducted with five different wheat varieties (3 *aestivum* and 2 *durum*), sown at nine different dates to study the impact of temperature on pollen sterility in wheat crop. Wheat varieties in which anthesis took place

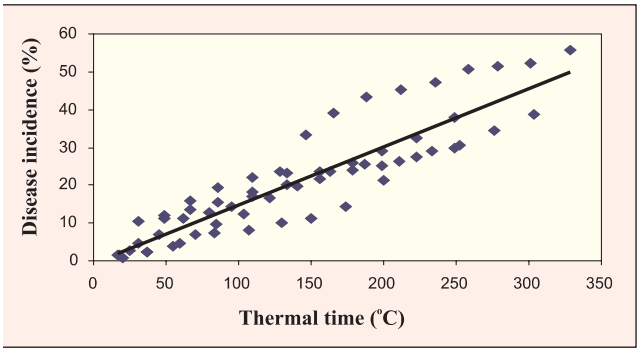


Relationship between temperature and pollen sterility in wheat

earlier (December and January) showed higher pollen sterility percentage as compared to others. Maximum sterility percentage in pollen grains (43%) was observed in the case of HI 8498 variety, which was exposed to very low temperature (2-3°C) during anthesis in the month of January. This shows that sudden fall in temperature during the *rabi* season will prove to be detrimental to the wheat crop.

3.13.7 Impact of Increasing Temperature on Wilt in Chickpea

A field experiment with different sowing dates was carried out to quantify the influence of increasing temperature (as in



Relationship between thermal time and disease incidence in chickpea

global warming conditions) on wilt incidence in chickpea. The study showed a significantly positive correlation of wilt disease incidence in chickpea crop with soil temperature as well as ambient maximum and minimum temperatures.

3.13.8 Agri-management of *Jatropha*

Biodiesel from *Jatropha* is a renewable source of energy. The development of *Jatropha* as a biofuel crop will reduce the pressure on traditional fossil fuels, which will subsequently enhance energy security in the country. *Jatropha curcas* plantation established earlier in the undulated terrain (difficult environment) of Yamuna ravines near Etawah, U.P. showed 90% survival rate in the year 2006. Out of 90%, 56% showed normal growth. Only 22% plants bore fruits in the first year of plantation. A three-year old *Jatropha* plantation irrigated with diluted distillery effluent showed better seed yield at Gajraula. Experiment was conducted this year to study the effect of different moisture regimes and nutrient levels on 3- year old plants of *Jatropha curcas*. Results showed that the yield per tree (1.980 kg) was maximum in plots receiving irrigation level 0.4 IW/ CPE and inorganic fertilizer @ 40 g N+ 200 g P_2O_5 + 50 g K_2O+ 10 g Zn SO_4 per tree.

3.13.9 Bio-ethanol from Maize and Sorghum

Fifteen different maize varieties (for starch, amylose and protein contents) were screened for the selection of suitable varieties for ethanol production. Experiments were carried out for optimum dry substance (DS) by taking three different concentrations of substrate, viz., 10%, 20% and 30% of corn substrate. The optimum liquefaction dose was 10ml/g of alpha amylase for corn substrate under slightly acidic condition within 2 hours. Two hundred ml/g of amylo-glucosidase enzyme dose can be considered optimum dose for saccharification (within 12 hours) of corn starch. The absence of calcium gives better condition for liquefaction and saccharification results.

Twenty five sorghum cultivars were also characterized for sugar production potential. The major component weights (%) in cultivar stalks were total soluble sugars ranging from 11.9% to16.2%, reducing sugars from 2.13% to 2.93%, lignin from 2.26% to 3.08% and cellulose 9.43% to12.87%. Based on biochemical characterization, 6 cultivars, namely, PC1, CSH 20MF, PC 6, PCH 109, Pant Chari 6, and PC 601 were selected for conversion of lignocellulos biomass of sorghum into fermentable sugar.

Pretreating lignocelluloses leachate with 2.0% sulphuric acid and cellulase enzyme (*T.virdi*) + β-glycosidase mixture @ 0.05% was found to be optimum for maximum saccharification and sugars yield. Maximum ethanol recovery, sugar utilization and fermentation efficiency were achieved with optimized fermentation condition of pH 4.5-5.0, temperature of 30 ºC, inoculum rate of 10%, and ammonium sulphate supplementation of 0.03% for saccharified lignocellulosic biomass of these sorghum cultivars by using promising strains of *Saccharomyces cerevisiae* and *Zymomonas mobiles*.

3.13.10 Solid-State Fermentation Technology for Biogas Production

Low rate of gas production, and higher requirement of fresh water for mixing and slurry management are some of the drawbacks of the conventional biogas plants as they form scum in the digesters. An alternative method for high solids concentration, i.e., dry anaerobic fermentation technique, was developed and applied to fibrous wastes. A multiple batch fed digester system was evolved to produce biogas uniformly and continuously both at the laboratory and pilot scale from *Jatropha* fruit coat (JFC) as supplemental feedstock to cattle dung. For pilot plant studies, 5x200 L pilot plants were used for performance evaluation. The average gas collected was 2765 L to 3020 L/10 kg JFC and cattle dung admixture (dry matter basis) at a temperature range of 18 - 29 ^{0}C.

In another lab experiment, the results showed that pretreatment of JFC with 0.3 - 0.5% NaOH increased the degradation of cellulose and hemi cellulose by 23% and 36%, respectively, and improved the gas production by 97.8% over that of the untreated material when digested with cattle dung. For maximum production of biogas, the feed ratio (cow dung: JFC) should be 2:1 on dry matter basis. Size reduction of JFC (between 40 and 60 mesh) increased the gas yield by 28.4 - 37.5%. The gas yield amounted to 84.4 -93.2% of total gas yield during 54 days of digestion.

3.13.11 Impact Assessment of Cry1 Ac (Bt toxin) of Bt Cotton on Underground Ecosystem

The impact of transgenic Bt cotton (Mech 162) and its

near isogenic line non Bt (Mech 162) was assessed on soil bacteria, fungi, actinomycetes and soil microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN). There was no significant difference in these between transgenic and its near isogenic line.

The impact of Bt toxin on belowground ecosystem could be dependent on the plant parts of Bt cotton residues that are incorporated in the field. The Cry 1Ac expression (amount of the Bt toxin) in different parts of the Bt cotton residues was quantified by the ELISA quantiplate method. The quantification of Bt toxin of Mech162-Bt hybrid revealed that the expression of Bt toxin (Cry 1Ac) was variable in different plant parts (viz., upper canopy leaves, lower canopy leaves, pollen, boll rind, boll tip, tap root, and fine roots). The upper canopy leaves showed the highest level of Bt toxin followed by taproot, pollen and Boll rind. The lowest level of Cry 1Ac was detected in progeny seed.

3.13.12 Evaluation of Irrigation and Nutrient Potential of Agro-Industrial Effluents and Identification of Crop Varieties Suitable for Agro Industrial Effluent Irrigations

In a field study, different levels of paper mill effluent (from Shreyansh Paper Mill, Ahmedgarh, Punjab) were applied along with irrigation and recommended dose of NPK on rice, okra and baby corn. The study observed that accumulation of sodium in soil did not show any change in productivity of crops. Effect of effluent on seed germination was more perceptible in vegetable crops compared to that in food grain crops.

3.13.13 Quantification of Heavy Metal Load in Peri-urban Agriculture

Agriculture zones of peri-urban areas are facing problems of heavy metal contamination. An assessment of heavy metal load in agriculture fields of peri-urban areas, due to the use of wastewater was done. The samples were analyzed for pH, EC, organic carbon (soil), Cr, Cd, Zn, Pb, Co, Cu and Ni. It was found that the major part of the peri-urban Delhi soils was contaminated with heavy metals, except for some soils of Okhla.

3.13.14 Phytoremediation of Heavy Metals through Non-edible Commercial Crops

Castor and *Jatropha* crops were grown in metal contaminated soil to assess their metal extraction efficiency from the soil. *Jatropha* plants showed higher removal of lead and cadmium from soil, while castor plants extracted more zinc and copper than *Jatropha* plants. Thus, these non-edible crop plants could be used both for phytoremediation and phytostabilization of heavy metals from metal contaminated lands.

3.13.15 Upgradation of an Environmental Impact Assessment Tool (Impasse)

An earlier developed field scale decision support system (IMPASSE) was further modified for (a) assisting a decision maker in automatically deriving rarely monitored soil hydraulic inputs (such as saturated, field capacity and wilting point moisture contents, soil bulk density and saturated hydraulic conductivity) from readily available soil textural data, (b) handling multi-season and multi-year scenario generation and simulation, and (c) auto-generation of crop and crop growth stage dependent local crop coefficients for more accurate accounting of evapo-transpirational losses. The new version of the above DSS also comprises more efficient and user-friendly algorithms for entering/loading/editing/saving/ copying/viewing and graphical presentation of farm scale input/ output data.

3.13.16 Effect of Ameliorants on the Transference of Nickel to Food Chain

Addition of toxic trace metals to marginal agricultural lands, particularly in peri-urban areas, through the use of sewage and/or industrial waste water is liable to contaminate the food chain which induces several important human-health-related problems. Hence a series of greenhouse experiments were conducted to study the effect of application of lime (25 and 50 g kg^{-1}), farmyard manure (2.2 and 4.4 g kg^{-1}), biogas slurry (2.2 and 4.4 g kg^{-1}) and hydrous manganese oxide (5 and 10 g kg^{-1}) on the bioavailability of nickel (Ni) using radish, lettuce and onion as test crops grown on soil receiving industrial effluents from Atlas Cycle Factory (Sonepat, Haryana) for the past 15 years. Results indicated that the DTPA-extractable Ni content was reduced from 17.4 mg kg^{-1} (control) to 13.1 and 14.4 mg kg^{-1} owing to application of lime (50 g kg^{-1}) and hydrous manganese oxide (10 g kg^{-1}), respectively. Similar effects of both of these ameliorants were reflected in plant Ni content also. Further, hazard quotients (HQ) were computed as a ratio of average daily dose (mg Ni/ kg body wt./ day) to safe reference dose (0.02 mg Ni/ kg body wt./ day) for intake of Ni by human through consumption of radish, lettuce and onion to assess the suitability of these vegetables for human consumption. The values of HQ indicated a significant threat to consumers (human) from consumption of lettuce grown on even lime and hydrous manganese oxide-treated soils. The values of HQ for other two crops were below one (within safe limit); high values cannot be accepted confidently even though these vegetables

constitute only a small portion of human diet. Hence, this Ni-contaminated soil could not be reclaimed effectively using these ameliorants.

Nickel hazard quotients (HQ) for human consumption of vegetables grown on the Ni-contaminated soil

Ameliorants (g kg^{-1})	Radish	Lettuce	Onion
Control	0.77	1.34	0.50
Lime (25)*	0.71	1.11	0.40
Lime (50)	0.64	1.02	0.34
Farmyard manure (2.2)	0.72	1.24	0.46
Farmyard manure (4.4)	0.70	1.21	0.41
Biogas slurry (2.2)	0.72	1.24	0.44
Biogas slurry (4.4)	0.71	1.18	0.39
Hydrous manganese oxide (5)	0.66	1.07	0.38
Hydrous manganese oxide (10)	0.64	1.02	0.34

***Figures in parentheses indicate the dose of ameliorants**

3.13.17 Impact of Heavy Metal Contamination on Soil Biota and Its Remediation

Analysis of the sewage irrigated (SI) and tube well irrigated (TI) soils collected from Madanpur Khadar village of Delhi showed that DTPA-extractable Zn, Cu, Fe, Mn and Cd contents in sewage irrigated soils increased by 184%, 106%, 160%, 117% and 108%, respectively over those in the adjacent tube-well irrigated soils. Nevertheless, total organic C, available N, available P and available K were increased by 51%, 62%, 322% and 67% over those in tube well irrigated soils. The enhanced biological activities in sewage irrigated soils might possibly be due to increased organic C and available nutrient contents.

3.13.18 Evaluation of *Brassica* species as Phyto-extractors of Copper and Nickel

Twenty-eight cultivars belonging to three species, namely, *Brassica carinata*, *B. napus* and *B. juncea* were tested for screening efficient phytoextractors for Cu and Ni. The cultivar

Screening of various cultivars of *Brassica* species for Cu and Ni

Species	Cultivar	Biomass yield (g pot^{-1})	Concentration (µg g^{-1})	Accumulation (µg pot^{-1})
			Cu	
B. carinata	JTC 1	4.76	57.6	271.7
B. napus	GSL 1	6.09	51.4	309.2
B. napus	GSL 2	5.18	55.2	286.6
B. juncea	Basanti	6.92	35.1	244.7
B. juncea	RCC 4	5.83	40.2	233.5
			Ni	
B. napus	TERI (OE) R 03	5.60	23.4	131.4
B. juncea	Varuna	6.64	16.9	110.2
B. juncea	RCC 4	6.27	27.2	163.3
B. juncea	GM 2	7.13	15.4	109.7
B. juncea	RH 8113	6.17	32.5	199.3

JTC 1 of *B. carinata*, GSL 1 and GSL 2 of *B. napus*, Basanti and RCC 4 belonging to *B. juncea* emerged as promising for greater accumulator of Cu. In case of Ni, TERI (OE) R-03 of *B. napus*, Varuna, RCC 4, GM 2 and RH 8113 of *B. juncea* were found promising. These screened species would be a valuable research material for choosing further efficient cultivars for the purpose of phytoremediation.

3.13.19 Effect of Potassium Fertilizer Application on Transfer Factor of ^{137}Cs in Rice

The transfer factor of ^{137}Cs in rice grain and straw reduced by half compared to that a year before, and application of potassium fertilizer at 150 kg ha^{-1} reduced it further. The transfer factor of ^{137}Cs in mustard was found to be nearly three times higher compared to that in wheat and maize after nine years of radionuclide contamination, indicating mustard to be a hyper accumulator of ^{137}Cs.

4. CROP PROTECTION

4.1 PLANT PATHOLOGY

4.1.1 Fungal Diseases

4.1.1.1 Wheat

Genetics of resistance in bread wheat cultivars to stem rust. The nature of inheritance of resistance to stem rust (*Puccinia graminis* f. sp. *tritici*) in HD 2733, HD 2768, HD 2781 and HD 2784 was analysed against four pathotypes of stem rust. The genetic analysis confirmed three dominant genes for resistance to stem rust in HD 2768; two dominant independent genes each for resistance in HD 2733 and HD 2784; and single dominant gene in HD 2781. Analysis of BC_1 and BC_2 with pathotype 122 (7G11) confirmed the above genes. F_2 segregation of intercrosses HD 2733 × HD 2781 and HD 2781 × HD 2784 showed different genes for resistance in the above cultivars. An adult plant resistant gene (*Sr2*) was also identified in HD 2733, HD 2781 and HD 2784 based on mottling effect in the seedlings.

Inheritance of resistance to leaf rust in bread wheat cultivars. The nature of inheritance of resistance to leaf rust in four bread wheat cultivars, namely, DL 788-2, GW 322, HUW 533 and HW 2045, was analysed against four pathotypes of *Puccinia triticina*, i.e., 77-1 (109R63), 77-5 (121R63-1), 104B (29R23) and 106 (0R9). Genetic analysis of F_2 seedlings of different crosses with Agra Local revealed the presence of three dominant independent genes each for resistance in GW 322 and HW 2045; and two dominant independent genes each in DL 788-2 and HUW 533 against pathotype 106 (0R9). Pathotype 77-5 (121R63-1) is the most virulent and 106 (0R9) is avirulent. The resistance genes identified in DL 788-2 and GW 322 were effective to pathotypes 77-1 (109R63), 104B (29R23) and 106 (0R9), but none of them was effective to 77-5 (121R63-1). Analysis of reciprocal crosses BC_1 and BC_2 of above cultivars confirmed the above findings. Absence of susceptible segregants in F_2 seedling of all intercrosses of resistant parents to pathotype 106 (0R9) indicated the presence of one common gene for resistance in all the wheat cultivars. Gene *Lr13* in HUW 533; and gene *Lr23* in HW 2045 and DL 788-2 were validated based on pedigree and Infection Types of cultivars.

A novel gene for adult-plant resistance to leaf rust in wheat. Genetic studies involving field tests of F_2 and F_3 populations using leaf rust pathotype 77-5 showed the presence of a partially dominant gene for adult-plant resistance (APR) to leaf rust in the bread wheat genotype CPAN 1842, a genetic stock of Peruvian origin. Allelic tests revealed that this gene is different from all the documented APR genes for leaf rust in wheat.

Complementary rust resistance of durum and bread wheats. Glasshouse evaluation of 318 IARI-wheat entries included in the Initial Plant Pathological Screening Nursery (2005-06) under the All India Coordinated Wheat Improvement Project for seedling resistance to stem rust pathotype 40A and leaf rust pathotypes 77-5 and 104-2 confirmed the earlier observation on the complementary nature of resistance to stem and leaf rusts among *durum* and bread wheats based on field studies. While all the 50 *durum* lines showed resistance to 77-5, currently the most prevalent leaf rust pathotype in India, 39% of the bread wheat lines were susceptible to this pathotype. Similarly, while 14% of the *durum* lines showed susceptibility to leaf rust pathotype 104-2, 27% of the bread wheat lines were susceptible to this pathotype. In contrast, higher percentage of *durum* lines (28%) were susceptible to stem rust pathotype 40A, compared to bread wheat lines (19%). Thus, this complementary nature of rust resistance between the two wheat species, i.e., the higher resistance of *durum* and bread wheats to leaf and stem rusts, respectively, can be utilized for protecting the wheat crop from both the rusts by simultaneous cultivation of the two wheat species.

Gene postulation for rust resistance. Gene postulation of 65 advance lines was done at the Institute's regional station at Tutikandi (Shimla), with the aim to select high yielding wheat genotypes with diverse resistant genes for leaf and stripe rust. *Lr* 34 was the most frequent leaf rust resistance gene occurring in 49% genotypes either singly or in combination of other genes. Other leaf rust resistance genes postulated were *Lr* 26 (34%), *Lr* 1 (25%), *Lr* 23 (19%), *Lr*13 (11%) and *Lr* 10 (6.2%). Similarly, three stripe rust resistance genes were postulated in above genotypes. *Yr*18 was the most frequent gene (49%), followed by *Yr*9 (34%) and *Yr*2 (12.3%).

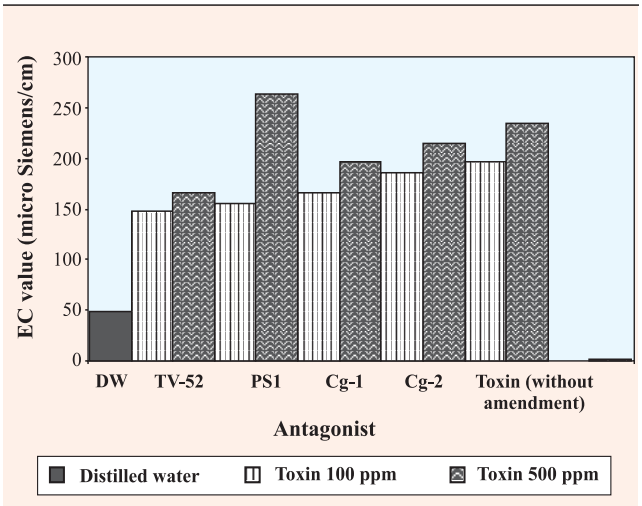
Developing species specific primer for detection of Karnal bunt (Tilletia indica). Species-specific primers (mtDNA KB1 and mtDNA KB2) were developed from

mitochondrial DNA of Karnal bunt pathogen. The difference in the EcoR1 restriction pattern between *T. indica* and *T. horrida* mtDNA was used to develop species-specific primers from 2.3 kb mtDNA sequence of *T. indica* which could amplify 885bp amplicon uniformly in all isolates of *T. indica*. A comparative study of two species-specific primers developed for detection of Karnal bunt pathogen revealed that the primers based on ITS sequences have higher sensitivity / uniformity with a single band than those based on other sequences of 2.3 kb fragment of mtDNA. ITS primers (ITS KB1 and ITS KB2) amplified spore DNA obtained from 500 teliospores and above, whereas mtDNA primers (mtDNA KB1 and mtDNA KB2) amplified 5000 and above teliospores DNA. This is the first report on comparative study of species-specific primers developed from ITS region with 2.3kb mtDNA fragment.

Isolation, purification and characterization of toxin from Bipolaris sorokiniana. The purity of pathotoxin produced by BS-25 was confirmed by TLC and HPLC. The, HPLC analysis of 22 isolates of *B. sorokiniana* showed maximum toxin (0.72 µg/ml) in BS-61 and minimum (0.05 µg/ml) in BS-41.

Bioassay of purified toxin showed sensitivity in wheat, barley, maize, sorghum, *Phalaris minor*, *Avena sativa* L. and *Cynodon dactylon* and none in chickpea, tomato, rice, and *Amaranthus tricolor*.

Detoxification of toxin produced by Bipolaris sorokiniana. Fungal antagonists, viz., *Trichoderma viride* (TV-52), *Pseudomonas fluorescence* (PS1) and *Chaetomium globosum* (Cg 1 & Cg 2), in toxin amended medium @ 100 ppm detoxified pathotoxin produced by *B. sorokiniana* compared with toxin without amendment.



Effect of antagonists on toxin-induced loss of electrolytes

Competitive saprophytic ability of C. globosum. The competitive saprophytic ability of *Chaetomium globosum* in soil was studied 15, 30, 45 and 60 days after amendment (DAA). It was observed that 15 DAA, the population of the fungal biocontrol agent reduced to 1.8×10^5 cfu/g soil from initial 2.4×10^5 cfu/g soil which was further reduced 30 DAA to 1.2×10^5 cfu/g soil. The population increased 45 DAA and reached 1.9×10^7 cfu at 60 DAA.

4.1.1.2 Rice

Efficacy of fungicides against sheath blight of rice in field. Seven fungicides, namely, Hexaconazole + Zineb 72WP, Tricyclazole + Mancozeb 80WP, Propineb, Carbondazim + Mancozeb, Tricyclazole, Sheathmar 3L and Hexaconazole were tested against sheath blight in field. Hexaconazole + Zineb 72WP was found most effective @ 2.5g/l showing least disease incidence of (32.5%) followed by Hexaconazole @2.0 ml/l (34.9%). Yield was also maximum in Hexaconazole + Zineb 72WP (1.487 kg/plot).

Efficacy of botanicals against sheath blight of rice in field. Six botanicals, namely, Biofer, Biotos (extract of gautheria), Defender (camphor), Ecomonas, Florezen-P (*Pseudomonas fluroscens*), Trichozen-T(*Trichoderma viride*) and extract containing Triterpene were evaluated against sheath blight. Biotos showed least incidence of 58.7% @2.5ml/l followed by Biofer (61.7%). However, Carbendazim used as standard fungicide at 1000 ppm was found to be most effective showing a disease incidence of 23.1% only. Biotos also gave maximum yield of 1.63 kg/plot.

4.1.1.3 Maize

Resistance to diseases. Thirty-two genotypes exhibited a high level of resistance to maydis leaf blight (MLB) while three, namely, DMR 452, DMR 329 and DMR 820 showed a high level of resistance against banded leaf and sheath blight (BLSB). Notably, DMR 452 had a high level of resistance to both MLB and BLSB.

Of the 34 quality protein maize (QPM) enteries evaluated, 13 showed high level of resistance against MLB, while DMR QPM 10 and DMR QPM 39 showed tolerable resistance against BLSB.

Genetic variability among different isolates of Bipolaris maydis and Rhizoctonia solani f. sp. sasakii. *B. maydis* isolate collected from ICRISAT, Hyderabad showed fast growth while the one from Karnal showed slow growth. The colour of colony ranged from black to dirty white. When conidial size was compared, the length and breadth of conidia were higher (69.75 µ × 16.00 µ) for the isolate from Kalibangan than those of the isolate from Ludhiana 1 (32.45 µ × 9.65 µ). The number of septa ranged from two to seven. The virulence

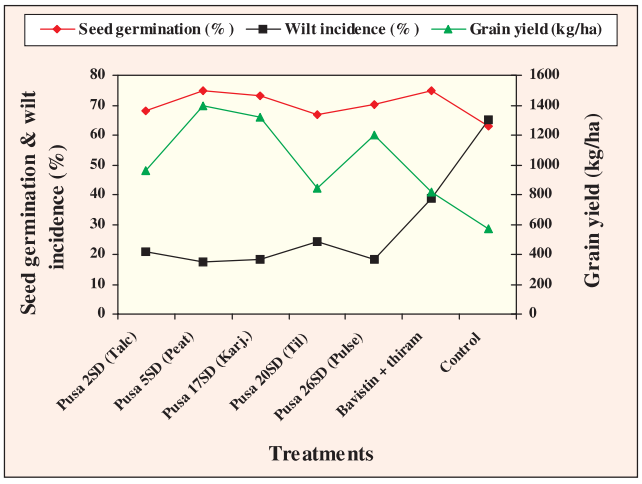
analysis indicated that only some of the isolates showed distinct symptoms between resistant and susceptible cultivars. However, the isolates belonging to Udaipur showed high virulence. In susceptible cultivars, virulence was low for the isolates, Ludhiana 1, Kalibangan and Mandsana.

OPP and OPS series of primers of Operon Technologies, U.S.A. were found to give reproducible and scorable bands with 72% polymorphism for genomic DNA extracted from 63 isolates of *R. solani* f. sp. *Sasakii*

4.1.1.4 Chickpea

Resistance sources of chickpea against wilt and Ascochyta blight. Out of 150 chickpea genotypes evaluated against wilt and ascochyta blight, 18 genotypes, namely, Pusa 256, Pusa 362, BG 2029, BGD 1033, JSC 31, RSG 963, Pusa 1003, GLK 22114, Pusa 1053, BG 2045, BGD 1040, IPCK 2002-31, BGD 131, PG 2000-109, BG 2050, HK 02-211, RSG 823 and RSG 902 were found resistant against wilt and 6 genotypes, namely, GL 22044, PG 9758-6-2, GL 1362, H 82-2, H 01-101 and JSC 29 were moderately resistant against Ascochyta blight.

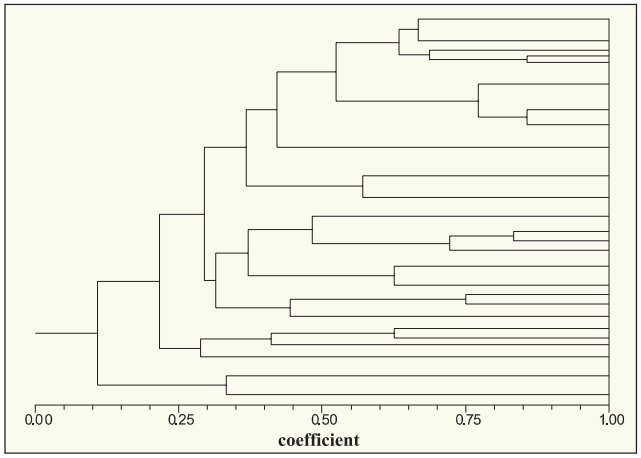
Evaluation of seed dressing formulations of Trichoderma viride against wilt of chickpea. The performance of different seed dressing formulations of *T. viride* was evaluated in sick field. Seeds treated with Pusa 5SD (peat based) formulation of *T. viride* supported maximum seed germination (75.1%) and grain yield (1393.3 kg/ha) with minimum wilt incidence (17.3%).



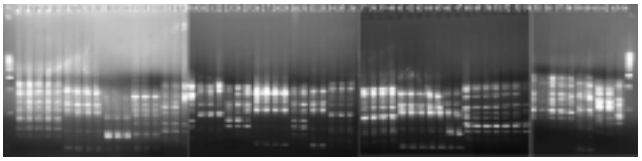
Effect of different seed dressing formulations of *T. viride* on seed germination, wilt incidence and grain yield of chickpea

Management of dry root rot (Rhizoctonia bataticola) and wet root rot (R. solani) of chickpea. Two isolates each of *T. viride*, *T. harzianum* and *T. virens* were evaluated against two isolates of *R. bataticola* (Rb_1=Bangalore, Rb_3=Delhi) in vitro. *T. harzianum* (IARIP-18) followed by *T. viride* (IARIP-1) caused maximum growth inhibition of *R. bataticola* in dual culture and by producing volatile and non-volatile compounds. Of the formulations evaluated, *T. harzianum* based Pusa 5SD for seed treatment and PBP-10G (pellet) for soil application, were found most effective in reducing dry root rot incidence and increasing yield, whereas, in the case of wet root rot, T. virens based Pusa 5SD for seed treatment and PBP-16G for soil application were found promising. The interaction of soil application of pellets and seed treatment with Pusa 5SD alone and in combination with carboxin was found highly effective in minimizing root rot incidence and increasing grain yield in field conditions.

***Variability in Fusarium oxysporum* f. sp. *ciceris* (chickpea wilt).** Based on morphological and cultural characters, 112 isolates were grouped into 12 different categories. The length and breath of microconidia varied from 7.6 µm to 12.8 µm and 2.5 µm to 4.9 µm, respectively, whereas those of macroconidia varied from 20.5 µm to 37.9 µm and 4.0 µm to 5.9 µm with 1 to 5 septations. Based on reactions of 54 isolates on 17 cultivars including international differentials, they were grouped into 3 categories. Cultivar KWR 108 could differentiate all isolates of Punjab, Haryana and Delhi and a few isolates of Rajasthan by showing resistant reaction. Rest of the isolates of Rajasthan placed in second group and CPS 1 distinguished Jharkhand isolates into third group. RAPD-PCR banding pattern of 64 isolates of *Fusarium oxysporum* f. sp. *ciceris* with OPM primers was analyzed. The dendrogram obtained after cluster analysis (UPGMA) showed 4 distinct groups at genetic similarity of 35%. The first group comprised 21 isolates (5 isolates of



Dendrogram derived from random amplified polymorphic DNA analysis of 64 isolates of *Fusarium oxysporum f. sp. ciceris* with primers OPM 6 by UPGMA (unweighted paired group method with arithmetic average). The bottom scale is the percentage of similarity by Jaccard's similarity coefficient



RAPD pattern of *F. oxysporum* f. sp. *ciceris* isolates with primer OPM 06 (Lanes 1-25: Rajasthan isolates, 26-33: Jharkhand isolates, 34-40: Delhi isolates, 41-47: Haryana isolates, 48-64: Punjab isolates, and M - 1kb molecular marker at both sides)

Rajasthan (Jaipur) and 16 isolates of Punjab), the second group comprised 28 isolates of Rajasthan, Delhi, Jharkhand and Haryana, the third group comprised 5 isolates of Punjab only, and the fourth group comprised 10 isolates of Rajasthan only. Some of the primers were very good in differentiating the isolates as per their place of isolation. OPM 6 primer was able to distinguish the isolates into 18 area specific groups with 100% similarity.

4.1.1.5 Urdbean

Resistance sources against major diseases. Out of 11 urdbean genotypes evaluated, three genotypes, namely, P 702, P 712 and P 713 showed multiple resistances against Cercospora leaf spots, Macrophomina blight and yellow mosaic virus.

4.1.1.6 Mungbean

Integrated management of major diseases. Twelve treatments including control were evaluated against diseases of mungbean under field conditions. The variety Ratna was sown on July 14, 2006 in 10 m^2 plot. The integration of seed treatment with bavistin + thiram (in equal ratio @ 2.5 µg/g of seed) + thiamethoxam (4 g/kg) with a foliar spray of thiamethoxam 0.02% at 21 days after sowing and bavistin 0.05% at 35 days after sowing supported maximum grain yield (2.18 t/ha) and minimum intensity of Cercospora leaf spots (3.0%) and Mungbean yellow mosaic virus (MYMV) (7.7%). The germination percentage recorded in this treatment was also maximum (93.4%) along with the highest plant height (47 cm) and moderate root length and nodulations.

4.1.1.7 Pigeonpea

Fusarium wilt resistance in pigeonpea. Anatomical and morphological features of root-like protoxylem and metaxylem number, their diameters and lateral root numbers have been found associated with resistance in pigeonpea against *Fusarium udum* as compared to susceptible ones. In addition, high lipoxygenase (LOX) activity was consistent in resistant genotypes.

Pathogenic variability in Fusarium udum. Among 69 pathogenic isolates tested, 37.7% were more pathogenic than the rest. Discriminant analysis showed that growth rate and number of septa in macroconidia were the major contributors to distinguish between the groups of highly pathogenic and less pathogenic isolates.

4.1.1.8 Rapeseed and mustard

Resistant sources. Entries ONK 1, NUDB 26-11, OCN 3, GSL 1, OCN 3, CAN 130 and PBC 9221 were found resistant to white rust; HNS 004 and ONK 1 MR to downy mildew; DMH 1 and NPC 16 to Sclerotinia rot; and OCN 3 and PBC 9221 to powdery mildew.

Management of Orobanche in rapeseed mustard. In initial experiments conducted for the biological management of *Orobanche ramosa* in rapeseed mustard, *Fusarium oxysporum* isolated from *Orobanche* was found to be non pathogenic to rapeseed mustard variety Pusa Bold. This is the first record of *F. oxysporum* (Fr.)Schl. – ITCC NO. 6148 from *Orobanche ramosa.*

4.1.1.9 Vegetables

Cultural, morphological, and pathogenic variability in F. oxysporium* f. sp. *cucumerinum. Fifty isolates of *F. oxysporium* f. sp. *cucumerinum* from different geographical regions in India were grouped into eight categories, viz., 1-A, 1-B, 1-C, 1-D, 1-E, 1-F, 1-G and 1-H, and vegetative compatibility groups (VCGs) demonstrating heterokaryosis by complementation tests using nitrate nonutilizing (nit) mutants. Based on pathogenicity on cucumber cultivars (Swarna Sheetal, DM-Dr-2, Hybrid No. 2, Hybrid No.4, Long Green and Poinsett), isolates were divided into 4 groups. Among tested cultivars, only DM-Dr-2 and Selection 319 (A) showed moderately resistant reaction. Pathogenicity between formae speciales of *F. oxysporum*, of melon and of cucumber showed that 4 of the tested isolates were pathogenic to both cucumber and melon, but they were more aggressive on their original host. Disease symptoms of cross pathogenicity on melon plants were less destructive and often expressed as growth retardation, but diseases symptoms on cucumber plants were more destructive.

Management of Alternaria blight of Brassica juncea. *Trichoderma*, *Bacillus* and *Pseudomonas* collected from different parts of country are being maintained in the lab. Most of the *Trichoderma* spp. were effective against *Alternaria brassicae, A. brasisicola, Alternaria alternata* and *Alternaria porri*. Ten isolates of *A. porri* were grouped into different pathogenic variants based on their reactions on different onion cultivars.

Epidemiology of Sclerotinia rot incited by Sclerotinia sclerotiorum of cauliflower. Fields of cauliflower were monitored during growing season for disease incidence, frequency of apothecia, and crop phenology. The maximum

percentage of plants infected was 3%, and the field variability was high. The coefficient of variation was the highest with relatively less disease. The disease was never observed before flowering and the lesions were often initiated at dead senescent petals lodged in leaf axils. Neither the disease progress curves nor final disease incidence had correlation with the relative abundance of apothecia in the field. Phenologically apothecia never developed before the crop was in curd stage.

Control strategy against Xanthomonas campestris in cabbage. The integration of mulching with need based protective sprays of the combination of copper oxychloride (0.25%) and streptocycline (200 ppm) gave a performance superior to their individual performances. The resulting plan disease index (PDI) was least (2.33) in comparison to that in control (28.40). On an average, calculated seed yield/plant in the best treatment was 30 g.

Eighty-seven cauliflower lines were evaluated artificially against black rot disease. Entries, namely, No. 1 x EC-162587 Pl-1-1-1 and RSK 1301 x (H x L) Pl-1-1 exhibited resistant reaction.

Biocontrol of Sclerotinia sclerotiorum. The biocontrol potential of twelve effective isolates of *T. harzianum* and *T. viride* was observed against *S. rolfsii* isolates using standard dual culture and cell free culture method. In dual culture TH3, TH10 and TH30 (*T. harzianum*), and TV15 (*T. viride*) could overgrow on *S. rolfsii* isolates completely and significantly reduced mycelial growth, while TV12 was ineffective. Contrary to dual culture, cell free culture filtrate of TV12 was able to inhibit the growth of sclerotia of *S. rolfsii* isolates. The results indicate greater effectiveness of cell free filtrate over dual culture technique for testing biocontrol potential of *Trichoderma* spp. Among four fungicides, mancozeb significantly reduced the growth of all isolates of *S. rolfsii in vitro*. However, the mycelial growth of only three isolates, namely, SRI-1, SRI-9 and SRI-10 was significantly reduced by bavistin.

4.1.1.10 Fruit crops

A rapid *in vitro* method for evaluation of apple germplasm against root rot pathogen (*Dematophora necatrix*) was standardized by the use of apple leaves, roots and grafting twigs. The shoot and root segments of *Malus simcoe, M. orientale* and *M. baccata* (Kharot) exhibited very restricted mycelial growth on shoots and root segments, which correlated with the field results.

Soil solarization (10 weeks) was found effective in reducing the population of *Dematophora necatrix* and other soil fungi, bacteria and actinomycetes at different soil depths (5 cm to 30 cm) and controlling white root rot disease in nursery. The soil temperature under tarped condition was 7 ºC to 10 ºC higher than that of untarped soil.

The plant materials inhibitory to *Dematophora necatrix, in vitro,* amended to pot mixture @ 5% (w/w) increased microbial population and it was maximum in the month of July, viz., 30.54×10^4fungi, 168.30×10^5 bacteria and 66.62×10^3 actinomycetes. Pre-inoculation amendment of garlic leaves resulted in minimum disease incidence (14.76%) followed by banana (26.54%) and lantana (33.97%) whereas in simultaneous inoculation it was 28.72%, 33.33% and 53.27%, respectively.

Mycosphaerella leaf spot in strawberry reduced runner production to nil in cultivars Selva, Confutra, Brighton, NR Round Head, Fair Fox, Hayward and Catskill having maximum disease severity. Its epidemiology on 38 cultivars revealed that all the genotypes were highly susceptible and attained maximum disease grade within 5 weeks. However, genotypes No.5, No.A, and Dauglus took 7 weeks and hence, showed minimum infection rate.

Forty genotypes of strawberry were evaluated for their response to Mycosphaerella leaf spot (*Mycosphaerella fragariae*). It was observed that all the genotypes were susceptible to leaf spot; however, there was variation in the degree of susceptibility. The genotypes having small fruit showed less disease severity as compared to those having bigger fruit size. Only two genotypes, i.e., Sasta and Shimla Delicious recorded less than 30% disease severity.

All popular cultivars of kiwifruit, namely, Hayward, Allison, Abott, Monty and Bruno were inoculated with the culture of *D. necatrix*, which succumbed to inoculations within a week's period.

Out of thirty-seven genotypes of peach, Nemmaguard, EC09015 and IC34993 showed below 10% Stigmina leaf spot severity.

4.1.1.11 Large cardamom

Characterization and management of leaf and sheath blight epiphytotic in large cardamom. Leaf and sheath blight, a new disease of large cardamom, which assumed epiphytotic proportions, has been reported to occur in large cardamom plantations of Sikkim and Darjeeling hills since 1999. On-farm demonstrations were taken up at two locations, namely, Singhik (North Sikkim) and Sribadam (West Sikkim) with the following treatments: (1) soil application of *Trichoderma viride* formulation only once after the annual harvest plus spraying the clump with *Pseudomonas fluorescence* formulation thrice at monthly interval (in January, March and May), (2) spraying the clump with 1% bordeaux mixture thrice at monthly interval (in January, March and May), and (3) maintaining general hygiene in the

plantation. The treatment-1 (application of biocontrol agents) and the treatment-2 (application of bordeaux mixture) apparently showed promising results.

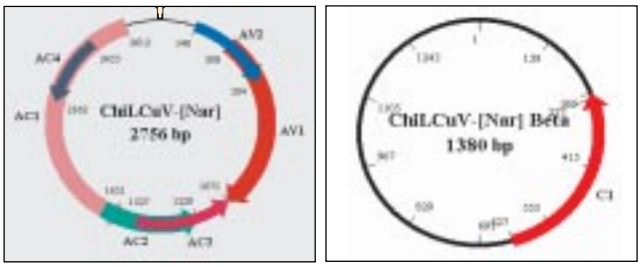
4.1.2 Viral Diseases

4.1.2.1 Functional genomic and promoter evaluation of DNA viruses

Among DNA viruses, whitefly transmitted *Mungbean yellow mosaic India virus* (MYMIV), and mealybug transmitted *Citrus yellow mosaic badna virus* (CYMV) are ideal choices for isolation of promoters and study of gene function. In MYMIV, the role of open reading frames (ORF) AV2 in DNA-A in pathogenesis was investigated by site directed mutagenesis. A bidirectional promoter was earlier isolated and characterized from MYMIV in the previous year. In the current year, transcript mapping of AV, AC1, AC2, AC3 genes of MYMIV was done, which showed a transcript for ORF AC2 distinct from ORF AC1. The potential promoter upstream of ORF AC2 is being isolated and cloned in the vector pBI101. The promoters will be further analyzed by transformation of *Nicotiana benthamiana*.

4.1.2.2 Viruses identified

Molecular characterization of chilli leaf curl virus. Several isolates were established through whitefly inoculation and one isolate designated as *Chilli leaf curl virus*-[Narwan] (ChiLCuV-[Nar]) was studied for biological and molecular characterization. The virus vector relationships and host range of ChiLCuV-[Nar] was determined. The host range of the virus was restricted to only Solanaceae and Caricaceae.

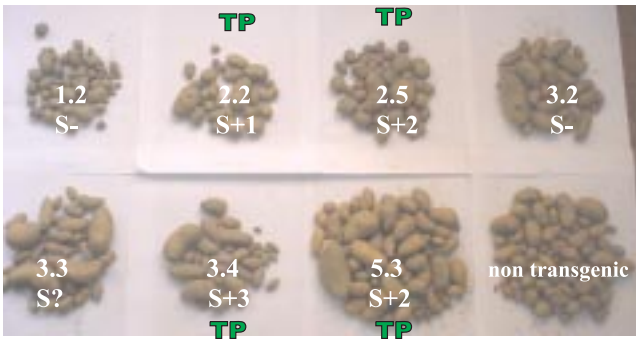


Genome organization of *Chilli leaf curl virus* DNA-A and associated DNA- â isolated from leaf curl disease of chilli in Jodhpur, Rajasthan

Molecular cloning and sequencing of complete DNA A and DNA â were determined and compared with the other begomoviruses. The DNA-A genome with 2756 bp consisted of six ORFs. The genome organization of the virus was typical to the Old World begomoviruses. The sequence comparison with 28 begomoviruses showed that ChiLCuV-[Nar] shared the greatest identity of 96.1% with ChiLCuV reported from Multan (Pakistan). The comparison of the sequence data of a DNA â (1380 bp) associated with ChiLCuV-[Nar] showed a close relationship with a DNA â in leaf curl disease of tomato isolated from Rajasthan. The present study for the first time demonstrated the association of a distinct *Begomovirus* species, ChiLCuV with the leaf curl disease of chilli in India.

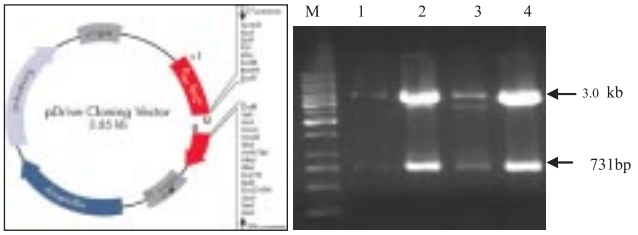
4.1.2.3 Transgenic resistance

Transgenic potato with coat protein gene from Potato virus Y (PVY). Potato variety Kufri Giriraj was transformed with the transgene derived from coat protein gene of PVY. Seven lines (1.2, 2.2, 2.5, 3.2, 3.3, 3.4 and 5.3) of the transformed plants were established in the pots under contained conditions and minitubers for each lines including nontransformed Kufri Giriraj were obtained. Transgenic plants were identified based on amplification of the coat protein by PCR and Southern hybridization. The analysis of genomic Southern hybridization showed the presence of 1-3 copies of the transgene in lines 2.2, 2.5, 3.4 and 5.3.



Minitubers of potato cultivar Kufri Giriraj obtained from transgenic lines (1.2, 2.2, 2.5, 3.2, 3.3, 3.4 & 5.3) following transformation with CP gene of *Potato virus Y*. S indiates Southern hybridization positive (+) or negative (-), and numbers (1,2 & 3) indicate copy number of the transgene

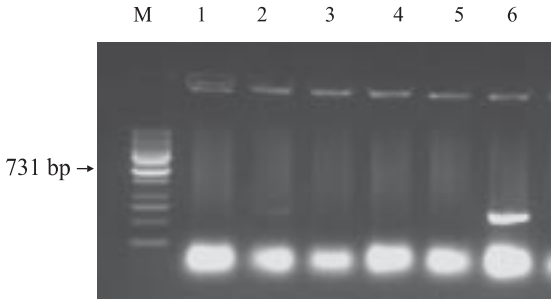
Transgenics in banana. The putative replicase gene (731 bp) of *Banana streak virus* (BSV) was amplified and cloned in pDrive cloning vector. The cloned fragment was restricted with Bam H1 and Xba1 enzymes and then was mobilized in pBinAR vector in antisense direction.



Cloning vector and restriction of cloned fragment of BSV using BamH1 and Xba1

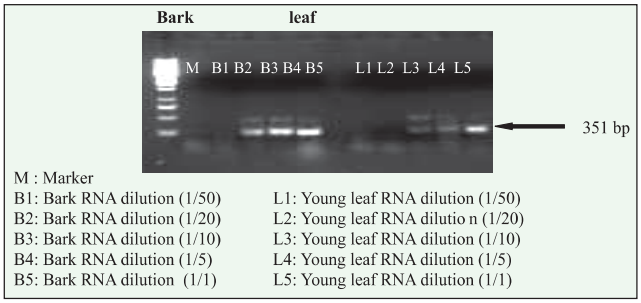
4.1.2.4 Management of virus and virus like pathogens infecting citrus

Full genome sequencing of two more isolates of *Citrus yellow mosaic virus* from acid lime and Sathgudi sweet orange was completed. In addition, cloning and sequencing of intergenic region and putative RNase H and reverse transcriptase (RT) gene of ORF 3 of six isolates of CMBV were achieved. The sequence analysis of eight isolates of CYMV associated with different citrus species indicated that there was variability in the 3' intergenic region of different isolates of CYMV while the amino acid and nucleotide sequences of the putative RNase H and RT gene were comparatively conserved.



Mobilization of putative RT and RNase H gene (antisense) in pBinAR vector as confirmed by colony PCR in lanes 2 and 6 (Pune isolate)

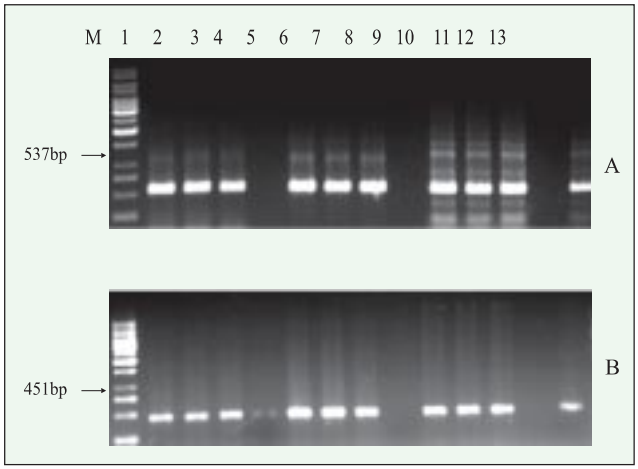
Using the standardized RT-PCR detection of ICRSV, an attempt was made to determine the relative distribution of ICRSV in different tissues of infected *Kinnow mandarin* plant. ICRSV could be detected in bark and buds in addition to leaves but could not be detected in seeds and roots. Young leaves showed higher sensitivity to the virus detection in comparison to old leaves.



RT-PCR detection of ICRSV in bark and leaves of infected *Kinnow mandarin* plant

4.1.2.5 Development of diagnostic kit for detection of viruses, viroids and greening bacterium

PCR detection of greening bacterium and *Citrus yellow mosaic virus* (CMBV) in citrus tissues was standardized using a simplified template preparation protocol. Crude extract prepared without the use of liquid nitrogen in an alkaline solution was spotted onto a nitrocellulose membrane (NCM) followed by elution in water by thermal treatment. Both the greening bacterium and CMBV were detected through PCR when the eluted liquid from the spotted membrane was used. The eluted liquid was found comparable in detection efficacy to a multi-step laboratory method or a commercial kit for nucleic acid preparation. The protocol is simple, inexpensive, rapid, and applicable to large-scale survey of citrus trees. Spotted membrane methodology can also be used for short-term sample storage for future testing or for long distance sample transport to a detection laboratory. By the use of the same method, viroids were detected in non-symptomatic ornamental plants.



Comparisons of NCM-eluted extract, commercial kit and sodium sulphite method of DNA isolation for the detection of Citrus yellow mosaic virus (CMBV) (A), and greening bacterium (Cla)(B) in sweet orange. Lane M=1 kb ladder; lanes 1-3: NCM–eluted extract; lanes 4, 8 and 12: healthy; lanes 5-7: kit extracted DNA; lanes 9-11: sodium sulphite extracted DNA, and lane 13: positive control using colony of transformed *E.coli*

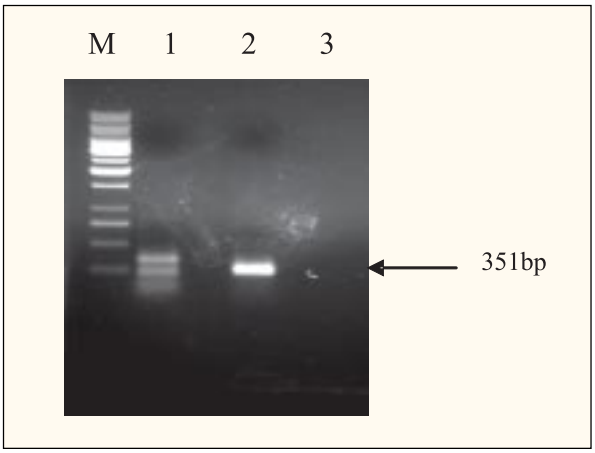
Kinnow mandarin orchard at the Institute was surveyed and bud sticks were collected from citrus trees showing the symptoms of ICRSV. Bud sticks were grafted on six months' old seedlings of kinnow mandarin and symptoms were observed after three months. The following primers were designed from putative nucleic acid binding protein (6856-7524) domain of ICRSV genome sequence available in GenBank Acc AF406744.

Primer	Sequence	Tm value
7141ICRSVIRF1	5'CCCTTTCAACACTTAAACAG	51.3
7209ICRSVIRF2	5'CCG AGA TAT CCA AAT TAC C	50.8
7460ICRSVIRR1	5'GTC AAT GAC CTA ATC GGT C	52.9

RNA from young leaves of infected as well as healthy kinnow plant was isolated using RNeasy kit (Qiagen, Gmbh, Germany). RT was carried out using Omniscript RT kit (Qiagen) in 20 µl reaction mixture using R1 primer (1µM) and Omniscript RT (4 units) at 42 ºC for 1 h. The PCR reaction volume of 25 µl contained 5 µl of cDNA reaction mix, 20 pmol of either F1 or F2 primer, 200 µM of each dNTPs, 3 mM $MgCl_2$, 10 mM Tris-HCl (pH 8.8), 50 mM KCl and 0.5 unit of *Taq* polymerase (MBI Fermentas Inc., Hanover, MD, USA). The reaction mix was heated at 94 ºC for 5 min, followed by 30 cycles of 94 ºC for 1 min, 50 ºC for 1min, 72 ºC for 2 min

Biological characterization of *Citrus tristeza* virus isolates from Darjeeling hills

Isolate	Symptoms on				
	***Kagzi* lime**	**Darjeeling orange**	**Mausambi lemon**	**Rough**	**Rangpur lime**
Poshyer Busti	Vein clearing; vein flecking; vein corking; die-back; stem-pitting	No symptom	No symptom	No symptom	Mild vein corking
Dalapchand	Vein clearing; mild stem-pitting	No symptom	Vein corking	-	No symptom
Kashyem Busti	Vein clearing; vein flecking; vein corking; die-back; stem-pitting	No symptom	No symptom	No symptom	No symptom
Tista Valley	Vein clearing	Chlorosis	-	-	-
Samsing	Vein clearing; vein flecking; mild stem-pitting	No symptom	No symptom	No symptom	No symptom



Detection of ICRSV in *Kinnow mandarin* by RT-PCR: M, 1Kb marker; 1, F1 & R1 primer; 2, F2& R1 primer; and 3, healthy control

with a final extension at 72 ºC for 10 min. All amplifications were carried out in a mastercycler gradient (Eppendorf, Germany). Primer F2 and R1 produced a sharp amplicon of ~ 300 bp of expected size in RT PCR and it will be used for further validation in the field trees.

4.1.2.6 Collection and maintenance of *Citrus tristeza* virus isolates

During 2006-07, one *Citrus tristeza virus* (CTV) isolate from Central Pandam (East Sikkim) was collected, indexed and maintained on *kagzi* lime (*Citrus aurantifolia* Swing).

4.1.2.7 Biological characterization of *Citrus tristeza* virus isolates from Darjeeling hills

Of the 18 CTV isolates from Sikkim and Darjeeling hills, being maintained at IARI Regional Station, Kalimpong, five isolates on five different citrus species, viz., kagzi lime (*Citrus aurantifolia* Swing), Darjeeling orange (*Citrus reticulata* Blanco), mausambi (*Citrus sinensis*), rough lemon (*Citrus jambhiri* Lush) and Rangpur lime (*Citrus limonia* Osb.) were indexed.

4.1.2.8 Survey and identification of aphids in citrus plantations

A survey of citrus plantations revealed 3–44% incidence of *Citrus tristeza virus* (CTV) in different localities of Vidarbha region of Maharashtra state. The aphids collected on citrus plants at Akola, Morshi (Amaravati Distt.) and Donde (Rajgurunagar) were identified as species of *Toxptera citricidus* (Kirk.), *T. auraintii* B. d. F. and *Uroleucon orientalis* Kulkarni.

ELISA test identified Donde isolates as severe CTV strain.

A six-and a half-year old virus free kagzilime plantation (500 plants) raised in the field showed healthy growth with no apparent symptoms of virus/virus like diseases.

4.1.2.9 Large cardamom

Characterization of the virus causing foorkey disease. PCR-amplification of the two components of *foorkey* virus genome could be achieved using primers designed to amplify putative replicase gene (in component 1) and putative coat protein gene (in component 3) of banana bunchy top virus. The amplified fragments of *foorkey* virus genome were approximately 861 and 1087 base pairs long, respectively.

4.1.2.10 Papaya

Papaya ringspot virus (PRSV) incidence was 100%, 33.33% and 1.66% in papaya transplanted in March, May and October, respectively.

A field papaya plant isolate and cucurbitaceous weed *Diplocyclos palmatus* (L.) C. Jaffrey, gave highly positive reaction for PRSV when tested by DAC-ELISA.

4.1.2.11 Peri-urban vegetables

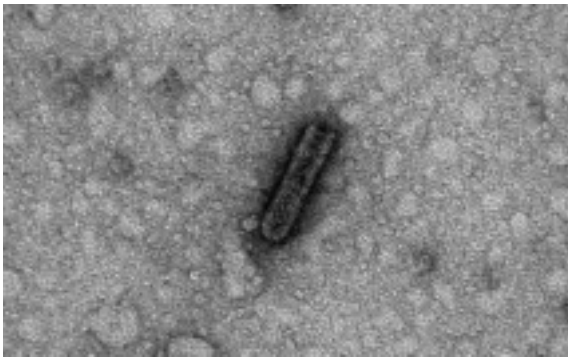
A survey conducted for cucurbits showed prevalence of PRSV-W in pumpkin (10%), sponge gourd (18%) and ridge gourd (13%). Occurrence of a poty virus in sponge gourd (8%), pumpkin (2%), cucumber (10%) and muskmelon (14%) was also recorded. In capsicum, occurrence of CMV and PVMV was recorded in polyhouse grown capsicum vars. Lario and Bomby and in California wonder in field grown capsicum.

Bioassay and serological studies were carried out for PRSV-W isolate collected from sponge gourd. The virus particles were decorated with PRSBV-W antiserum and observed under ISEM.

A field experiment revealed preservance of *Watermelon bud necrosis virus* (WBNV) in watermelon (50-80%), *Zucchini yellow mosaic virus* in cucumber (20 - 30%) and muskmelon (35%) and a poty virus (8%) in sponge gourd. It was found that the disease incidence was low in crop grown in the first week of February as compared to the crops sown in the third week of February. The occurrence of WBNV in watermelon was the highest in crop sown on 15th February and this coincided with the thrip population in the field.

4.1.2.12 Orchids

Characterization of the virus infecting Cymbidium and Coelogyne. Transmission electron microscopic studies on mosaic streak disease of *Cymbidium* and ring spot disease of *Coelogyne* revealed the presence of rhabdovirus like particles.



Electron microscopic photograph of the virus associated with mosaic streak disease of *Cymbidium* and ringspot disease of *Coelogyne*

4.1.3 Mushroom Cultivation

4.1.3.1 Biology and strain improvement in mushroom

Strain improvement studies in edible mushrooms. Gamma radiation dose of 0.6 kGy to *Agaricus bisporus* spawn was found to increase the yield over control and other treatments.

Button mushroom strains, Nos. ITCC 3741 and 3708, gave significant increase in button mushroom yield over other strains. The above strains, therefore, can be recommended for cultivation in Delhi and adjoining areas under seasonal growing conditions.

4.2 ENTOMOLOGY

4.2.1 Insect Pest Management

4.2.1.1 Cereals

Efficacy of insecticides, viz., chlorpyrifos (1.0 kg a.i./ha), carbofuran (1.0 kg a.i./ha), ethiprole+imidacloprid (0.1 kg a.i./ha), thiamethoxam+lambda-cyhalothrin (0.033 kg a.i./ha), deltamethrin (0.015 kg a.i./ha), indoxacarb+lambda-cyhalothrin (46 g a.i./ha), spinosyn (0.045 kg a.i./ha) and monocrotophos (0.5 kg a.i./ha) was evaluated against leaf-folder *Cnaphalocrosis medinalis* and plant hoppers on rice variety Pusa Basmati 1 during *kharif* 2006. The insecticides were applied twice each, first at 15 days after transplanting (DAT) and then at 70 DAT. The initial plant hopper population consisting of 82-94% of white-backed plant hopper *Sogatella furcifera* and 6-18% of brown plant hopper *Nilaparvata lugens* in different treatments was significantly reduced at 65 DAT because of the various insecticidal treatments except indoxacarb+lambda-cyhalothrin. Also, the incidence of leaf-folder was significantly less in comparison to that of the untreated control. At 85 DAT, the lowest cumulative incidence of leaf-folder was observed in treatment with thiamethoxam+lambda-cyhalothrin. The yield in all the insecticidal treatments, except ethiprole + imidacloprid, was significantly more than that in the untreated control. Based on the effect of insecticides against leaf-folder and plant hoppers as well as on crop yield, the insecticidal treatments, viz., thiamethoxam+lambda-cyhalothrin, spinosyn and deltamethrin were observed to be better than others.

InfoCrop, a crop-pest model was used to establish economic injury levels (EILs) for yellow stem borer *Scirpophaga incertulas* incidence on rice cultivar Pusa Basmati 1. The EILs with market price of Pusa Basmati 1 as Rs. 9000/t and control expenditure as Rs. 1234/ha for two sprays with monocrotophos were determined to be 6.5%, 5.5%, 4.5%, 4.0%, 3.5% and 2.5% at 30, 40, 50, 60, 70, 80 DAT, respectively. The model was also used to formulate iso-loss curves, which depicted various combinations of pest damage and crop age resulting in the same yield loss. These iso-loss curves can be utilized for pest monitoring and management interventions.

Effect of insecticides on incidence of leaf-folder and plant hoppers and yield of Pusa Basmati 1 during *kharif* 2006

Insecticide	Dose (kg a.i./ha)	Per cent folded leaves*		Plant hoppers/5 hills**		Yield (kg/ha)
		50 DAT	85 DAT	65 DAT	80 DAT	
1.Chlorpyrifos 10 G	1.000	1.16(6.17)	3.63(10.98)	47.6(6.76)	34.7(5.76)	3733
2.Carbofuran 3G	1.000	0.81(5.06)	5.13(13.12)	43.0(6.55)	22.3(4.67)	3378
3.Ethiprole (40%) + imidacloprid 40%	0.100	1.09(5.83)	6.25(14.25)	36.3(5.78)	44.7(6.52)	2555
4.Thiamethoxam+lambda-cyhalothrin	0.033	0.93(5.52)	3.61(10.93)	34.0(5.91)	12.7(3.36)	4333
5.Deltamethrin 10 EC	0.015	1.48(6.92)	4.98(12.80)	41.0(6.13)	13.7(3.65)	3355
6.Indoxacarb+lambda-cyhalothrin	0.046	1.18(6.19)	3.71(11.02)	52.7(6.98)	23.0(4.96)	3111
7.Spinosyn A (50%)+Spinosyn D (50%)	0.045	0.85(5.22)	3.98(11.52)	34.3(5.72)	21.0(4.56)	3533
8.Monocrotophos 36 WSC	0.500	0.87(5.31)	5.04(12.89)	50.6(6.72)	32.0(5.59)	2933
9.Untreated control	-	3.28(10.39)	8.85(17.25)	77.0(8.61)	30.0(5.45)	2218
S.Em	-	(0.92)	(1.09)	(0.85)	(0.79)	342
C.D. (0.05)	-	(1.91)	(2.25)	(1.75)	(1.63)	705

***Values in parentheses are arc sine transformed values ** Values in parentheses are square root transformed values**

4.2.1.2 Oilseeds

A total of 96 lines of germplasm/cultivars of mustard under three different trials, were screened against *Lipaphis erysimi* during *rabi* 2005-06. Aphid Infestation Index varied from 1.15 to 2.95. Studies on the bioefficacy of some newer insecticides along with conventional ones and a mixture were undertaken against *Pieris brassicae* infesting Ethiopian mustard *Brassica carinata* variety Swarnim. Indoxacarb (0.005%), ethofenprox (0.01%), an insecticidal mixture [50:5] of chlorpyrifos and cypermethrin (0.05%) and triazophos (0.05%) caused more than 99% larval mortality.

In *B. nigra* variety Sangam, higher pollination due to honeybees and other pollinators led to an increase in pods/plant by 31.1%, number of seeds/pod by 70% and a 1000-seed weight by 25%.

4.2.1.3 Vegetables

A field experiment was conducted to evaluate eight treatments against the spotted bollworm *Earias vittella*, a serious pest of okra. The treatment schedule involving a spray of imidacloprid at 30 days after sowing followed by two foliar sprays with spinosad @150 g a.i./ha at fortnightly interval recorded the minimum damage of 12.57% with 170.43% increase in yield over that of untreated control.

Brinjal var. Pusa Kranti when planted with a border of either radish or *guar* or maize followed by two foliar sprays of spinosad @ 75 g a.i./ha proved most effective against brinjal fruit and shoot borer *Leucinodes orbonalis* and registered 5.68%, 3.89%, 4.93% infestation, respectively, as against 13.92% in control. Two foliar applications at fortnightly interval of a higher dose of spinosad @150 g a.i./ha were also equally effective.

Different insecticide combinations were evaluated against insect-pest complex of seed crop cauliflower transplanted in October, 2005 and harvested during June/July, 2006. Cabbage aphid *Brevicoryne brassicae* (December to May) and cabbage butterfly *Pieris brassicae* (April) were the major insect pests. Hence, maximum seed yield (700.00 kg/ha) was obtained in the case of fortnightly sprays of dimethoate (0.05%) at the vegetative stage and endosulfan (0.05%) at the reproductive stage by controlling the above two pests.

Per cent damage due to fruit and shoot borer *E. vittella* in various treatment schedules of okra

Treatment	Treatment schedule	Dosage (g a.i./ ha)	% Damage		Increase in yield over control (%)
			On number basis	On weight basis	
T_1	Thiamethoxam (S.T.)- Nimbecidine- Nimbecidine	3 g/kg 5 ml/l 5 ml/l	24.42 (29.56)	24.10 (29.35)	113.66
T_2	Thiamethoxam (S.T.)- Indoxacarb- Indoxacarb	5 g/kg 140 140	16.28 (23.60)	14.77 (22.57)	132.78
T_3	Thiamethoxam (S.T.)- Acetamiprid- Endosulfan- Emamectin benzoate	5 g/kg 20 700 10	19.51 (25.94)	16.78 (24.35)	103.52
T_4	Imidacloprid- Spinosad- Spinosad	20 150 150	13.25 (20.77)	12.57 (20.20)	170.43
T_5	Emamectin benzoate- Emamectin benzoate- Emamectin benzoate	10 10 10	19.20 (25.98)	23.72 (28.98)	124.95
T_6	Abamectin- Spinosad- Abamectin	15 75 15	21.65 (27.67)	21.20 (27.37)	116.86
T_7	Indoxacarb- Indoxacarb- Indoxacarb	70 70 70	20.56 (26.96)	21.27 (27.41)	102.95
T_8	Untreated control	-	32.87 (34.95)	28.01 (32.13)	-
S.E.			3.19	2.99	
C.D. (0.05)			6.84	6.41	
C.D. (0.01)			9.49	8.90	

Values in parentheses are based on arc sine transformation; S.T. = seed treatment

Management of insect pest complex of seed crop of cauliflower

Treatment	Cabbage aphid plant infestation (%)		Cabbage butterfly (EM/plant)	Seed yield (kg/ha)
Methods	1 Feb	15 March		
T_1	15.26	12.64	2.43	700.5
T_2	10.90	9.36	2.85	675.5
Control	64.54	59.92	2.50	70.5
CD (P=0.05)	24.52	22.26	NS	322.0

T_1 = Dimethoate (0.05%) at 15 days' interval (vegetative stage) and endosulfan (0.05%) at 15 days' interval (post bolting stage)

T_2 = Furadan @ 0.5 g/plant on 15 DAT, dimethoate (0.05%) at 15 days interval and endosulfan (0.05%) at post bolting stage

4.2.1.4 Soybean

Ninety-six soybean lines in three different trials (IVT = 39, AVT II = 7, PYT I = 30 and PYT II = 20) were evaluated during *kharif* 2006 against stemfly and yellow mosaic virus (YMV) disease transmitted by white fly under their natural incidence. Soybean variety DS 9712 showed resistance consistently for the last three years and was identified as a promising source of resistance against whitefly attack.

Seed treatment with imidacloprid 70 WS @ 10 g/kg seed or thiamethoxam 70 WS @ 1.0 g/kg seed was effective against major pests of soybean with respective tunneling percentage of 8.21 and 15.60 due to stemfly, respectively, as against 31.08 in control while the corresponding YMV scores were 1.33 and 1.66 due to whitefly as compared to 5.00 in control. The seed yield in these treatments was more, i.e., 2.814 t/ha and 2.711t/ha, respectively, compared to 2.088 t/ha in control.

4.2.1.5 Pulses

A field trial for the management of American bollworm *Helicoverpa armigera* on chickpea was conducted during *rabi* 2005-06 using some biopesticides in combination with synthetic insecticides. The biopesticides used were: PG (*Bacillus thuringiensis*), *B.t.* Z-52(Biolep®), *Bt. Kurstaki*(Lipel®), *Metarhizium anisopliae*, *Verticillium lecani*, *Beauveria bassiana,* and neem emulsion. The crop was sprayed twice, first at 122 days after germination with biopesticide and then 15 days after the first spray with chlorpyrifos only. The Highest yield was recorded in treatment with PG + chlorpyrifos followed by *B.t. kurstaki* + chlorpyrifos, *B. bassiana* + chlorpyrifos, *M. anisopliae* + chlorpyrifos and *B.t.* Z-52 + chlorpyrifos with yields as 3700 kg/ha, 3500 kg/ha, 2950 kg/ha, 2750 kg/ha and 2575 kg/ha, respectively.

A trial with twelve treatments including seven biopesticides, viz., indoxacarb @ 1 ml/l, chlorpyrifos @ 2.5 ml/l, chlorpyrifos + cypermethrin @ 3.8 ml/l, lambda-cyhalothrin @ 0.2 ml/l, cypermethrin @ 0.5 ml/l, *B. t.* Z-52 @ 1 g/l, PG @ 1 g/l, *B. bassiana* @ 1 g/l, *M. anisopliae* @ 1 g/l and *V. lecanii* @ 1g/l, neem emulsion (obtained from local market) @ 8 ml/l, and untreated control was conducted during *kharif* 2006 against pod borer complex and podfly in pigeonpea. The spraying of the crop was done only once at 138 days after germination.

Treatments with indoxacarb, chlorpyrifos and PG recorded maximum healthy pods, i.e., 86.68%, 86.11% and 86.06%, respectively, compared to 78.81% in control. The rest of the treatments did not vary significantly from control with regard to healthy pods. When the damage caused by borer complex was considered, the treatments did not vary significantly because of low incidence of *H. armigera, Maruca testulalis* and *Lampides boeticus*. However, damage caused by podfly varied significantly among different treatments. The lowest podfly damage was registered with indoxacarb (3.14%) followed by chlorpyrifos (4.96%) and chlorpyrifos + cypermethrin (4.99%) treatments while the highest pod fly damage was recorded in the plot treated with *B.bassiana* (7.83%), followed by the treatment of *M. anisopliae* (7.49%) and *V. l*ecanii (7.15%). When pod damage due to bruchids was considered, the treatments varied significantly among each other. The highest number of bruchid-damaged pods was observed in control (6.17%) followed by *B. bassiana* (4.96%) and cypermethrin (4.33%) treatments. The least number of bruchid damaged pods were recorded in the plots treated with chlorpyrifos + cypermethrin mixture (1.06%), followed by the treatments of indoxacarb (2.33%), neem emulsion (2.79%) and lambda-cyhalothrin (2.80%).

4.2.1.6 Storage entomology

Studies involving the screening of ten varieties each of paddy and sorghum for resistance against angoumois grain moth, *Sitotroga cerealella* under storage indicated paddy variety Taiwan T(N)1 and sorghum variety IHT 405 as least susceptible to *S. cerealella* attack.

Wheat grains containing 15 days' old larvae of *Rhyzopertha dominica*, exposed to microwave for 30s resulted in 85% and 90% reduction in adult emergence 160 W and 320 W, respectively. Similarly, 94.4% reduction in adult emergence of *Callosobruchus maculatus* was observed with 30 s exposure at 320 W. Externally feeding, larvae of *Tribolium castaneum* and *Trogoderma granarium* were more sensitive to microwave exposure.

Complete inhibition of hatching of 1 d, 2 d, 3 d and 5 d old eggs of *Corcyra cephalonica* could be achieved within 72 h at 45%, 35%, 30% and 25% concentration of CO_2, respectively, while complete mortality of the adults of *Lasioderma serricorne* could be achieved within an exposure period of 48 h at 55% concentration of CO_2.

4.2.2 Biological Control

Molecular differentiation of different populations of sugarcane woolly aphid *Ceratovacuna lanigera* and its natural enemy *Dipha aphidivora* obtained from different locations, (viz., Deoband (UP), Bangalore (Karnataka), TNAU and Sugarcane Breeding Institute in Coimbatore (Tamil Nadu), Pune (Maharashtra) and Navsari (Gujarat) was attempted using Internal Transcribed Ribosomal primers, viz., ITSa and ITSd. The amplified product of *Ceratovacuna* populations of TNAU (Coimbatore), SBI (Coimbatore) and Bangalore (Karnataka) ranged from 500bp to 800 bp with ribosomal DNA primers ITSa and ITSd. The ITS region of Coimbatore *Dipha* population was about 868 bp. *Ceratovacuna* and *Dipha* amplicons obtained with the ITSa and ITSd primers were cloned in PGEMT essay vector and the recombinants were subjected to EcoRI and Pst1 digestion to release the inserts. The inserts ranged from 550bp to 650 bp for *Ceratovacuna* and 750bp to 800 bp for *Dipha* populations. Nucleotide sequence of *D. aphidivora* has been submitted for the NCBI database for the first time (Accession No : EF061910).

The larva of *Tribolium castaneum* was identified as a better host for the mass production of green lacewing *Mallada boninensis* because of its easy, economical and ecofriendly mass multiplication besides improvement in biological attributes. The cost of producing 1,000 eggs of *M. boninensis* in the laboratory was Rs. 7.36 on *T. castaneum* larvae compared to Rs. 15.91 on *Corcyra cephalonica* eggs.

Feeding risk of Parthenium beetle *Zygogramma bicolorata* on non-target plants was further evaluated. Adults survived for a period of 29 days on *Chrysanthemum* sp without any visible feeding damage. Slight feeding on *Heliotropium indicum* was observed for the first time. In no choice test, adult did not feed on sunflower cultivar Co 4 while larva fed on Co4, TCSH-l and Co2 but did not develop further. These results confirm the safety of *Zygogramma* for its potential release and spread for *Parthenium* containment.

4.2.3 Insect Physiology

Bt transgenic dual stacked cole crops are being developed under CIMBAA in view of high damage of *Plutella xylostella* and other lepidopteran insects to cole crops. Evaluation of Cry1B and Cry1C toxins against 6-day old larvae of *P. xylostella* revealed a 15-fold and 18-fold range of susceptibility, respectively.

Studies on the identification of molecular markers for detecting *cry1Ac* resistance in the larvae of *H. armigera* were carried out by the use of forward and reverse pairs of four different primers. These primers were synthesized on the basis of cadherin gene reported in heliothines. Primers e04 and e017 amplified 149bp and 170 bp regions of genome of 14 different populations while e09 amplified 249 bp region of genome of all except Akola population wherein 165 bp region was amplified. The primer e24 amplified 162 bp region of genome of all except Khandwa population wherein 134 bp region was amplified. Each population DNA was pooled from a minimum of 4 and maximum of 20 individuals.

An effort was made to enhance the activity of oxime ether compounds having juvenile hormone mimicking activity on tobacco caterpillar *Spodoptera litura* by the addition of classical synergist PBO. Amongst the compounds tested, 4'-(2,6,6-trimethyl-2-cyclohexen-1-yl)-3'-buten-2'(E)-ketoxime - N-O- pentyl ether, when mixed with PBO in the ratio of 1: 10, showed a synergistic ratio of 4.6.

Chemically defined diet of *Trogoderma granarium* was improved. Twenty per cent reduction in protein content and 28% increase in carbohydrate content of the diet reduced the developmental period by 2.45 days and increased fecundity of *T. granarium* by 14%.

Effect of cobaltous chloride ($CoCl_2$ $2H_2O$) on life span and oviposition of oriental fruitfly *Bactrocera dorsalis* was studied in the laboratory. Cobaltous chloride was fed to adults of fruitfly in a solution of different concentrations for five days. The egg laying was completely affected at the minimum concentration of 0.25%. Cobaltous chloride at 0.007% in maggot diet, increased pupal weight and fecundity, while at 0.012%, it proved detrimental to the growth and development of maggots.

4.2.4 Insect Toxicology

Laboratory studies with hexane, methanol, butanol, ethyl acetate and aqueous extracts of *Caesalpinia crista* seeds incorporated in the artificial diet of third instar larvae of *H. armigera* significantly deterred feeding till 24 h. The antifeedancy ranged from 81.0 - 30%, 91.0 - 22.0%, 75 -20%, 58 - 20% and 46 -12% in hexane, methanol, ethyl acetate, butanol and aqueous extract, respectively. Methanol extract was found to be the most effective with AI_{50} value of 0.018% followed by hexane (0.02%), ethyl acetate (0 .04%), butanol (0.07%) and aqueous extract (0.08%). The larval mortality ranged from 10.0% to 70.0%. The per cent I_{50} values for inhibiting normal adult emergence in different extracts were 0.029%, 0.032%, 0.048%, 0.098%, and 0.055% for methanol, hexane, ethyl acetate, aqueous and butanol extracts, respectively. Amongst the various extracts evaluated, methanol and hexane extracts caused more antifeedancy and all the extracts significantly reduced the normal adult emergence compared to control.

Amongst the various extracts, viz., hexane, methanol and

aqueous extracts and pure compound saponin from *Madhuca indica* seeds, evaluated against *H. armigera,* methanolic extract caused more antifeedancy and larval growth inhibition but the dose required was very high, i.e., 7.14% and 5.40% while the dose required for 50% normal adult emergence inhibition by saponin, the pure compound, was only 0.75%. Further, these extracts of *M. indica* proved safe to the predator *Coccinella septempunctata*.

Studies on insecticide resistance showed that the third instar larvae of *S. litura* collected from Phagwara district of Punjab were 20.7, 15.5, 12.9, 9.6 and 7.1 folds resistant to deltamethrin, alphamethrin, cypermethrin, betacyhalothrin and fenvalerate, respectively, as compared to the Delhi population.

Relative resistance of 7-day old larvae of *S. litura* to various synthetic pyrethroids

Insecticides	LC_{50} (µg ml^{-1})		Relative resistance
	Delhi	Punjab	
Deltamethrin	71.0(62-81)	1473(1285-1687)	20.7
Alphamethrin	51.9(44-61)	803(653-984)	15.5
Cypermethrin	159.0(128-484)	2056(1841-2297)	12.9
Beta cyfluthrin	5.4(3.6-7.2)	52(44-58)	9.6
Fenvalerate	368.0(296-457)	2597(2318-2910)	7.1

Deltamethrin, lamdacyhalothrin, bifenthrin, betacyfluthrin and fenpropathrin were 23.2, 14.5, 10.5, 8.9, 7.7 and 0.6 times more toxic than cypermethrin to the 4th instar larvae of *P. brassicae*, respectively. The data revealed that among all the lepidopterous pests, *P. brassicae* is presently most sensitive to various synthetic pyrethroids. The results were also confirmed in the field.

Susceptibility of 4th instar larvae of *P. brassicae* to various pyrethroids

Insecticides	LC_{50} (µg ml^{-1})	Relative toxicity
Deltamethrin	0.5 (0.65-0.47)	23.2
Lamda cyhalothrin	0.8 (1.0-0.6)	14.5
Alphamethrin	1.1 (1.4-0.9)	10.5
Bifenthrin	1.3 (1.5-1.1)	8.9
Beta cyfluthrin	1.5 (1.4-0.9)	7.7
Fenpropathrin	1.9 (2.6-1.5)	6.1
Cypermethrin	11.6 (14.0-8.4)	1.0
Fenvalerate	19.0 (25.6-15.0)	0.6

Antifeedant activity of *Andrographis paniculata* was evaluated against *S. litura* and was found to be due to ethanol soluble active principles.

Antifeedant activity of hexane and methanol extracts of *A. paniculata* against 7-day old *S. litura* larvae by choice method

Conc.	Hexane extract		Methanol extract	
	24 h	48 h	24 h	48 h
	Feeding deterrence (%)	Feeding deterrence (%)	Feeding deterrence (%)	Feeding deterrence (%)
0.007	0.32[a]	0.53[b]	3.64[c]	15.10[c]
0.01	0.77[a]	1.69[b]	19.45[bc]	18.62[bc]
0.030	8.04[a]	0.55[b]	27.24[abc]	54.74[bc]
0.050	11.42[a]	0.44[b]	38.15[ab]	56.17[ab]
0.070	18.00[a]	5.61[ab]	41.13[ab]	63.93[a]
0.100	16.04[a]	31.39[a]	53.37[a]	67.65[a]

Figures in any column followed by the same letter are not significantly different at p<0.05 by Tukey's test

4.3 NEMATOLOGY

4.3.1 Biodiversity

4.3.1.1 Plant parasitic nematodes

An extensive survey was conducted in 6 districts (Almora, Bageshwar, Champawat, Nainital, Pithoragarh and Udham Singh Nagar) of Kumaon region of Uttarakhand, to study nematode diversity in cereals, vegetables, pulses, oilseeds, fruit crops, tea, fern and mosses. Spiral nematode *Helicotylenchus dihystera* was the most frequently occurring one with maximum relative frequency (26%), followed by root-knot nematodes, *Meloidogyne incognita* and *M. javanica* (14.5%), *Tylenchorhynchus mashhoodi* and *T. indicus* (11%), *Rotylenchulus reniformis* (9.9%), *Quinisulcius acti* (7.6%), *Trichodorus christei* (6.7%) and *Hemicriconemoides mangiferae* (4.6%).

Nematode bio-diversity studied in fruit crops, viz., mango, guava, papaya and *jamun*, in Bulandshahr district of Uttar Pradesh revealed the presence of 15 species of plant parasitic and 12 species of microbivorous and predatory nematodes.

Similarly, nematode diversity was studied in peri-urban vegetable-based cropping system in NCR of Delhi, especially, Najafgarh Block (Kair, Kichera, Mudela Khurd, Bakkargarh, Dhansa), Alipur Block (Puth, Kurd, Barwala, Prahaladpur, Narela) and Kanjhawala Block (Chandpur, Mazra, Kan, Tatesar, Jhonti). The major nematodes encountered were *M. incognita* in okra and tomato in Najafgarh block and in brinjal in Alipur block, whereas, *R. reniformis* was predominant in Najafgarh, Alipur and Kanjhawala blocks.

The cereal cyst nematode *Heterodera avenae* was observed in wheat fields in Narela (Alipur block).

Pigeonpea cyst nematode *Heterodera cajani,* grass cyst nematode *H. mothi* and two other unidentified species of cyst nematodes were found in Raigarh and Jashpur districts

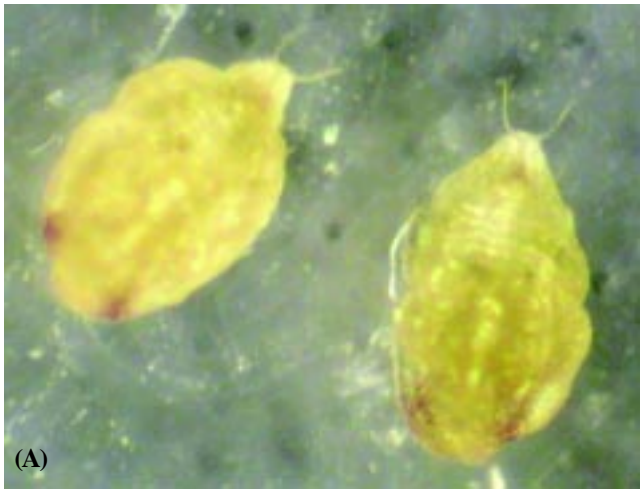
of Chhattisgarh for the first time. Dominance of rice root-knot nematode *Meloidogyne graminicola* was observed in rice-wheat cropping system followed in Sonepat district of Haryana and Modipuram areas of Meerut (UP).

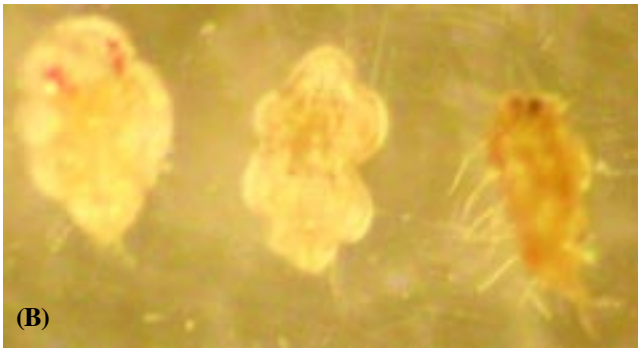
The presence of yet another species of cyst nematode *Heterodera filipjevi* was encountered in Hosiarpur and Ludhiana districts of Punjab while *H. avenae* was observed for the first time in Sonepat and Sirsa districts of Haryana. Rice root nematode *Hirschmanniella oryzae* was predominantly present in Raigarh, Jashpur and Korba districts of Chhattisgarh in the rice based cropping system.

4.3.1.2 Entomopathogenic nematodes

Two new strains of *Steinernema* one each from Chhattisgarh and Kerala, and two strains of *Heterorhabditis* from Gujarat and Kerala were isolated. The Kerala strains were identified as *S. bicornutum* and *H. indica*, while Gujarat strain was identified as *H. bacteriophora*.

Bioefficacy of entomopathogenic nematode Steinernema thermophilum against whitefly. Brinjal and tobacco leaves infested with pupae of whitefly, *Bemisia tabaci,* a vector of plant viruses, were sprayed with aqueous formulation of *S. thermophilum* @ 1000 IJ/ml, with untreated infested leaves as a control. There was no emergence of fly from pupae on the treated leaves up to ten days. After six days, the nematode treated pupae exhibited emergence of nematode progenies. After ten days, the treated pupae became empty sacs containing infective juveniles of nematode. It showed that *S. thermophilum* could induce 100% mortality of pupae of whitefly.





Bioefficacy of *Steinernema thermophilum* against whitefly (*Bemisia tabaci*) on brinjal leaf when used as foliar spray. A: Control (healthy pupae); B: sprayed with S. *thermophilum* (deformed pupae)

Bioefficacy of *Steinernema thermophilum* against termite, *Coptotermes heimi (Wasmann).* Under laboratory conditions, *S. thermophilum* @ 50 IJs /soldier was found effective, causing 100% mortality within 36 h to 48 h. The IJs penetrated the termite, developed, multiplied and then emerged from the abdomen of dead termites at five days after inoculation.

A novel bio-pesticidal formulation with enhanced shelf-life. A novel biopesticidal formulation of *Steinernema thermophilum* with significantly improved shelf-life, ranging from a few hours to 36 months at storage temperatures 5 °C to 50 °C, with 80% survival was developed. The polymer used in its preparation offers additional water retention aid in the soil, or other plant growth media. It has been applied for patenting.

4.3.2 Molecular Characterization

Work has been taken up to study the genetic variability in pigeonpea cyst nematode *Heterodera cajani* by the use of morphological characters and Amplified Fragment Length Polymorphism (AFLP). Morphologically authenticated 11 populations of *H. cajani* collected from Hyderabad, Allahabad, Ghaziabad, Bahadurgarh, Kanpur, Meja, Coimbatore, Gulberga, Hisar and Delhi were characterized using AFLP. Twenty-six primer pair combinations amplified 1511 AFLP fragments, out of which 1376 were polymorphic and 135 were monomorphic bands. Three out of 26 primers showed 100% polymorphism and two primer combinations showed less than 80% polymorphism. UPGMA analysis categorized 11 populations into two distinct clusters and one out-group. The present study revealed that there was no correlation between morphological characterization and molecular characterization.

4.3.3 Mechanism of Resistance

In an endeavor for metabolomics of amino acids, growth regulators, vitamins, coenzymes and secondary metabolites, etc., a new liquid chromatographic method for seven selected amino acids and eight growth regulators and also a new gas

chromatographic method for salicylic acid were developed. These are being refined further for metabotyping in systemic acquired resistance against *Meloidogyne incognita* on tomato.

Effect of salicylic acid (SA) and nematode infestation was observed on lignin (thiogycolic acid, TGA) content in shoots and roots of susceptible (Pusa Ruby) and resistant (Pusa Nemamukt) tomato cultivars. Irrespective of the cultivars, *M. incognita* infestation as well as SA application significantly increased the TGA lignin in roots and shoots.

In the field study on the fate of soil-applied xenobiotics against nematodes, it was found that the application method affected the uptake of cadusafos(Rugby 10G) by tomato crop from soil. It was maximum in spot treatment followed by broadcast and furrow application. Despite differential plant uptake, the residue levels in fruits were very low to non-detectable.

Lectins (100 ìg/ml) from mature seeds of pigeonpea, chickpea, mungbean, and pea were antagonistic to *M. incognita* on tomato. Lectins reduced hatching of second stage juveniles of *M. incognita* by 9% to 29%, adversely affecting the mobility of the hatched juveniles and restricting their invasion into roots by 61% to 81%. This ultimately reduced the fecundity, population of the nematode in soil and root and the disease measured in terms of root galling of tomato.

Effect of lectins on hatching, mobility, invasion, fecundity and reproduction of *Meloidogyne incognita* and root galling of tomato

Lectin source	% hatch of J2 (7days)	% im-mobility (7days)	% invasion (15 days)	Fecundity*	Soil population /200 g soil (90 days)*	Root population (90 days)*	Gall index (90 days)
Pigeonpea	16.4	04.5	13.4	13.3	17.9	06.1	2.5
Chickpea	19.8	02.1	05.5	14.8	16.9	08.3	2.3
Mungbean	18.4	00.6	15.6	11.2	10.1	06.9	2.6
Pea	21.0	01.6	18.1	11.1	08.1	08.1	2.3
Control (-lectin)	23.1	01.9	29.8	21.1	59.3	46.0	3.9

N=10; *square root transformed values

4.3.4 Management

The sonicated cells of the nematotoxic cyanobacterium *Synechococcus nidulans* caused an average mortality of 47.7% in J2 of the cereal cyst nematode *Heterodera avenae*, and 14.3% in IJ3 of entomopathogenic nematode *Heterorhabditis indica* after 24 h of incubation.

A microplot trial on the efficacy of *Arthrobotrys oligospora*, a fungal biocontrol agent of *Meloidogyne incognita* on tomato showed that *A. oligospora*, when applied in combination of root tip for 30 min+soil application @ 20 g/plot (5.2 x 10^8 spores /g soil), suppressed root-knot galls, eggmass/plant and juvenile population (J2) in the soil by 52.5%, 64.2% and 41.9%, respectively.

All the eight species of *Trichoderma* @ 2 kg/ha, reduced the number of galls (ranged between 5 and 6 galls compared to 26.3 in control) of *M. incognita* in cowpea and enhanced the plant growth considerably.

Leaf extracts of *Ricinus communis* along with *Sepedonium maheswarium* at S/2 dilution was found to be the most toxic causing 94% mortality of *M. incognita* juveniles (J2) followed by leaf extracts of *Calotropis procera* along with fungus at S/2 dilution which exhibited 80% mortality after 72 h exposure period.

The cultures of *Photorhabdus luminescens* (symbiotic bacteria) living in the gut of the entomopathogenic nematode *Heterorhabditis indica* (IARI strain) were subjected to solvent extraction with ethyl acetate and passed through Silicon Gel Column Chromatography. Fractions PD1C and PD3, when fed orally along with artificial diet of the insect, imparted 100% mortality to the neonates, and first and second instar larvae of *Galleria mellonella* in 72 h. PD2 and PD7 showed only 20% mortality after 48 h in the case of neonates. These fractions were not toxic to the older instars of *Galleria*. PD2, however, showed a strong antifungal activity against a number of soil borne fungi like *Rhizoctonia* and *Pythium* spp.

Actively growing cultures of *P. luminescens* were encapsulated in sodium alginate beads and examined for their ability to infect insect hosts. These beads, containing approximately $2.5x10^7$ bacterial cells per bead, when mixed with sterilized soil and exposed to *Spodoptera litura* larvae resulted in 100% mortality in 48 h, while the use of alginate encapsulated *H. indica* resulted in 40% mortality after 72 h. The LD_{50} dose of *Photorhabdus* cells was estimated at 1010 cells/larva for killing *S. litura* 6^{th} instar larvae in 48 h.

Six indigenous isolates of *Xenorhabdus* were tested for their oral insecticidal activity independent of their nematode hosts. The cells of strains 1 and 4 showed oral toxicity against *Galleria* when fed along with the artificial diet of the insect.

4.4 AGRICULTURAL CHEMICALS

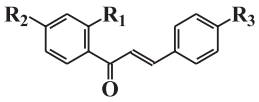
4.4.1 Development of Natural and Synthetic Agrochemicals and their Adjuvants

4.4.1.1 New agrochemicals/technologies

Nematicidal activity of chalcones. Six substituted

chalcones were evaluated for their nematicidal activity against *Meloidogyne incognita* and *Rotylenchulus reniformis*. NAS I and NAS II were found to be active against J_2 of *M. incognita* (LC_{50} =1.9 ppm and 4.0 ppm, respectively) while NAS I was found active also against *R. reniformis* (LC_{50} = 3.9 ppm). Both these compounds were as effective as carbofuran (LC_{50} = 3.1 ppm).

Nematicidal activity of chalcones against *M. incognita* and *R. reniformis*



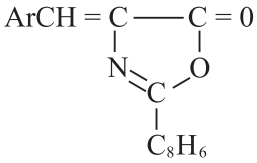
R_1	R_2	R_3	LC_{50} (ppm) after 72 h	
			M. incognita	*R. reniformis*
OH	H	OCH_3	13.2	10.8
H	CH_3	CH_3	15.7	9.7
H	Br	CH_3 (NAS I)	1.9	3.9
OH	H	H	13.6	14.7
OH	H	Cl	29.4	23.0
H	CH_3	OCH_3 (NAS II)	4.0	
Carbofuran			3.1	

Synthesis and antifungal activity of essential oil based oxime esters. A series of oxime esters derived from carvone were synthesized and evaluated for their antifungal activity. Carvone oxime N-O-acetyl ester (EC_{50}, 145.3 ppm) and carvone oxime N-O-pentanoyl ester (EC_{50}, 155.1 ppm) were found to be most effective against *Rhizoctonia solani*, whereas carvone oxime N-O-acetyl ester (EC_{50}, 83.2 ppm) and carvone oxime N-O-cinnamoyl ester (EC_{50}, 61.5 ppm) were found effective against *Sclerotium rolfsii*. As compared to the commercial Bavistin, these compounds were slightly less active.

Chemical hybridizing agents. Ethyl 4-bromo oxanilate was tested on *Arabidopsis thaliana* as a foliar spray at a concentration of 300 ppm as a daily basis from 23rd to 40th day after sowing on separate plants to find out the optimum growth stage. Pollens from treated flowers were carefully collected five days after spray and tested under stereo binocular microscope using acetocarmin (2% solution) stain test. It was observed that the plants showed maximum response to pollen sterility between 37th day and 38th day after sowing.

Arylidene-2-phenyl-5(4H)-oxazolones as nitrification inhibitors. A number of 4-arylidene-2-phenyl-5(4H)-oxazolones were evaluated for nitrification inhibitory activity in a laboratory incubation experiment at 10% of urea-N applied. Most derivatives showed 48.9% to 64.5%, 20.0% to 37.7%, 6.7% to 14.0% and 1.2% to 6.5% nitrification inhibition after 7, 14, 21 and 28 days, respectively. 4-(3-Ethoxy-4-hydroxy-benzylidene)-2-phenyl-5(4H)-oxazolone (10) was found to be most effective followed by 4-(3-methoxy-4-hydroxy-benzylidene)-2-phenyl-5(4H)-oxazolone (9) and 4-(2-hydroxy-benzylidene)-2-phenyl-5(4H)-oxazolone (5).

Effect of 4-arylidene-2-phenyl-5(4H)-oxazolones on the per cent nitrification inhibition



Compounds (Ar)	NI 7 d*	NI 14 d	NI 21 d	NI 28 d
(C_6H_5)	50.0	23.1	8.1	3.7
(4-FC_6H_4)	59.4	20.0	7.8	4.5
(2-ClC_6H_4)	58.2	26.0	8.8	4.1
(4-ClC_6H_4)	55.2	25.4	8.9	3.6
(2-HOC_6H_4)	61.4	28.5	8.1	5.9
(4-HOC_6H_4)	56.5	24.1	7.9	4.9
(2-$NO_2C_6H_4$)	52.6	21.2	6.7	3.5
(4-$MeOC_6H_4$)	48.9	24.3	8.5	1.2
(3-EtO-4-HOC_6H_3)	61.2	33.7	8.7	4.8
(3-MeO-4-HOC_6H_3)	64.5	37.7	14.0	6.5

d=days after incubation; NI=nitrification inhibition

Performance evaluation of acrylamide based hydrogels in nursery and post-transplantation growth of high value tomato. A study on the effect of two acrylamide based hydrogels on the nursery establishment as well as post transplantation growth of high value tomato under protected conditions was carried out by the amendment of soilless media (a mixture of coir husk, vermiculite and Perlite mixed in the ratio 4:1:1) with two hydrogels, HG-1 (WAC 70 g/g @ 0.5%, 1.0% and 1.5%) and HG-2 (WAC 350 g/g @ 0.25%, 0.5% and 1.0%). Three fertigation schedules comprising (i) F_1-fertigation only once followed by irrigation, (ii) F_2-fertigation only, and (iii) F_3- alternate fertigation and irrigation were adopted. Of these, F_3 treatment proved to be most economical and exhibited drastic reduction in the frequency of watering (35 to 37 irrigations and only one fertigation) as compared to control (50 fertigations). In spite of the limited fertigation and lesser number of irrigations, the seedlings of the treated plants showed superior growth as compared to those of control, thus indicating the potential of the developed hydrogels in protected vegetable cultivation.

4.4.1.2 Biopesticides

Extraction of artemisinin from Artemisia annua. Since extraction based on organic solvents is not cost effective, a need was felt to develop alternative technologies using minimum quantities of the solvent. Therefore, a method was standardized for efficient extraction of artemisinin with fluorinated solvents such as phytosols. Dry leaf material was extracted in a specially designed assembly with phytosol-A. After filtration the phytosol was allowed to evaporate at room temperature and the resulting material weighed for artemisinin content. The plant materials, remained after three extractions, were finally extracted with methanol to obtain the extract containing the residue. The study revealed that the first extraction gave the highest yield of artemisinin rich extractive (55.4 mg) followed by second and third extractions with respective yields of 38.5 mg and 24.4 mg, respectively. Unlike conventional solvents, the fluorinated solvents like phytosol A and D are more efficient as extraction solvent.

Identification of chemical constituents and antifungal activity of Alpinia galanga oil. Dried and crushed rhizomes of *Alpinia galanga* (family Zingiberaceae) were hydrodistilled to obtain essential oil (2.6%). Some of the major constituents identified from the oil include 1,8-cineole, acetoxy-1,8-cineole, caryophyllene, caryophyllene oxide, carvacrol/thymol, dihydrojasmone, bisabolol, anethole, á-fenchyl acetate, methyl cinnamate, â-pinene, eugenol, eugenyl acetate, camphor, along with glucoside of hydroxy-1,8-cineole. The essential oil exhibited moderate antifungal activity against *Sclerotium rolfsii* (70% growth inhibition at 250 ppm test concentration).

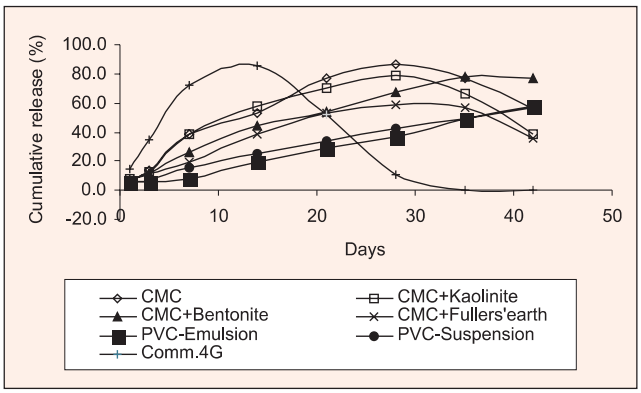
Antifungal activity of essential oils and aroma chemicals. Twelve aroma chemicals were evaluated for the management of sheath blight of rice caused by *Thanethoporus cucumeris (Rhizoctonia solani*) Chemicals such as eugenol, cedar oil, tagetes oil, terpenyl acetate, terpineol, linalyl acetate, â-pinene, linalool and anethole were found to manage the infection comparable to carbendazim, the standard fungicide.

Antifungal activity of secondary metabolites isolated from *Fusarium oxysporum*. Secondary metabolites, namely, sporol, sporotrichiol, 6-butyl-α-pyrone, fungerin, moniliformin, visolitricin, 8-hydroxyisotrichodermol, T-2 toxin, zerealenone and diacetoxyscirpenol isolated and characterized from the culture filtrate extracts of *F. oxysporum* were tested for fungicidal activity against *Rhizoctonia bataticola, M. phaseolina, S. rolfsii, P. aphanidermatum* and *P. debaryanum*. Maximum activity was found with moniliformin against *P. aphanidermatum* (ED_{50}, 29.25 ppm), and *P. debaryanum* (ED_{50}, 78.00 ppm) followed by 6-butyl-α–pyrone (ED_{50}, 37.2 ppm and 34.9 ppm, respectively) and sporotrichiol (ED_{50}, 66.54 ppm against *P. aphanidermatum*).

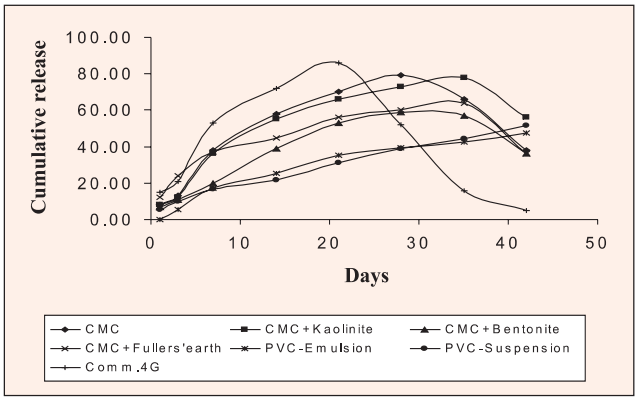
4.4.2 Pesticide Formulation

Preparation of tablet formulation of imidacloprid. A tablet formulation incorporating imidacloprid and neem seed derivatives was developed. The physicochemical properties of the tablet are: size diameter, 8.5 mm; mass, 500 mg; imidacloprid content, 25 mg; neem seed derivative, 25 mg; attrition quality-break point, 15 kg/cm^2; and disintegration time in standing water, 2 h. The tablet was subjected to accelerated storage at 54°C ± 1°C for 14 days and the stored tablet was tested for its active ingredient content. The tablet was evaluated for its bio-efficacy in pest control on tomato crop raised in pot culture experiments. There was no pest incidence on the crop compared to that of control.

Release kinetics of cartap hydrochloride in water and soil from controlled release formulations. Controlled release formulations of insecticide cartap hydrochloride (2-dimethylaminopropane-1, 3-diol) have been prepared using commercially available polyvinyl chloride (emulsion and suspension), carboxy methyl cellulose with clay (bentonite, kaolinite and Fullers' earth). Release of cartap hydrochloride in soil and water from the different formulations was studied in comparison with the commercially available granules (4G). Release from the commercial formulation was faster than that from the CR formulations. Addition of clay in the carboxy methylcellulose matrix reduced the rate of release. The diffusion exponent (n value) of cartap hydrochloride in water and soil ranged from 0.53 to 0.74, and 0.46 to 0.74, respectively, in the tested formulations. The release was diffusion controlled with a half release time ($T_{1/2}$) of 4.8 to 36.3 days in water and 7.5 to 44.8 days in soil from different matrices. The period of optimum availability of cartap hydrochloride in water and soil from controlled released formulations ranged from 15.3 to 37.5 days and 20.3 to 43.4 days, respectively. The



Rate of release of cartap hydrochloride in water from controlled release and commercial formulations



Rate of release of cartap hydrochloride in soil from controlled release and commercial formulations

results suggest that, depending upon the matrix of polymer used, the application rate of cartap hydrochloride can be optimized to achieve insect control at the desired level and period.

4.4.3 Pesticide: Risk Assessment, Environmental Fate and Remedies

4.4.3.1 Persistence of pesticides

Persistence of thiamethoxam and acetamiprid in tomato following root-dipping treatment. Translocation and persistence of thiamethoxam and acetamiprid in tomato were studied by dipping the roots of the seedling for three hours in 2% solution/suspension of thiamethoxam and acetamiprid prepared by mixing the required quantity of their formulations (Actara 25 WG and Pride 20 SP in 200 ml) in water. Both the pesticides translocated to the shoot portion of the plant. The residues in whole plant just after dipping treatment varied from 1.58 µg/g to 2.42 µg/g. The residues in plant persisted beyond 30 days. In shoot portion of the plant, 0.33 µg/g to 0.41 µg/g residues were recorded on 15th day after transplanting. The leaves after 30 day of transplanting contained 0.08 µg/g to 0.11 µg/g. However, fruit samples drawn after 45 days of transplanting recorded non-detectable residues.

Persistence of indoxacarb in mustard. Residues of indoxacarb when applied @ 75 g a.i./ha and 150 g a.i./ha at 50% pod formation stage on mustard (var. Pusa Bold) were below detectable limit in grains at harvest time.

Persistence of flubenamide in pigeonpea. Residues of flubendiamide (NNI 480SC) when applied on pigeonpea (var. Pusa 855) at the pod formation stage @ 24 kg a.i./ha and 48 kg a.i./ha were below detectable limit in grains (0.005 mg/kg. This is the first report of the persistence of flubendiamide on a pulse crop.

Persistence of imidacloprid in okra. Field trials were conducted at the Institute using randomized block design to study the residues of imidacloprid 70 WG when used as foliar application on okra at initial fruit formation stage @ 24.5 g a.i./ha. and 49.0 g a.i./ha.. A second spray was made ten days after first application. Residues persisted till five days in okra fruits at the recommended dose of application and till seven days at double dose of application after which the residues were below detectable limit (< 0.05 mg/kg) in okra fruits. The LOD and LOQ were 0.02 and 0.05 mg/kg, respectively. The residues in soil were below detectable limit (<0.05 mg/kg) on 30th day.

Persistence of cypermethrin on okra and deltamethrin in brinjal. Field experiment was conducted to study the residues of cypermethrin on okra and deltamethrin on brinjal crop. The initial deposits of cyeprmethrin on okra fruits were 0.40 mg/kg and 0.52 mg/kg from 15 g a.i./ha and 30 g a.i./ha treatments, respectively, whereas the initial deposits of deltamethrin in/on brinjal were found to be 0.45 mg/kg from 20 g a.i./ha treatment. The reported concentration of the two insecticides declined with time and reached non detectable level after five days in the case of lower treatment rate of cypermethrin on okra. However, the residues were non-detectable on 7th day in brinjal fruits after deltamethrin spray on the crop. The insecticidal schedules appeared safe and free from residue hazards.

Persistence of bifenthrin in/on tomato. Residues of bifenthrin on tomato when applied @ 25 g a.i./ha and 50 g a.i./ha at flowering/fruit formation stage as spray treatment dissipated with time and more than 90% dissipation was recorded on 5th day at both the doses. At high dose, residues persisted beyond seven days, whereas at low dose, no residues were found on 7th day samples. Half-life values calculated, following first order dissipation kinetics model, were 1.17 and 1.25 days at low and high doses, respectively.

4.4.3.2 Environmental fate of pesticides

Persistence of bifenthrin in soil under different moisture regimes. Experiments were conducted to study the persistence of bifenthrin in soil under different moisture regimes. Residues of bifenthrin persisted in soil for more than 60 days in all treatments. On an average, 13.6% to 21.5% of the residues dissipated on 15th day, 35.4% to 59.7% on 45th day and 42.3% to 77.1% on 60th day. The dissipation followed first-order kinetics with half-lives of bifenthrin under different treatments and ranged from 29.5 to 73.4 days. Bifenthrin was found to persist longer under air-dry conditions than under field capacity and submerged moisture regimes. The half-life values ranged from 29.5 to 36.7 days under field capacity and

submerged condition compared to 66.9 to 73.4 days under air-dry condition. Among field capacity and submerged moisture regimes, bifenthrin persisted longer under field capacity moisture than under submerged conditions. The half-life values ranged from 35.0 to 36.7 days under field capacity compared with 29.50 to 35.40 days under submerged condition.

Leaching of fluchloralin in soil. Leaching of fluchloralin was studied in IARI soil column under saturated flow condition. In general, no residues were detected in 0 to 25 ml fraction of the leachate. Further fractions contained traces of fluchloralin. Analysis of soil cores at different depths revealed that after leaching with 35 ml of water (2 x FC), fluchloralin residues got distributed in soil of 0-10 cm depth. No residues were detected beyond 10 cm depth. With 70 ml water (4 x FC), the residues moved down and a concentrated band was observed in soil between 5 cm and 15 cm depths. However, no residues were detected beyond 15 cm depth. With 140 ml water (8 x FC), residues were detected throughout the column soil. However, the concentration was low at top and bottom soil. A diffused band was observed between 5 cm and 20 cm depth soil.

Degradation of triasulfuron, a sulfonyl urea herbicide, in soil. Persistence of triasulfuron [3-(6-methoxy-4methyl-1,3,5-triazin-2-yl)-1-{2-(2-chloroethoxy)-phenylsulfonyl}-urea] in soil was studied under wheat crop and laboratory conditions. Triasulfuron was applied as post-emergent application to wheat crop at two rates of application, viz., 15 g a.i. ha^{-1} and 20 g a.i. ha^{-1}. Dissipation of triasulfuron followed a first order rate kinetics. Residues dissipated from field soil with half-life of 5.8 days and 5.9 days at two rates of application. The study indicated biphasic degradation with faster rate initially ($T_{1/2}$ = 3.7 days) followed by a slower dissipation rate at the end ($T_{1/2}$ = 9.4 days). Similar trend was observed with non-sterile soil in laboratory with a higher half-life. Acidic pH and microbial activity contributed towards the degradation of triasulfuron in soil.

In wheat field with alluvial soil, triasulfuron dissipated with a half-life of 5.9 days under Indian tropical climate. Similar trend was found in non-sterile alluvial soil under controlled laboratory conditions with a longer half-life (22.1 days) of triasulfuron. The study indicates the mobility of triasulfuron to lower layers of soil.

Sorption of metribuzin on fly ash. To exploit the potential of fly ash for clean up/ decontamination of pesticide-contaminated water, adsorption of metribuzin was studied on fly ash. Sorption studies [1: 10 (w/v) fly ash to water ratio] at metribuzin concentrations ranging between 2.5 ppm and 500 ppm were performed using batch method. Results indicated that fly ash has very high capacity to sorb metribuzin and sorption of herbicide depends up on the initial concentration of herbicide in solution. Sorption of metribuzin was 100% up to 7.5 ppm concentration. However, at higher metribuzin concentrations (> 10 ppm) sorption decreased with increase in concentration of herbicide in solution and sorption decreased from 98.2% (10 ppm) to 53.9% (500 ppm).

Persistence of acetamiprid and thiacloprid under uv and sunlight. Acetamiprid dissipated with the half-life of 4.4 to 11.1 days under UV light and 4.9 to 25.1 days under sunlight. Dissipation half-life observed for thiacloprid was 7.2 to 12.8 days under UV light and 17.7 to 18.2 days under sunlight. Both the compound dissipated faster as thin film ($T_{1/2}$ = 4.4 to 17.7 days) as compared to soil-incorporated residues ($T_{1/2}$ =11.1 to 25.1 days).

4.5 WEED MANAGEMENT

4.5.1 Integrated Weed Management in Onion

A field experiment was conducted during *rabi* season of 2005-2006 to find out suitable integrated weed management practice for effective weed management in onion.

The dominant weed species were: *Dactyloctenium aegyptium, Elusine indica, Cynodon dactylon, Cyperus rotundus,* and *Parthenium hysterophorus.* Sequential application of pendimethalin @ 0.75 kg/ha as pre-emergence

Effect of different weed control treatments on weed growth and bulb yield of onion

Treatment	Weed dry weight (g /m^2)	Bulb yield (t/ ha)	Weed control efficiency (%)
Pendimethalin @ 1.0 kg/ha pre-em + 1 hand weeding (30 DATP)	18.54	21.77	83.76
Pendimethalin @ 0.75 kg/ha pre-em fb pendimethalin @ 0.75 kg/ha at 30 DATP	16.20	22.05	85.80
Fluchloralin @ 1.0 kg/ha PPI	28.52	15.87	74.95
Fluchloralin @ 1.0 kg/ha PPI + 1 hand weeding (30 DATP)	20.56	21.79	81.98
Fluchloralin @ 1.0 kg/ha PPI fb fluchloralin @ 1.0 kg/ha, sand mix broad cast at 30 DATP	18.64	21.90	83.66
Oxyflurofen @ 0.25 kg/ha pre-em	93.82	9.86	17.75
Oxyflurofen @ 0.25 kg/ha pre-em + 1 hand weeding (30 DATP)	76.43	12.94	32.99
Three hand weedings (20,40 and 60DATP)	15.80	22.33	86.15
Weedy check	114.07	3.93	
CD (P= 0.05)	5.44	0.58	

followed by (fb) pendimethalin @ 0.75 kg/ha as broadcast (sand mix) at 30 days after transplanting (DATP), fluchloralin @1.0 kg/ha pre plant incorporation (PPI) fb fluchloralin @ 1.0 kg/ha (as broadcast), pendimethalin @ 1.0 kg/ha + 1 hand weeding and fluchloralin @ 1.0 kg/ha + 1 hand weeding were on a par with 3 hand weedings (22.33 t/ha). The lowest bulb yield (3.91 t/ha) was recorded in unweeded plot due to severe weed competition. Pre-emergence application of oxyflurofen at 0.25 kg/ha did not prove effective in controlling weeds in onion.

4.5.2 Comparative Effect of Soil Solarization, Herbicides and Incorporation of Various Plant Materials on Weed Growth and Productivity of Soybean

An investigation was carried out to study the effect of soil solarization, herbicide application and incorporation of various plant materials on weed growth and productivity of soybean.

Hand weeding twice was on a par with pre-emergence application of ready mix of pendimethalin + imazethapyr (1.0 + 0.2 kg/ha) and pendimethalin application alone at 1.5 kg/ha. The solarization of soil for 40 days during May-June with transparent polyethylene film (TPE) of 0.05-0.10 mm thickness significantly reduced the weed density. Among the plant materials, incorporation of *sheesham* dried leaves @ 4 t/ha resulted in the highest reduction in weed density followed by *Parthenium,Eucalyptus*, neem leaves and sunflower stalk.

Hand weeding twice recorded the highest seed yield of soybean (2.26 t/ha), which was on a par with that of pre-emergence application of ready mix of pendimethalin + imazethapyr (1.0 + 0.2 kg/ha) and pendimethalin alone at 1.5 kg/ha. Pre-plant incorporation of fluchloralin at 1.25 kg/ha and soil solarization were on a par in terms of seed yield of soybean. Among the plant materials, *Eucalyptus* @ 4 t/ha recorded the highest seed yield of 1.54 t/ha, which was closely followed by incorporation of *sheesham* dried leaves. Incorporation of *Parthenium* dried leaves and neem leaves resulted in poor crop stand.

4.5.3 Effect of Planting Methods and Herbicides on Weed Control and Productivity of Wheat

In a field experiment, three planting methods, viz; conventional/flat sowing, FIRBS and skipping every fifth row in conventional sowing; and five weed control methods, viz., weedy check, fenoxaprop-p-ethyl @ 100 g/ha post-emergence, tank mix of fenoxaprop-p-ethyl + 2,4-D (80 g/ha + 0.25 kg/ha) post-emergence, tank mix of fenoxaprop-p-ethyl + isoproturon (80 g/ha + 0.40 kg/ha), and isoproturon @ 0.75 kg/ha post-emergence at 30 days after sowing, were tested in a three times replicated split-plot design, allocating methods of planting to main-plots and methods of weed control to sub-plots.

Dry weight of weeds and tiller number of wheat were statistically similar across the methods of planting, but skipping every fifth row recorded higher values of these parameters. Skip-row treatment recorded significantly higher leaf area for 20 flag leaves over conventional sowing. Conventional sowing and skipping every fifth row in conventional sowing being on a par, recorded significantly higher grain yield over FIRBS. Tank mixes of fenoxaprop-p-ethyl + 2,4-D (80 g/ha + 0.25 kg/ha) post- emergence and fenoxaprop-p-ethyl + isoproturon (80 g/ha + 0.40 kg/ha) were equally effective towards reduction of total weed dry biomass compared to fenoxaprop-p-ethyl alone and weedy check. Wheat grain yield in isoproturon alone, fenoxaprop-p-ethyl @ 100 g/ha +2,4-D and fenoxaprop-p-ethyl + isoproturon (80 g/ha + 0.40 kg/ha) were significantly higher than in fenoxaprop-p-ethyl alone and weedy check. Skip-row method recorded 20 % saving in seed yield over conventional sowing without any loss in seed yield.

Effect of planting and weed control methods on weed control and wheat growth and yield

Treatment	Weed dry wt. (g/m^2)	Tillers/ plant	Leaf area for 20 flag leaves (cm^2)	Wheat grain yield (t/ha)
Methods of planting				
Conventional sowing	14.4	5.3	264.5	5.45
FIRBS	11.9	4.3	303.1	4.62
Skipping one row after every fourth rows	14.5	5.9	317.5	5.46
CD (P =0.05)	NS	NS	26.56	0.41
Weed control methods				
Weedy check	17.5	5.4	284.7	4.86
Fenoxaprop @100 g/ha	22.0	5.4	306.1	4.75
Fenoxaprop @ 80 g/ha + 2,4-D @ 0.25kg/ha	7.6	5.3	263.1	5.47
Fenoxaprop @ 80 g/ha + isoproturon @ 0.4 kg/ha	6.4	5.1	302.7	5.46
Isoproturon @ 0.75 kg/ha	15.0	4.5	318.7	5.38
CD(P=0.05)	7.45	NS	51.24	0.43

5. BASIC AND STRATEGIC RESEARCH

5.1 PLANT BIOTECHNOLOGY

5.1.1 Development and Testing of Bt-brinjal

Brinjal is an important vegetable crop grown throughout the year. It is highly susceptible to a Lepidopteran pest called brinjal shoot and fruit borer (BSFB; *Leucinodes orbonalis*). Transgenic brinjal expressing Bt-Cry1Fa1 tested earlier was found to be highly resistant to BSFB. In our attempt to develop a gene stacked Bt-brinjal, a codon-modified synthetic gene encoding *Cry1Aa* was introduced in brinjal variety Pusa Purple Long, and the variety tested in a glasshouse. The data demonstrated that two transgenic lines exhibited significantly reduced fruit damage in comparison to that in normal lines.

Fruit damage in normal transgenic lines of brinjal expressing *Cry1Aa*

Line	No. of fruits	Damaged	Undamaged	Damage %
Bt-Aa1	51	4	47	7.84
Bt-Aa12	64	12	52	18.75
Bt-Aa 18	47	4	43	8.51
Bt-Aa21	73	24	49	32.87
Bt-Aa32	43	9	34	20.93
Normal	99	30	69	30.30

5.1.2 Tomato Genome Sequencing

The tomato genome-sequencing project was initiated on a scale similar to that of the rice genome project. Tomato (*Solanum lycopersicum)* has a diploid genome with 12 pairs of chromosomes and a genome size of 950 Mb. The objectives of the Indian Initiative for Tomato Genome Sequencing at NRCPB are: (i) to produce a high quality sequence of the gene rich 5 Mb euchromatin of the long arm of chromosome 5; (ii) to process and annotate this sequence in a manner consistent and compatible with similar data from *Arabidopsis*, rice and other plant species; (iii) to submit the sequence to an international bioinformatics portal for comparative Solanaceae genomics, and (iv) to make the information available to research community for the identification of agronomically important genes from tomato genome.

The tomato genome is expected to work as a model reference for the Solanaceae family. The project was initiated with the identification of 12 seed BACs from chromosome 5 for sequencing. Six clones were sequenced to Phase II and five to Phase I. To fill the gaps further, extension BACs are being identified and characterized.

5.1.3 Marker Assisted Selection for Bacterial Blight Resistance Genes in Rice

Earlier, two genes (*xa13* and *Xa21*) for bacterial blight (BB) were combined with the *basmati* quality traits of Pusa Basmati 1 through molecular marker-assisted selection (MAS) in collaboration with the Division of Genetics, IARI. During the year under report, one of the recombinant lines, Pusa 1460-01-32-6-67 (IET-18990), developed in this programme, was registered with the NBPGR (INGR No. 05002). This line was also promoted to Advanced Varietal Trial II of multi-location evaluation under All India Coordinated Project. Efforts were also made to carry out MAS for four BB resistant genes, namely, *Xa4, xa5, xa13* and *Xa21* in the F_2/F_3 progeny of two different crosses involving *basmati*/aromatic rice lines. IRBB60 was used as the donor of the BB resistance genes. Four recombinants carrying all the four BB resistance genes were identified in the F_2 from the cross Pusa 2512 × IRBB60 and three recombinants from the cross Pusa 1121 × IRBB60. These selected recombinants will be used for further assessment of their performance.

5.1.4 Development and Molecular Characterization of an Improved CMS Line of *Brassica juncea*

A CMS line was derived by sexual hybridization between *Diplotaxis berthautii* and *Brassica rapa* followed by backcrossing with *B. juncea*. However, this CMS line had low female fertility and its flowers lacked nectaries. Further, no fertility restorer gene was found for this CMS line thus

Male sterile flowers of CMS (*D. berthautii*) *B. juncea*

Flowers of fertility restored plant

making it unsuitable for commercial use. An improved CMS line has now been obtained by further backcrossing and selection. The improved CMS line has flowers with well developed nectaries and stable male fertility. The female fertility is close to 100%. The restorer of *Moricandia arvensis* system is able to confer male fertility to this CMS line and the mode of restoration is gametophytic.

5.1.5 Molecular Characterization and Micropropagation in Fruit Crops

Genetic diversity was studied in 48 *ber* accessions (47 cultivated *Ziziphus mauritiana* and one wild relative *Z. nummularia*) using Inter-Simple Sequence Repeat (ISSR) markers. Eighteen primers produced polymorphic bands. Genetic similarity ranged from 43.07 to 90.30 per cent. The highest similarity was noted between the genotypes Narma and Banarasi Karaka.

Thirty grape genotypes were characterized using 125 random decamer RAPD primers, out of which 31 gave satisfactory amplification. Primers OPB-12, OPG-08, OPG-16 and OPY-16 were most efficient for genetic diversity analysis. In total, 216 bands were obtained, out of which 186 (86.1%) were polymorphic.

Somatic embryogenesis was achieved from nucellus of monoembryonic (cultivars Amrapali and Pusa Arunima) and polyembryonic (Olour and Kurukkan) genotypes. The ideal stage for culture initiation in mango was when the fruitlets were 35 to 40 days old. Of the different media and growth regulator combinations tried, modified B5 medium supplemented with 1.0 mg/l 2,4-D and 0.5 mg/l BAP gave the best result for callus initiation. Studies on somatic embryogenesis from nucellar explants of different varieties revealed that maximum callus induction was recorded in Olour followed by Kurukkan. The earliest somatic embryo induction was observed in Kurukkan followed by Olour. Amrapali showed the highest frequency of embryogenesis, whereas, the highest germination and normal embryo percentage was observed in Olour. Better germination, irrespective of the varietal response, was noticed on phytagel solidified medium compared to that of agar-agar solidified medium.

Culture initiation was higher in Allahabad Safeda (58.2%) compared to that in Pusa Srijan (13.5%). Pusa Srijan showed poor shoot multiplication (1.2 shoots/explant) compared to Allahabad Safeda (3.5 shoots/explant).

In grape, shoot multiplication rate was compared using Two-node Repetitive Micro-cutting technique in different genotypes. It was maximum in Pusa Urvashi (10-13 micro-cuttings/subculture) followed by Pusa Seedless (10-11 micro-cuttings/subculture). Centennial Seedless gave the minimum number of micro-cuttings (5-7 micro-cuttings). The multiplication cycle was of six weeks in Pusa Urvashi, Pusa Navrang and Pusa Seedless, while that for Hybrid 76-1 and Centennial Seedless was of seven weeks.

Micropropagation of different grape genotypes through Repetitive Micro-cutting Technique

Genotype	No. of micro-cuttings/ subculture	Multiplication cycle (weeks)
Pusa Urvashi	10-13	6
Pusa Navrang	9-11	6
Pusa Seedless	10-11	6
Hybrid 76-1	7-8	7
Centennial Seedless	5-7	7

5.1.6 Grape Breeding through Embryo Rescue

Thirty-three hybrid grape plantlets raised through embryo rescue technique, involving four cross combinations and selfing, were transplanted in field for evaluation. Embryo rescue was best on NN medium supplemented with 1.0 mg/l IAA + 0.5 mg/l GA_3 along with 100 mg/l casein hydrolysate. After three months, matured ovules were given three weeks of chilling treatment followed by incision to facilitate germination. MS medium supplemented with 1.0 mg/l IBA along with 100 mg/l activated charcoal gave good germination.

DNA fingerprinting of *Malus* species is being carried out at the Institute's regional station at Tutikandi (Shimla), in collaboration with the scientists of the Central Potato Research Institute (CPRI), Shimla, and the Division of Fruits and Horticultural Technology of the Institute at New Delhi. Total genomic DNA from 24 accessions of apple spp. was extracted from young leaf samples by a modified CTAB procedure. Quality and quantity of DNA preparations were

checked by standard spectrophotometer as well as by agarose gel electrophoresis.

5.2 BIOCHEMISTRY

5.2.1 Isolation of Genes Involved in Lipid Biosynthesis

Total RNA isolated from *Brassica juncea* developing seeds was used to carry out 5' RACE using *DGAT*(Diacyl glycerol acyl transferase) gene specific and adaptor specific primers. The total length of *Bj DGAT1* and *Bj DGAT2* cDNA was found to be 1768 base pairs, which include 80 base pairs of 5' UTR, 1509 bp of coding sequence and 179 base pairs of 3' UTR including the termination codon TAG. The length of coding region was the same in both cases but they differed in their nucleotide sequence. The 5' upstream region of *DGAT* gene was PCR amplified by adaptor PCR technique from genomic DNA and a 0.5 kb amplicon obtained. This fragment was cloned in T/A cloning vector.

5.2.2 Characterization of Functional Domains of AVP/RIP from the Leaves of *Bougainvillea xbuttiana*

Earlier studies had revealed that different RIP/AVP show toxicity towards the transformed plants because of ribosome inactivating activity. Hence, three C-terminal deletion mutants of *Bougainvillea xbuttiana* RIP/AVP gene were isolated, cloned and expressed in *E.coli*. The purified truncated proteins, when tested for different activities, showed that a deletion of 35 amino acids from C-terminal end had no effect on RNase, DNase and antiviral activity of the protein but a strong inhibition of N-glycosidase activity (toxicity) was observed. This mutant could serve as an important tool to engineer broad-spectrum resistance in crop plants.

Purified AVPs/RIPs isolated from *Amaranthus tricolor, Celosia cristata,* and *Bougainvillea xbuttiana* showed 40% to 60% inhibitory action against the fungus *Rhizoctonia solani.*

5.2.3 Isolation and Characterization of *fad2-1* Gene Encoding ω-6 Desaturase from Soybean

Chimeric fragments (~3.4 kb) containing *fad2-1* gene in both sense and antisense directions with respect to vicilin promoter were cloned into the plant transformation vector pAKVS, a binary vector carrying plant selection marker "bar" gene and kanamycin resistance gene. Restriction analysis of the recombinant clones was carried out to confirm their orientation before mobilization into the *Agrobacterium* strain GV 3101. The intron-spliced hairpin construct was prepared with inverted-repeat regions consisting of 212 bp of 3'-UTR of the *fad 2-1* gene separated by a 420 bp intron of the *fad 2-1* gene in a spliceable orientation. The inverted repeat arms were oriented in the antisense and sense directions at the 5' and 3' ends of the construct, respectively.

5.2.4 Nitrate Reductase in Various Cultivars of Wheat as Affected by Climatic Changes

Fifteen heat tolerant and 7 heat susceptible wheat cultivars were grown in the field and also in the net house to study the nitrate reductase activity with time and change of environmental conditions.

Nitrate reductase activity decreased (50% to 63%) after 15 days of age in both heat tolerant (15 cvs) and susceptible (7 cvs) cultivars and thereafter remained steady for the next 75 days. The level of dephosphorylated nitrate reductase (active form) was higher in heat tolerant cultivars than that in heat susceptile ones, which may be one of the factors imparting heat tolerance.

5.3 PLANT PHYSIOLOGY

5.3.1 Physiological Constraints Limiting Productivity

5.3.1.1 Heat shock proteins and thermo-tolerance for grain growth in wheat

Wheat (*Triticum aestivum* L.) cultivars DL 153-2 and HD 2285 (relatively tolerant), HD 2329 and WH 542 (relatively susceptible) were exposed to post anthesis high temperature by growing in heated open top chambers (OTCs) and by late sowing. The mean maximum temperature was 3.2 ºC and 3.6 ºC higher than that of the control during grain growth period under the two conditions, respectively. This increased the accumulation of low molecular weight heat shock protein (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 that in susceptible types. The high molecular weight HSPs did not show such a response and were constitutively present. The LMW-HSP could, therefore, be important in providing increased tolerance to moderate heat stress during grain development. Late sowing of wheat, being generally practiced in rice-wheat cropping system, could, therefore, be one of the reasons of overall decline in wheat productivity.

5.3.1.2 Screening of wheat genotypes for phosphorus use efficiency in the field

Screening of 150 wheat genotypes was carried out in the field for P use efficiency which revealed significant differences in terms of biomass, grain yield, HI and test weight. Among the genotypes, Credit (*Triticale* spp.) produced maximum

relative shoot dry matter while DT 139, a hexaploid triticale, was the lowest yielder (<86%). In terms of grain yield, species *T. carthlicum*, a tetraploid, and Alondra, *T. aestivum*, produced relative grain yield >160% at P0 compared to P60. The HI was the highest in species *T. carthlicum* (239%) followed by *T. polonicum* (216%), a tetraploid, while the lowest was observed in Sunstate (35%). Similarly, the relative increase in 1000-seed weight was observed in Kauz/Gen (156%) followed by *T. carthlicum* (155%), and the lowest was recorded in species *T. polonicum* (70%).

5.3.1.3 Role of jasmonic acid in natural and induced senescence in mungbean

Both jasmonic acid and ethylene have been implicated in promoting senescence, but the specific roles of each and the mechanisms by which they act are still not known.

Endogenous levels of jasmonic acid increased in the leaves with age of the plant and were highest in the senescing leaves. Water stress stimulated jasmonic acid synthesis. There was a close association between endogenous levels of jasmonic acid and ethylene biosynthesis in senescing as well as stressed leaves as evidenced by ACC synthase activity. When detached leaves were treated with jasmonic acid, it exerted significant influence on ethylene biosynthesis as well as on senescence characteristics of leaves suggesting that jasmonic acid may be causing stress induced senescence.

Endogenous jasmonic acid content, ACC synthase activity and RWC in the leaves of water stressed mungbean plants

Days after stress	Jasmonic acid (ng. g^{-1} F. W.)	ACC synthase activity (nmol. g^{-1} F.W.h^{-1})	Relative water content (%)
0 (control)	135.133 ± 3.709	2.367 ± 0.065	82.167 ± 2.313
3	297.400 ± 6.102	4.167 ± 0.143	73.633 ± 2.533
6	187.933 ± 5.158	5.067 ± 0.139	67.133 ± 1.889
9	182.400 ± 3.742	3.267 ± 0.112	63.200 ± 2.174
CD at 5%	6.943	0.173	3.250

Chlorophyll content in the jasmonic acid treated leaves declined with an increase in jasmonic acid concentration. There was an increase in antioxidant enzyme activity in response to stress and jasmonic acid treatment though the activity declined subsequently.

5.3.2 Improvements in Abiotic Stress Tolerance in Crop Plants:Physiological Approaches

5.3.2.1 Protective role of antioxidant enzymes under high temperature stress in wheat

A pot culture study with five wheat genotypes, viz., HDR 77, HD 2815 (heat tolerant), PBW 175 and HD 2865 (moderately susceptible), and PBW 343 (susceptible) revealed significant positive correlation with chlorophyll content, and significant negative correlation with membrane injury index for most of the antioxidant enzymes and Chl/MII at three sowing dates and two growth stages. This established the role of antioxidant enzymes in maintaining chlorophyll content and membrane stability in wheat under temperature stress conditions.

Correlation coefficient (r) between antioxidant enzymes and chlorophyll content/MII in wheat genotypes

Anti-oxidant enzyme	Stage	Chlorophyll content			Membrane injury index		
		Normal	Late	Very late	Normal	Late	Very late
SOD	Anthesis	0.47*	0.49*	0.63*	-0.66*	-0.29	-0.49*
	15 DAA	0.13	0.41	0.01	-0.39	-0.17	-0.51*
APX	Anthesis	0.56*	0.84**	0.62*	-0.56*	-0.68*	-0.30
	15 DAA	0.42	0.61*	0.96**	-0.32	0.76**	-0.64*
CAT	Anthesis	0.39	0.89**	0.35	-0.37	-0.50*	-0.40
	15 DAA	0.49*	0.51*	0.85**	-0.45*	-0.01	-0.62*
GR	Anthesis	0.49*	0.64*	0.45*	-0.07	-0.48	-0.44
	15 DAA	0.03	0.30	0.62*	-0.59*	-0.06	-.80**

*Significant at 5%, **Significant at 1%

In a field experiment, tall genotypes (C 306, HD 2913, RR 3 and HD 2834) recorded lower membrane stability index and breaking strength compared to dwarf genotypes (HD 2329, NW 2036, Raj 4014 and Raj 3765) having thicker and stronger stem.

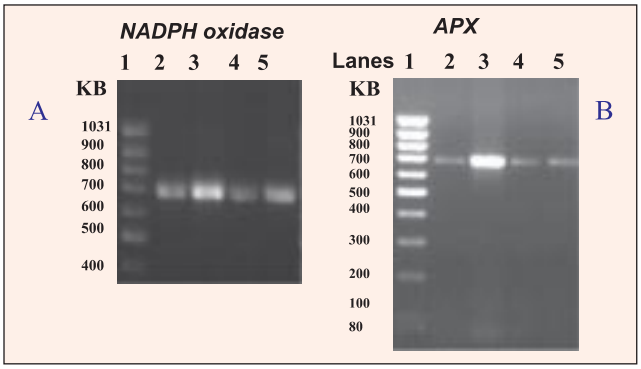
5.3.2.2 Waterlogging induced oxidative stress and antioxidant activity in pulses

In a study conducted with 4 pigeonpea genotypes, (comparatively tolerant ICP 301 and ICPL 84023, and susceptible ICP 7035 and Pusa 207), one- month old plants were subjected to 6 days' water logging.

Waterlogging caused a gradual decrease in RWC, chlorophyll content in leaves, and membrane stability index (MSI) in leaves and root tissues in all the genotypes. However, comparatively tolerant genotypes maintained high levels of RWC, Chl and MSI than susceptible ones. Tolerant genotypes showed almost complete recovery 5 days after termination of water logging treatment, while susceptible genotypes could not recover fully even after 10 days of treatment termination. Chl a/chl b ratio increased during waterlogging, more in the susceptible genotypes than in tolerant ones and decreased more rapidly to pre-stress level in tolerant than susceptible genotypes during recovery. The results suggest more damage to Chl b than to Chl a under waterlogging, which was higher in susceptible genotypes.

Oxidative stress in the form of superoxide radical ($O_2^{\cdot-}$) and hydrogen peroxide (H_2O_2) contents initially decreased over control plants at 2 days waterlogging; however, at 4 days and 6 days of waterlogging it increased over 2 days waterlogged plants in all the genotypes. Addition of diphenylene iodonium chloride (DPI), an inhibitor of membrane linked NADPH oxidase, inhibited the $O_2^{\cdot-}$ production under waterlogged condition, which further increased upon termination of the treatment. Superoxide production in the presence of DPI could be due to some amount of mitochondrial activity or due to reduction of oxygen by highly reduced root-soil interface environment. There was very little NADPH oxidase dependent (diphenylene sensitive) $O_2^{\cdot-}$ production in control plants (0 day), which continuously increased during waterlogging, reaching maximum on 6th day and decreased upon termination of treatment. Gene expression studied by RT-PCR showed increased expression of NADPH oxidase-mRNA under waterlogging, which was more in tolerant genotypes. This suggested that ROS generated during waterlogging is due to activation of DPI-sensitive NADPH oxidase. Secondly, the NADPH oxidase induced ROS production may be having a role in signal transduction.

Antioxidant enzymes such as superoxide dismutase (SOD), ascorbate peroxidase (APX), glutathione reductase (GR) and catalase (CAT) also increased under waterlogging, the increase being more in tolerant genotypes. The activities of SOD, APX, GR and CAT further increased when 4 days waterlogged plants were put for recovery.



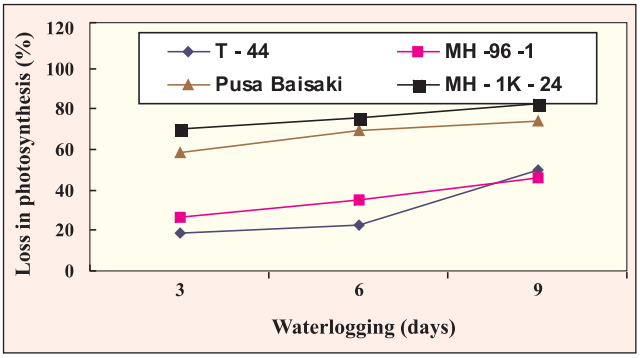
RT-PCR gene expression of *APX* and *NADPH oxidase* under water logged condition in tolerant and susceptible pigeonpea genotypes (1:ladder, 2:control ICPL 84023, 3:W.L. ICPL 84023, 4:control ICP 7035, and 5:W.L. ICP 7035)

Waterlogging induced activity of the antioxidant enzymes is due to enhanced gene expression, as is evident from the increase in APX-mRNA expression in tolerant genotype ICPL 84023 under waterlogged condition.

It is concluded that comparatively greater activity of antioxidant enzymes resulting in less oxidative stress ($O_2^{\cdot-}$ and H_2O_2) after recovery from waterlogging could be one of the factors determining tolerance of pigeonpea genotypes to flooding. Secondly, this study also demonstrated that waterlogging induced increase in ROS is via NADPH oxidase, which may be having a role in signal transduction.

5.3.2.3 Photosynthesis and yield response to waterlogging in mungbean

In a pot experiment, waterlogging at vegetative stage in mungbean resulted in decreased leaf area, crop growth rate, net assimilation rate, root nodules number, root growth, flowering rate, partitioning of dry matter to economic sink, membrane stability index, photosynthesis rate, chlorophyll and carotenoids contents, pod setting, yield and its attributes. Susceptible genotypes, viz., Pusa Baisakhi and, MH-1K-24, exhibited greater decline of aforementioned physiological traits and slow recovery in terms of photosynthesis rate as compared to tolerant genotypes. The losses in photosynthesis and yield due to waterlogging in the most susceptible genotype MH-1K-24 were up to 82.81% and 84.92%, respectively.



Photosynthetic loss among mungbean genotypes during waterlogging

5.3.3 Post-harvest Physiology of Fruits, Vegetables and Flowers

5.3.3.1 Evaluation of hypoxia treatment and peel anatomy in fast and slow ripening varieties of tomato

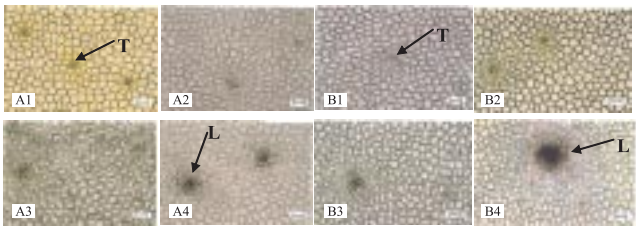
Significant delay in ripening (in terms of RI% and RRT%) was caused by hypoxia of 4 and more days in slow and fast ripening varieties.

Delay in ripening under hypoxia condition was probably due to inhibition of ACC oxidation and suppression of C_2H_4 biosynthesis. Prolonged hypoxia is known to shift the respiration in favour of glycolytic fermentation, where ethanol is the end product, and ethanol is known to delay the ripening

in tomato. The results, therefore, indicated that the standardization of hypoxia/anoxia duration could be an effective, economic and non-chemical approach for delaying the process of ripening, provided the enhanced rottage due to rapid increase in RH could be controlled.

Effect of hypoxia on membrane stability determined at 14 days after harvest showed reduction in ion leakage with the duration of hypoxia treatment. Ion leakage from the variety Pusa Gaurav (slow ripening and good keeper) was significantly more (64.0%) than that of Pusa Ruby (52.1%), which is fast ripening and poor keeper.

In tomato fruits, scar tissue, lenticels and trichomes participate in gaseous exchange and loss of moisture across the fruit boundary. There was a gradual change in hair base cell of trichomes into the lenticels of variable sizes during storage period. Significantly lower values were recorded in Pusa Gaurav compared to those in Pusa Ruby for the sites of gaseous exchange and water loss (lenticels along with trichomes). Examination of fruit peel at different days after harvest also showed lesser number for such sites and lesser conversion of hair base cell of trichomes into the lenticels in Pusa Gaurav in comparison with Pusa Ruby.



Gradual change of hair base cells of trichomes cell into the lenticels of variable sizes during the storage of tomato fruits harvested at green mature stage. A 1-4: Pusa Ruby, and B 1-4: Pusa Gaurav. T: hair base cell of trichome, and L: lenticel. Bar is equivalent to 50 µm

Results suggest that more resistance to gaseous exchange and, therefore, O_2 to CO_2 ratio inside the fruits are related to the differences in the surface anatomical features.

5.3.3.2 Carbohydrate metabolism in rose petals during flower bud development

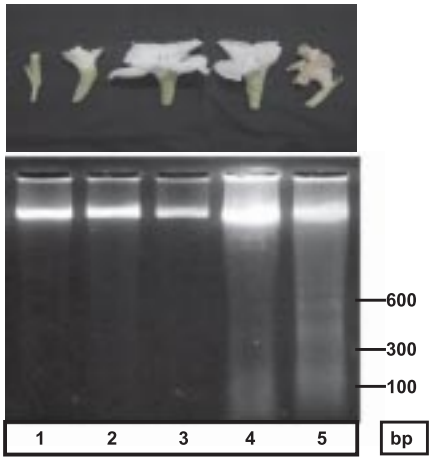
The carbohydrate metabolism in rose petals during flower bud development stages demonstrated that the opening of rose flower bud required the import of carbohydrates. The development of corolla at stage 3 is almost completed and becomes a storage site for assimilates required for petal expansion. This is supported by the accumulation of starch up to stage 3 of flower bud development.

SPS activity increased with early development of petal with a corresponding increase in sucrose concentration. During flower bud opening, the starch, non reducing sugar and sucrose content of the expanding petals decreased with progressive rise in the level of reducing sugars reflecting cell expansion along with other developmental changes. The decline in sucrose accumulation appeared to be a result of the greater capacity of flower petals for sucrose degradation in contrast to sucrose synthesis, and is suggestive of sucrose turnover.

5.3.3.3 Regulation of flower senescence in gladiolus

Abscisic acid (ABA) is considered to be a possible candidate for hormonal trigger for senescence of gladiolus flowers, as it does not respond to ethylene. Since no specific inhibitors for ABA biosynthesis are available, fluridone and sodium tungstate, inhibitors of carotenoids biosynthesis, and the precursor of ABA biosynthesis, were used. However, these inhibitors could not delay the senescence of gladiolus flowers. The ability of exogenous ABA to cause senescence could be inhibited by the treatment of flowers with GA_3, a hormone that extends the vase life of flowers, suggesting that the effect of GA_3 could, in part, be due to the antagonizing ability of ABA to cause flower senescence.

Programmed cell death (PCD) is associated with petal senescence, but little is known about the triggering or execution of the process of cell death in petals. Membrane disruption and DNA fragmentation, the events characteristic of PCD, were found to occur at the advanced stage of petal senescence in ethylene insensitive flowers of gladiolus. Treatment with inositol suppressed/delayed both wilting and DNA fragmentation.



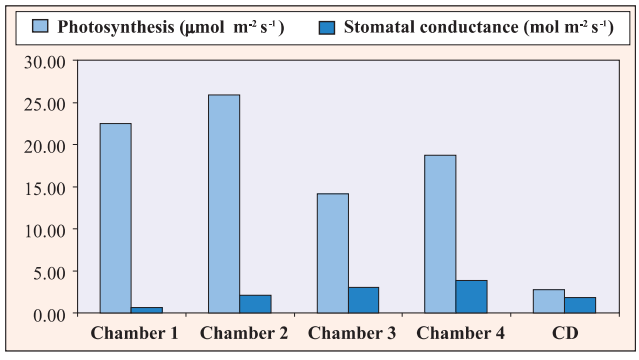
DNA fragmentation detected in petals from each stage during different stages of floral development and senescence. The different developmental stages of flower studied are – stage 1: bud stage; stage 2: half open; stage 3: fully open; stage 4: incipient senescent; and stage 5: senescent

To understand the possible roles of *GgERS1a* and *GgERS1b*, the mRNA expression in petals and anther during flower development was analysed. The expression of *GgERS1b* transcript was lower than that of *GgERS1a*. In petal and anther tissues, *GgERS1a* mRNA expressed constitutively at all the stages of flower development. *GgERS1b* mRNA expression decreased in petal tissue with flower senescence and increased in anther tissue. GgERS1b was apparently a truncated ERS1 type ethylene receptor occurred by alternative splicing according to cDNA sequence data. As a consequence of the sequence analysis, it was revealed that every fundamental component for ERS1 type ethylene receptor was preserved in both short and long *GgERS1* DNA, and the differences between short and long *GgERS1* DNA were in the sequence coding of first intron. The short *GgERS1* DNA lacked 812 nucleotide of long *GgERS1* DNA and the other sequence in first intron was slightly different. According to the data described above, it was suggested that each *GgERS1* gene was generated by splicing from different genomic DNA after duplication. It seems that *GgERS1b* expressed differently in various tissues, which suggested that *GgERS1b* gene works functionally and it could be a good example for sub-functionalization process.

5.3.4 Characterization of Crop Responses to Global Climate Change

5.3.4.1 Effect of elevated CO_2 and temperature on photosynthesis, dry matter production and yield in rice cultivars

Two rice genotypes, Pusa Sugandh 2 (*basmati* type) and Pusa 44 (non *basmati*), were grown in the open top chambers under puddled conditions at two temperature levels and two CO_2 concentrations.



Effect of elevated CO_2 and temperature on photosynthesis and stomatal conductance in rice cultivar Pusa 44 (Chamber 1, elevated CO_2 + ambient temperature, Chamber 2 : elevated CO_2 + elevated temperature, Chamber 3: ambient CO_2 + elevated temperature and Chamber 4: ambient CO_2 + ambient temperature)

Higher temperature treatment resulted in decrease in photosynthesis, total dry matter and seed yield at ambient and elevated CO_2 concentration and thereby decreasing the harvest index. Cultivar Pusa 44 showed a higher response to temperature and CO_2 changes in terms of dry matter production and seed yield. The stomatal conductance and transpiration rate also decreased with elevated CO_2 and led to higher photosynthetic water use efficiency. However, elevated CO_2 levels combined with elevated temperature resulted in an increase in stomatal conductance and transpiration rate, which reduced the photosynthetic water use efficiency. It is, therefore, concluded that increase of temperature by 1-4 °C can override the beneficial effect of elevated CO_2 on photosynthesis, dry matter production, seed yield and photosynthetic water use efficiency.

5.3.4.2 Interactive effect of elevated CO_2 and moisture stress on photosynthesis in *Brassica*

The responses of *Brassica* crop to the changed CO_2 and temperature conditions were studied at different canopy positions in FACE (free air CO_2 enrichment technology).

Elevated CO_2 significantly increased the rate of photosynthesis in the leaves irrespective of their position and variety, whereas moisture stress caused significant decrease in it. The rate of photosynthesis was greater in variety *Brassica juncea* RH 30 compared with that of variety *Brassica campestris* Pusa Gold. The CO_2 induced increase in photosynthesis was significantly higher in top leaves followed by middle and lower leaves irrespective of variety and treatment.

Interactive effect of elevated CO_2 and moisture stress on rate on photosynthesis (µmol m^{-2} s^{-1}) in leaves of *Brassica campestris* and *B. juncea* at different canopy levels

Variety	Treatment	Top canopy leaf	Middle canopy leaf	Lower canopy leaf
***B. campestris* Pusa Gold**	**Ambient CO_2**			
	Irrigated	17.96	15.75	14.90
	Moisture stress	16.63	13.91	12.62
	Elevated CO_2			
	Irrigated	19.96	16.91	15.27
	Moisture stress	19.38	16.17	13.62
***B. juncea* (RH 30)**	**Ambient CO_2**			
	Irrigated	20.17	17.10	15.45
	Moisture stress	17.85	15.51	12.65
	Elevated CO_2			
	Irrigated	22.98	18.61	17.44
	Moisture stress	21.06	17.09	15.11

5.3.5 Genetic and Physiological Regulation of Phytosiderophore Production in Relation to Zinc Efficiency in Wheat

Mixed culture experiment conducted with bread and

durum wheat genotypes showed that Zn uptake capacity of *durum* wheat could be increased in the presence of high phytosiderophore in their rhizosphere, enriched by bread wheat.

5.3.6 Genetic Transformation of Wheat for High Phytosiderophore Production and Evaluation for Zinc Efficiency Traits under Zinc Deficiency

Plant transformation vector having 1.6 kb (containing the 35S promoter, *nas* gene and *nos* terminator from p157) and pCAMBIA3301 was prepared and used for A*grobacterium* mediated genetic transformation in wheat, and T0 lines were established in controlled environmental condition.

5.3.7 Ontogenic Changes in Reduced Nitrogen Content of the Whole Plant of New Wheat Types

An experiment was conducted to study the genotypic variation in relation to reduced N loss in three wheat types, DL 1266-5, DL 1266-2 and PBW 343, under field condition. DL 1266-2 was found to be more efficient in minimizing the reduced N loss from plant canopy followed by DL 1266-5, a new plant type, and PBW 343. The highest protein (%) was observed for DL 1266-2 followed by DL 1266-5 and PBW 343. It seems that DL 1266-2 and DL 1266-5 are most efficient nitrogen utilizers as they produce limited number of synchronous tillers with thick stem and compact long ear heads. The protein (%) supports the above postulation and indicates a superior assimilate reserve accumulation and its mobilization to the developing grain sink. Another positive indicator and highly significant attribute of the DL types is the minimum loss in reduced N content after anthesis compared to that in PBW 343.

5.4 GENETICS

5.4.1 Wheat

5.4.1.1 Leaf rust resistance studies

Nineteen backcross lines carrying *Lr19*/*Sr25* and *Sr36*/*Pm6* were tested in adult stage at New Delhi with a leaf rust pathotype *77-8* virulent on *Lr19*. Backcross lines, HD2285*3/ Cook*6/ C80-1 and WH147*3/Cook*6/C80-1, showed moderate susceptibility, while Kalyansona*3/ Cook*6/C80-1, J24*3/Cook*6/C80-1 and PBW226*3/Cook*6/C80-1 showed low susceptibility to *77-8* at adult stage. The remaining lines showed total freedom from leaf rust infection. The results also indicated that the pathotype *77-8* is avirulent on *Lr26* and also to unknown genes carried by Lok 1 and UP 262. Adult plant reaction of NI 5439, Kalyansona, and WH 147 further revealed that *Lr19* virulent pathotype is non-aggressive. High degree of resistance to stem rust and powdery mildew as exhibited by all the backcross lines indicated that the backcross lines carry the genes *Sr36* and *Pm6*. The availability of a combination of useful resistance genes in the background of adapted wheat cultivars will enhance their exploitation in wheat breeding in India and elsewhere, and these lines could be used for molecular mapping and tagging of genes.

5.4.1.2 Inheritance of stem rust resistance

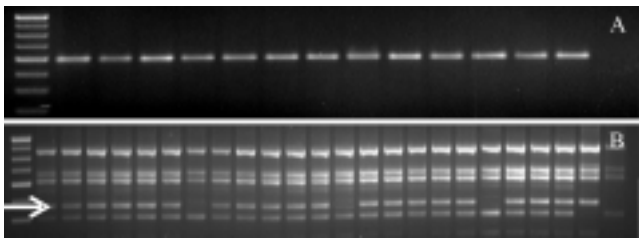
An interspecific derivative 'Selection T2836-1' of wheat (*Triticum aestivum* L.) was tested with 3 stem rust pathotypes, namely, 62G29 (40A), 62G29-1 (40-1) and 137G19 (117-6). The study on mode of inheritance revealed that a single dominant gene controlled the resistance to 62G29 and 137G19 pathotypes, while single recessive gene governed resistance against 62G29-1 pathotype. Result of test of alleles with stem rust resistance genes *Sr24* and *Sr25* indicated that the resistance present in Selection T2836-1 is diverse from that conferred by *Sr24* and *Sr25*. The genetic analysis revealed that two dominant complementary genes control clubbed ear shape. The identification of diverse resistant sources may be useful in breeding, and the determination of genetic control of club ear shape may be a useful marker in genetic analysis.

5.4.1.3 Genetic studies on rust resistance

A study on inheritance of resistance against the most virulent pathotype 46S119 of stripe rust on new resistant source WBM 1587 developed by the Institute's regional station at Tutikandi (Shimla), was further validated for the presence of dominant complementary genes on the basis of F_3 generation analysis. Resistance source HS 431 showed monogenic recessive control of inheritance against the most virulent leaf rust pathotype 121R63-1.

5.4.1.4 Molecular breeding

Molecular marker assisted selection was practised in wheat to pyramid combinations of one seedling (*Lr24* or *Lr28*) and one adult plant resistance (APR) gene (*Lr48*) for leaf rust resistance in wheat from a segregating population carrying PBW 343 and CSP 44 as parental lines. Stable lines for the



MAS identified progeny of F_3 family, which was stable for the SCAR marker $SCS1302_{500}$ linked to gene *Lr24* (A), and progeny segregating for marker $S3_{451}$ (arrow) being selected for the APR gene *Lr48* (B)

two gene combinations were isolated from F_2 and subfamilies, which were non-segregating types from F_3 families selected by the use of sequence characterized amplified region (SCAR) markers and random amplified polymorphic DNA markers linked to the Lr genes.

In two populations from the crosses, PBW 343/HD 2329+*Lr24*/ *4//CSP44 and PBW 343/HD 2329+ *Lr28*/*3//CSP 44, employing MAS, it was possible to select 48 F_4 sub-families for the genes *Lr28 + Lr48* and *Lr24 + Lr48* for showing homozygosity for the two gene combinations in F_3 families. The MAS selected progenies were evaluated in field and desirable single plant selections were further identified for evaluation in F_4 generation.

Field evaluation of F_3 progenies of MAS identified pyramided lines for gene combinations of *Lr24 + Lr48* and *Lr28 +Lr48*

5.4.1.5 Diversity analysis by the use of molecular markers

Microsatellite or Simple Sequence Repeat (SSR) marker analysis of 68 Indian bread wheat genotypes, including the contrasting varieties and landraces for various quality traits, agronomic traits, disease resistance, heat tolerance, etc. was carried out to assess allelic diversity at 35 loci and prepare a DNA fingerprint database. Thirty-five SSR markers distributed on the three genomes (A, B and D) covering all the seven chromosomes identified a total of 92 alleles. Thirty loci were polymorphic and five were found to be monomorphic. The number of alleles ranged from one to five. A total of six alleles were found to be unique. Genetic relationships among various genotypes were analyzed using UPGMA cluster analysis, which formed several distinct clusters among the genotypes. The developed database distinguished the contrasting bread wheat genotypes and the results can be used in mapping genes/QTLs for quality traits and improving breeding programme efficiency by validation and utilization of these markers.

5.4.1.6 Grain hardness evaluation

Soft wheat has softer endosperm texture, requires less energy for milling, and yields smaller particles (with less starch damage upon milling) than that of the hard wheat. Hard wheat is suited for bread and *chapati* making, whereas soft wheat is suitable for biscuit making. To identify donors with hard and soft grains, 1291 germplasm lines comprising old and obsolete varieties, cultivated varieties, genetic stocks of indigenous landraces and exotic lines were screened following the AACC approved method. A number of promising hard and soft genotypes were identified on the basis of hardness score. Genotypes HI 917, C 306, Flw 3, Int 320, and NP4 were identified as hard, and CIMMYT line 406, Lerma Rojo, Yang Mai, Quang Feng, and Semong 2 were identified as soft genotypes.

Distribution of Indian wheats based on their hardness score based on SKCS test

Hardness score	<35	35-54	55-74	>74	Total
Varieties (bread wheat)	-	3	6	78	87
Germplasm (bread wheat)	2	4	33	1135	1174
Varieties (*durums*)	-	-	1 (YB)	29	30
Total	2	7	40	1242	1291

5.4.1.7 Hectoliter weight analysis

Two hundred fifty genotypes were tested for their hectoliter weight, a test that indicates the grain quality and flour recovery. Twelve genotypes with Hectoliter weight of more than 80 kg/hl were identified. These were MACS 2496, GW 496, HUW 510, HW 2004, HI 1479, Sujata, Raj 3765, AKAW 1071, AKAW 3722, HI 1418 and HI 1454.

5.4.1.8 Grain protein content evaluation

Varieties with protein content below 10 per cent coupled with grain softness are desirable for biscuit making, whereas those with protein content above 12% coupled with hardness are preferred for bread making. About 500 genotypes were screened for protein content using the kjeldahl method. Out of 250 old and new varieties, and genetic stocks, NP numbers were the most promising type. Five NP (NP 12, NP 101, NP 737, NP 761 and NP 875) varieties were found to have protein content over 15% (at moisture 11-12%). Among the 250 landraces and indigenous germplasm, nine were found to have protein content more than 15% along with high thousand-grain weight (42-60 g). Among the 120 exotic germplasm, four had high protein content (≥15%) with high thousand-grain weight (36-40g).

Classification of Indian wheat germplasm for grain protein content

Genotypes screened	High protein (≥15%)	Low protein (≤10%)	Medium protein (11-15%)
500	18	Nil	482

5.4.1.9 Genotypes with high molecular weight glutenin subunits

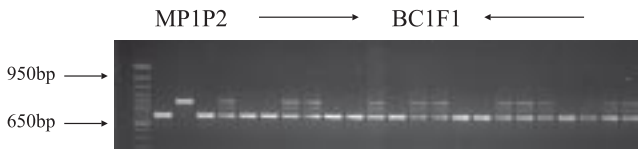
Two hundred bread wheat germplasm, including stocks, varieties and landraces, were screened for HMW alleles/ subunits. Amongst these, four novel variants of the known subunits were identified.

5.4.2 Rice

5.4.2.1 Pyramiding of genes for resistance to bacterial blight and blast diseases in Pusa 6A, PRR 78 and Pusa 1460

Bacterial blight (BB) and blast are the two most important diseases of rice limiting its productivity in northern India. A marker assisted backcross breeding programme for pyramiding the genes *xa 13* and *Xa 21* for resistance to BB and *Pi k*^{h} and *Piz-5* for resistance to rice blast in the parental lines of Pusa RH 10, namely, the female parent Pusa 6A/B and the male parent PRR 78, was initiated. Similarly, Pusa 1460, an improved version of Pusa Basmati 1 carrying *xa 13* and *Xa 21*, was used as recurrent parent for transfer of gene *Pi k*^{h} and *Piz-5* for resistance to blast.

The rice line C101A51 carrying *Piz-5* and Tetep carrying *Pi k*^{h} were used as the donor parents for resistance to blast and Pusa 1460 was used as donor parent for BB resistance genes *xa13* and *Xa 21*. Pusa 6B, PRR78 and Pusa 1460 were used as recurrent parent in the independent backcross breeding programme for BB and Blast. BC_1F_1 population was grown during *kharif* 2006 and subjected to foreground selection with tightly linked marker (RG 136 (CAPS) for *xa13*, pTA 248 for *Xa21,* RM 527 for *Piz-5* and RM 206 for *Pi k*^{h}). The BC_1F_1 plants positive for the genes of interest were backcrossed to produce BC_1F_2 and BC_2F_2 seed.



Gel picture showing the profile of BC_1F_1 plants from the cross Pusa 6 B/Pusa1460//Pusa6B using Xa21 based marker pTA248 amplifying 950 bp and 650 bp fragments in resistant and susceptible parents, respectively. BC_1F_1 plants showing both bands were heterozygous for the marker. M:1 Kb ladder, P1:Pusa 6B, P2:Pusa 1460. lanes 4-24: BC_1F_1 plants

5.4.2.2 Enrichment of rice with provitamin A

Marker assisted backcross breeding was taken up for transfer of provitamin A trait from the transgenic "Golden Rice" lines of Taipei 309 and IR 64 in the genetic background of Swarna, a widely adapted high yielding rice variety popular in the vitamin A deficiency (VAD) afflicted parts of India. In the case of Taipei 309, the NILs were advanced to BC_3F_2 generation and in the case of IR 64, the NILs are in BC_2F_2 generation. The NILs derived from Taipei 309 × Swarna cross showed more than 95% similarity to the recurrent parent with respect to the 48 STMS loci polymorphic between the parents. The IR 64 derived NILs were homozygous for the recurrent parent alleles at more than 70% of 48 STMS loci analyzed. Further, new versions of Golden Rice lines (SGR1 and SGR2) having higher level of carotenoid expression are being used in the backcross breeding.

5.4.3 Maize

5.4.3.1 Phenotypic and molecular analyses of maize landraces

Multi-location evaluation of over 200 maize landraces was undertaken at four locations, namely, (i) IARI, New Delhi; (ii) Maize Winter Nursery, Hyderabad; (iii) VPKAS, Almora; and (iv) HPKV Regional Station, Bajaura. Several promising landraces for diverse agronomically important characters were selected.

'Sikkim Primitives', with a unique prolificacy habit (nearly 6-8 ears per plant) are a valuable genetic resource for mining favourable alleles for the prolificacy-influencing *teosinte branched-1* (*tb1*) gene in maize. Forward and reverse primers were designed for *tb1* and the gene was successfully amplified from diverse maize landraces. Allele sequencing is being undertaken using PCR-amplified products.

Sikkim primitive maize landrace

5.4.3.2 Genetic and molecular analyses of BLSB resistance in maize

Generation of a diallel set using nine inbred lines showing distinct responses against BLSB isolates, and evaluation of these crosses, along with the parental lines, under artificial inoculation conditions against different BLSB isolates at Udaipur, Pantnagar, and New Delhi, highlighted the differential responses of the inbred lines and experimental hybrids to BLSB isolates as well as the polygenic nature of inheritance of resistance to BLSB at different locations. The study also revealed the potential utility of promising inbred lines and experimental crosses in breeding for resistance to BLSB.

Genotypic analysis of a $F_{2:3}$ mapping population using 115 SSR markers, coupled with phenotypic analysis for resistance to Banded Leaf and Sheath Blight (BLSB) caused by *Rhizoctonia solani* f. sp. *sasakii* at three locations in India

(Delhi, Udaipur and Pantnagar) led to the identification of QTLs conferring resistance to BLSB for the first time in India.

5.4.3.3 Generation of a maize RIL mapping population

Two hundred recombinant inbred lines (RILs) in $F_{5:6}$ stage were forwarded to the $F_{7:8}$ stage using single seed descent method. These RILs, derived from a cross between CA00106 (BLSB resistant) and CM140 (BLSB susceptible), will be helpful in QTL analyses and functional genomics.

5.4.4 Pearl Millet

5.4.4.1 Screening of elite inbreds for zinc and iron contents

Fifty-six inbred lines suitable for drought and resistant to downy mildew with diverse genetic origin were selected for quality analysis. These genotypes exhibited the range for iron content between 1.23 to 90 micro gram/g and between 10.4 to 105 micro gram/g for zinc. Seven lines showed Fe content and zinc content more than 90 micro gram/g and 70 micro gram/g, respectively. Five lines showed significantly higher content of both zinc and iron.

5.4.4.2 Analysis of pearl millet grain protein content

Analysis of grain protein content carried out during 2005-06, indicated that out of 244 parental lines/hybrids tested, 38 genotypes had higher protein content, i.e., over 13%. Two hybrids, namely, MS411 A × PPMI 465 and MS 431 A × PPMI 863 showed more than 19% protein content.

5.4.5 Chickpea

5.4.5.1 Heterosis and combining ability

The IARI Centre for Pulses Improvement, Dharwad, studied heterosis and combining ability for biomass (BY) and harvest index (HI) in chickpea (i) to identify the predominant type of gene action governing BY and HI, (ii) to estimate the magnitude of heterosis, (iii) to estimate combining ability effects, and (iv) to assess correlations between *per se* performance and general combining ability (GCA) of parents. The predominant role of additive gene action for BY and HI indicated that these economically important traits could be improved through direct selection. Chickpea genotypes BGD 111 and JG 11 were identified as good general combiners for BY and HI. The large number of crosses showed positive mid-parent heterosis (MPH) and better parent heterosis (BPH) for BY and HI. The majority of heterotic crosses involved poor × good combiners indicating the role of combining-ability diversity in addition to genetic diversity in realising heterosis. Observations on specific heterotic cross combinations suggested that simultaneous improvement of BY and HI is difficult in chickpea under short duration environment (SDE). The higher magnitude of MPH and BPH recorded for BY in the present study indicated that the scope for increasing the HI in chickpea under drought prone rainfed SDE is limited and further increase in chickpea productivity has to come mainly through enhanced BY.

5.4.5.2 Traits to improve biomass and grain yield in chickpea under drought prone rainfed short duration environment

Correlation and path coefficient analysis conducted to identify the traits associated with biomass and grain yield, and formulate an effective selection strategy to improve biomass of chickpea in a drought prone rainfed short duration environment showed that selection for tall types with more number of primary and secondary branches and seeds of large size would be highly rewarding in increasing biomass and grain yield. The phenological traits like days to flowering, flowering duration and days to maturity should also be considered to improve adaptation to such environments characterised by terminal drought and heat stress.

5.4.6 Mungbean

5.4.6.1 Development of mapping populations

For generating mapping populations, the following F_1s were raised: UPM 99-03 × Pusa Baisakhi, PM 4 × K 851, IPM 99-125 × BDYR 2, ML 818 × PS 16 and PS 16 × UPM 99-03. However, disease pressure was low. Leaf tissues were collected from three populations of the cross PM 4 × K 851. Pods from the said cross, and the cross EC 398885 × PDm 139 were collected for developing RIL through single seed descent method.

5.4.7 Pigeonpea

5.4.7.1 Breeding for 'A' 'B' and 'R' lines

Four 'A' lines, viz., Pusa 33A, Pusa 2008 A, GPL100A and GPL 290A, were established by incorporating sterile cytoplasm from GT 288A. Moreover, two 'A' lines are in BC_2 stage, namely, Pusa 9 and Pusa 855. Additionally, during the year, three new released varieties, namely, Pusa 992, Pusa 991 and Pusa 2001 were taken for conversion programme of CMS cytoplasm. In order to develop additional sources of restorer and CMS lines, F_4 progenies derived from the cross *C. scarabaeoides* × Pusa 33 were screened for male sterility which indicated that progenies were having plants with varying degrees of male sterility and fertility. Five progenies had plants with male sterility over 60%, whereas most of the progenies had majority of plants with male sterility ranging from 20% to 60%. Crosses between male sterile and male fertile plants in the F_4 progenies were attempted.

5.4.7.2 Interspecific hybridization studies

Bilateral compatibility was observed in *Cajanus acutifolius* (ICP 15607) x *C. cajan* cv. Pusa 33, whereas unilateral compatibility was observed in *C. scarabaeoides* (ICP 15685, ICP 15692) × *C. cajan* cv. Pusa 33. Compatibility barriers may be post-fertilization as seedling mortality was observed after 41 DAS in reciprocal cross *C. cajan* cv. Pusa 33 × *C. acutifolius* (ICP 15607), pre-fertilization or early stages of embryo development in reciprocal cross *C. cajan* cv. Pusa 33 x *C. scarabaeoides* (ICP 15685, ICP 15692) as seed formation was not observed, and flowers drop after pollination in *C. lineatus* (ICP 15641) × *C. cajan* cv. Pusa 33/cv. Pusa 991/cv. Pusa 855/ cv. UPAS 120. Characterization of interspecific F_1 [*C. acutifolius* (ICP 15607) × *C. cajan* cv. Pusa 33] indicated transfer of earliness gene/s (viz., days to 50% flowering and maturity duration) in F_1. BC_2 (8% success) was possible only when F_1 pollen was used [*C. cajan* cv. Pusa 33 × (ICP 15607 × *C. cajan* cv. Pusa 33) F_1].

5.4.7.3 Biochemical analysis

Biochemical characterization of seed proteins using SDS-PAGE indicated species closest to *C. cajan* to be *C. scarabaeoides* based on similarity index values. The phytogenetic tree formed two major clusters. The first cluster contained all the four varieties of cultivated species, i.e., *C. acutifolius, C. goensis, C. lineatus, C. mollis* and *C. scarabaeoides*. The second cluster consisted of *C. platycarpus* and two accessions of C. *scarabaeoides.*

5.4.8 *Brassicas*

5.4.8.1 Mapping populations for Alternaria blight and white rust

Screening of over 450 germplasm lines including *Brassica juncea, Brassica rapa, Brassica carinata, Brassica napus, Brassica nigra, Brassica oleracea, Sinapis alba,* and *Brassica tournifortii* was undertaken. Except a few lines of *Brassica carinata* and *Sinapis alba*, which had tolerance to *Alternaria* blight, the rest of the lines were found to be susceptible to highly susceptible.

White rust susceptible (A) and resistant (B) populations

For white rust resistance, the populations developed involving the resistance sources BEC 144 and Bio-YSR with Varuna, Bio-902 and Laxmi were back crossed and the DNA was isolated from the F_2, parents and backcrosses for validation of the markers for confirming their resistance to white rust. Phenotyping of these populations is also being done under artificial inoculation conditions.

5.4.8.2 Inheritance studies of white rust

On the basis of parental, F_1s, backcrosses and F_2 populations, the genetic studies for white rust were conducted. The same is being confirmed through genotyping by the use of molecular markers.

5.4.9 Soybean

5.4.9.1 Soybean ideotype for moisture stress areas of central India

An attempt was made to study the moisture stresses in relation to low productivity of soybean pertaining to two meteorological regions of Madhya Pradesh for the development of ideotype; and to suggest alternative ways to deal with the stress situation for enhancing the productivity. The study indicated that the crop undergoes an acute moisture stress in both the regions at the initial stages when the germination or seedling establishment takes place. The crop undergoes moderate to acute stress in the Indore region at the terminal stage when seed development takes place. Contrary to this moisture deficit stress, the crop also experiences excess moisture stress with almost 97% occurrence because of heavy rains during its intermediate stage of development, adversely affecting the vegetative growth as a result of water logging. In view of these observations, an ideotype was suggested.

5.4.9.2 Method for selecting accessions in soybean collection with high diversity

A diversity efficient and computationally convenient procedure for selecting distinct accessions for breeding as well as germplasm core-set formation purpose was developed. Soybean germplasm data comprising 270 accessions, evaluated for seven important quantitative traits, were used for the purpose. Thirty entries scoring the highest inertia values in individual clusters, when selected, resulted in the highest pooled Shannon Diversity Index as well as coefficient of variability for individual characters.

5.4.10 *Drosophila melanogaster*

5.4.10.1 Molecular genetic analysis of *stambhA*

An attempt was made to sequence the 4.7 kb stmA sequence in three alleles (*stmA2, stmAPΔ1, stmAPΔ6*) in order to study the relation between the mutant lesion and its functional relation to behavior. Forward and reverse primers were designed for 4 overlapping fragments (A, B, C, D)

spanning *stmA* and the fragments amplified from the three alleles. Sequencing of the PCR products was carried out commercially. However, the entire PCR product could not be sequenced owing to technical difficulties and, therefore, only a partial sequence of the gene could be obtained from the three alleles. A repetition and confirmation of the sequencing is awaited. Mutations in *stmA* were shown to affect the olfactory response of the flies towards the odorants– benzaldehyde, ethyl acetate, propionic acid, butanol and isoamyl acetate by different magnitudes. Electrical recordings (Electro antennograms; EAGs) taken from the antennal lobes of normal (wild type) and flies homozygous for the three alleles show several fold differences in their ability to respond to the odors.

It was also shown that stmA (a mutation in PLCβ) interacts with a mutation in itpr. Both genes are in the G protein-signaling pathway. The interaction was shown for two parameters-survival and pupation timing. The following table shows that flies that carry homozygous mutations at PLCβ and itpr (column 3) have lower survival when compared to the others which have 2 copies of PLCβ mutations (column2), or 1 copy of an itpr mutation (column 4) or two copies of the itpr mutation (column5). It was also shown that flies with two copies of the PLCβ and itpr mutations are slower in development than those that don't have the mutation.

Survival of flies with varying doses of mutant and wild type copies of PLCβ and itpr

	[stmA2; ug3/Tb]× [stmA2; ka1091/Tb]		[+/+; Ug3/Tb] × [+/+; Ka1091/ Tb]	
	StmA2; ug3 (or ka1091) /Tb	StmA2; ug3/ka 1091	+/+; Ug3 (or ka 1091) /Tb	+/+;Ug3/ ka1091
No. of flies survived	666	216	1091	557
Mean survival value	112.50	75.00	99.30	101.39
SD	7.42	14.83	0.75	1.50

5.5 AGRICULTURAL PHYSICS

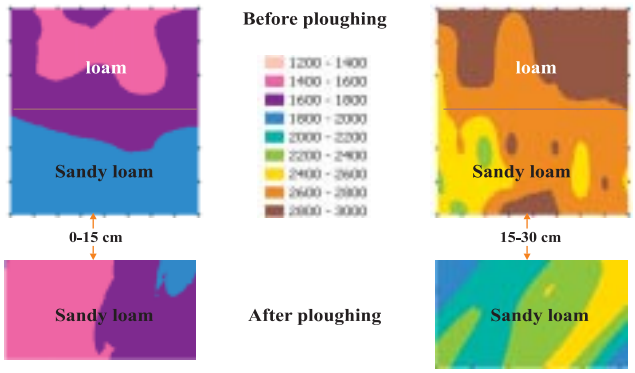
5.5.1 Soil Physics

5.5.1.1 Transport of soil water and nitrogen under different hydrothermal regimes

Field studies were conducted to quantify water and nitrogen transport under different hydrothermal regimes induced by polyethylene and rice husk mulches in sandy loam soil. Fluxes of water, nitrate-N and ammonium-N were simulated using Hydrus-2D model in uncropped but mulched soil profiles. Water flux was reduced and nitrate nitrogen was conserved to maximum extent and for longer period under polyethylene mulch followed by rice husk as compared to unmulched profile. Mulching significantly increased nitrogen uptake by maize through increased availability of nitrogen in soil profile and moderating the soil temperatures in upper soil layer up to 2 ^{0}C in polyethylene mulch and –1 ^{0}C in rice husk treatment. The successful simulation of nitrogen transport under various hydrothermal regimes by Hydrus-2D can be used for increasing nitrogen use efficiency by matching the maximum N availability depth with rooting depth.

5.5.1.2 Geo-statistical analysis of soil bulk density and penetration resistance for delineation of compaction zones

Geo-statistical analysis of two important indicators of compaction, i.e., soil penetration resistance (PR) measured two days after watering, and soil bulk density (BD), were carried out by taking observations at 54 locations at a grid interval of 33.3 m x 50 m, covering a total area of 12 hectares of IARI main farm from surface 0-30 cm soil layer before and after ploughing. ARC GIS 8.3 was used first to conduct exploratory data analysis (ESDA) followed by spatial structure analysis to develop spatial models, which were used for drawing kriged maps. Ordinary kriging was used for interpolation as ESDA showed normal distribution and absence of trend. Before ploughing, major and minor ranges of PR and BD varied between 160-178 m but they were reduced by 30 and 100 m after ploughing, which suggested that ploughing increased short range variation. Low to medium nugget ratios for PR and BD indicated their strong to moderate spatial dependence. The prediction maps of PR and BD indicated the presence of subsurface pan (PR >2000kPa and BD >1.50Mgm^{-3}) in major portion of the studied area. Hence, deep ploughing was recommended for the area where plough pan existed even after ploughing. It was also concluded that PR two days after watering could be assumed as an indicator of soil compaction status.



Kriged maps of penetration resistance (kPa) before and after ploughing

5.5.1.3 Nitrogen response behaviour of soils using GIS and simulation in Shikohpur, Gurgaon

The study demonstrated the use of soil informatics and its linkage with simulation model to evaluate the fertilizer-N response and its application rates in soils of Shikohpur, Gurgaon. Arc View and IDRISI GIS software were used to generate the spatial distribution of pH, EC, organic C, cation exchange capacity and texture. Pedo-transfer functions were developed to quantify the relationships between these parameters. Technical coefficients for water use efficiency and nitrogen uptake behaviour of four important crops were generated. The QUEFTS model was tested with farmers' field data to find out the required fertilizer N for selected soil units in the village.

5.5.1.4 Resource inputs (including water) based production functions for wheat in northern India

The study dealt with growth and yield of wheat with respect to varying agronomic and resource management practices. The reduction in wheat yield due to delay in sowing, limited inputs of water and nitrogen, interaction among various biotic and abiotic stresses have been discussed on the basis of historic dataset or by using simulation models. Agri-production functions to assess the grain yield of wheat under various biotic and abiotic stresses were developed, which subsequently can help in developing simple growth model. Simulated datasets of biomass production and yield indicated that the water production functions based on seasonal evapo-transpiration and transpiration were rather site specific and did not reflect inter-seasonal weather variability. The possibility of using the wheat growth simulator WTGROWS and InfoCrop was explored to understand the cultivar diversity of wheat. Impact of climatic variability (mainly the variations in the winter rains and abrupt changes in the temperatures during critical growth stages) is different in different production environments.

5.5.1.5 Effect of increasing temperature on yield of some winter crops in north-west India

Effect of increase in temperature on grain yield of some winter crops (wheat, mustard, barley and chickpea) in north-west India was evaluated on the basis of historic records and through dynamic crop growth model WTGROWS. The optimal date of sowing was also evaluated in view of the increase in seasonal temperature. The yield of these crops, especially wheat, already showing signs of stagnation in most of the places in north-west India, is most likely to be affected by temperature changes. The solar radiation-temperature interaction study in wheat reveals some interesting trends, which are seen to vary from one location to another. Keeping in view the trends in global climate change, a shift in sowing time, as an adaptation strategy is recommended. The simple and empirical relations between yield and seasonal temperature changes can be used for estimating the yield of these winter crops under temperature rise.

5.5.1.6 Simulating agri-production estimates and land use planning under normal and extreme climatic events: a case study for Shikohpur, Gurgaon

The study aimed at linking the bio-physical and socio-economic database layers with the technical coefficients or simulation models for agri-production estimates and land use planning under normal and extreme climatic events, and exploring the resource and inputs management options in Shikohpur village, Gurgaon. The socio-economic profile of Shikohpur is highly skewed with mostly small and marginal farmers. Though the areas under wheat in Shikohpur are increasing, the productivity seems to be declining or remaining stagnant over the years. Most of the area during *kharif* remains fallow. Pearl millet based cropping systems (pearl millet-mustard and pearl millet-wheat) are predominant. During *rabi,* most of the areas are brought into cultivation, leaving very small area under fallow. Soils are mostly loamy sand to sandy loam with an average of 70%-80% sand content. Organic C content is less than 0.3% because of the high prevailing temperature with little rainfall and also intensive agriculture followed in this region. The annual average seasonal rainfall in Gurgaon did not have much variation over the years. The occurrence of extreme climate events has increased in the last two decades, the crop intensity is low and the water table is declining. Water and nitrogen production functions were generated for important crops in this area which were used in InfoCrop and WTGROWS as inputs for characterizing the crop's response used extreme climatic events.

5.5.2 Remote Sensing

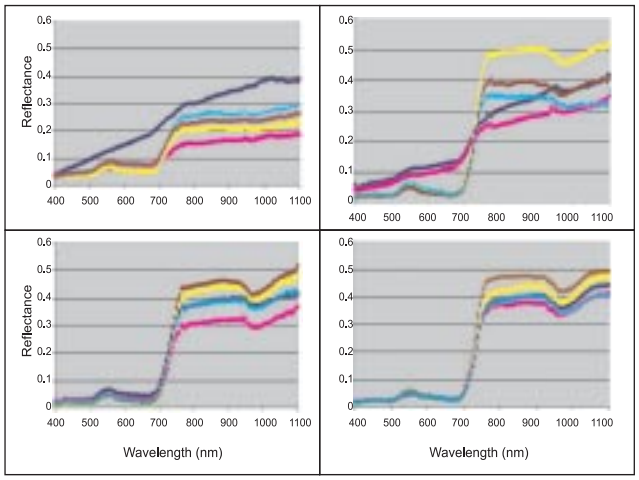
5.5.2.1 Non-destructive retrieval of plant biophysical parameter through inversion of PROSAIL Radiative Transfer Model

Leaf area index and leaf angle distribution, two most important parameters affecting radiation use efficiency of mustard crop, were retrieved from hyperspectral remote sensing data through inversion of radiative transfer model PROSAIL. Inversion of the model was done using a merit function and numerical optimization technique. Same approach would be applied for retrieval of plant biophysical parameters at regional scale from multispectral remote sensing satellite data for a better crop growth monitoring system.

Modified spectroradiometer sensor assembly measuring bidirectional reflectance of mustard crop for further use in retrieval of plant parameters inverting radiative transfer model

5.5.2.2 Remote sensing based growth monitoring of wheat in RCT adopted rice based cropping system in trans-Gangetic plains region

Spectral signatures from 400 nm to 1100 nm at 5 nm interval were recorded in different resource conserving technologies (RCTs) adopted fields in Darad and Rambha villages of Karnal district, using hand held spectro-radiometer (LICOR LI-1800) on four different dates during crop growing season synchronizing with passes of IRS-P6 satellite over the area. Global positioning system (GPS) was used to ensure same locations while taking spectral measurement each time and identify them in satellite image. Different RCTs options in Darad were: (i) zero tillage with full residue and late sown (ZT-FR-LS), (ii) zero tillage with full residue (ZT-FR), (iii) zero tillage with partial burning (ZT-B), (iv) bed planting (BP), and (v) conventional tillage (CT), and those in Rambha were: (i) rotary disc drill with standing stubble (RDD-ST), (ii) happy seeder with residue retention (HS-RR), (iii) zero tillage with partial burning (ZT-B), and (iv) zero tillage (ZT). Differential spectral behaviour of wheat crop in different RCTs was found to be clear in near infra red (NIR) range of electromagnetic spectrum, i.e., NIR band could be used to differentiate wheat crop under different RCTs. Most suitable time period found to discriminate the wheat crop with different RCTs is January, when crop was at peak vegetative growth stage. Wheat with bed planting (BP) and zero tillage with partial burning (ZT- B) in Darad village, and happy seeder with residue retention (HS-RR) and rotary disc drill with standing stubbles (RDD-ST) in Rambha village found to have higher reflectance in NIR and lower in red band resulting in higher NDVI which indicates their better effect on crop growth and vigour.



Spectral pattern of wheat under different RCT options in Darad village, Karnal

5.5.2.3 Spectral and thermal behaviour of wheat under varying levels of fertilizers

A study was conducted to characterize the spectral and thermal behaviour of wheat canopy in long-term fertilizer experiments on Typic Haplustept in maize-wheat-cowpea sequence with 50%, 100%, and 150% NPK; 100% NPK+FYM @ 15 t/ha/yr and control ($N_0P_0K_0$). Temporal variation of vegetation index and normalized difference vegetation index showed similar pattern in all the treatments but their magnitude differed considerably. The highest vegetation index (8.8) was found with 100%NPK+FYM. Significantly higher positive correlations were obtained between vegetation index and dry matter (r=0.92) and grain yield (r=0.82), and negative correlation (r= -0.90) was found between cumulative stress days and grain yield.

5.5.2.4 Characterization of landform for resource potential evaluation – an integrated remote sensing and GIS approach

A new methodology was developed to characterize and classify landforms using remote sensing and GIS tools, which included morphometric landform parameters like profile curvature, plan curvature, compound topographic index, and stream power index, in addition to the conventional generic landform parameters. It followed the hierarchical decision-tree analysis and was tested in Alwar district of Rajasthan with natural management options, which possessed around 12 landforms (with classification accuracy of 83% - kappa coefficient). The classified landform was then linked with soil and water resources and their change in potential with time when pre- and post-monsoon potentials were evaluated using area coverage, rainfall calibrated depth units with time, drainage density, parent material and landform were considered. The land potential map, i.e., combined soil and water potential map, was also generated for different landforms.

5.5.2.5 Remote sensing and GIS based methodology for identification of degraded areas in irrigation commands

For monitoring and simulation of water logging and salinity problems in irrigation command by the use of GIS and remote sensing techniques, research work was undertaken with the objective of developing a GIS and remote sensing based integrated technique for identification of water logging and salinity in irrigation command, evaluation of the developed technique and simulation of the risk prone areas for water logging and salinization in relation to the causative factors within the irrigation command.

For simulation of risk prone waterlogged area, corresponding to the observed available highest hydrologic event, a remote sensing imagery was used to prepare an FCC indicating flooded and non-flooded area. This FCC was used to study the effect of different rainfall amounts on flooded area. It was concluded that as the effective rain fall is added beyond the threshold layer resulting from the actual effective rain fall, the area under water logging increases uniformly. For simulation of risk-prone salt-affected areas, the salt balance approach was used. The results obtained by adopting the developed procedure for a study area of a part of western Yamuna canal command have shown that at drainage coefficient of 1.5 mm/day the area with increasing salinity was drastically reduced. At a drainage coefficient of greater than 2mm/day the rate at which the area with increasing salinity was very low and the normal area remains unaffected with no change in its areal extent. It was also observed that at the 2mm/day drainage coefficient the extent of the area with increasing salinity was negligible. Therefore, if a drainage system is designed for drainage coefficient of more than 2mm/day the additional cost will be incurred for the installation of drainage system and the benefits obtained will not be commensurate with the cost involved. The first part of the methodology is useful for calculation of the submerged area due to rising flood levels in the outlet drains. The second part of the methodology has its applicability for calculation of the flooded area for different magnitudes of rainfall storms. The methodology has its practical application for the design of drainage system for control of soil salinity problem in an irrigation command. This methodology also gives an idea about the location of the area faced with the problem of soil salinity corresponding to different amounts of drainage coefficient. This methodology will also be useful for prioritising the area, which essentially requires effective drainage for control of salinity problem at different levels in an irrigation command.

5.5.3 Agricultural Meteorology

5.5.3.1 Effect of de-branching on the spectral behaviour and micrometeorology of mustard

Debranching was done on *Brassica juncea* vars., Pusa Jaikisan (V1) and BIO169-96 (V2) during *rabi* (2005-2006) 50 days after sowing (early debranching) and 60 days after sowing (late debranching) in separate plots. Sowings of both cultivars were done on two dates, i.e., 15th and 30th October. Initial debranching helped the plants to recover leaf area and biomass due to re-growth and translocation of nutrients to the younger branches resulting in higher leaf area index in case of early debranching compared to that in late debranching and the control. The biomass was significantly higher in the early debranching plots of both the varieties. The early defoliation (50 DAS) increased photosynthetic parameters maximally. Since leaf removal reduces the competition between organs at early stages, the plant can make use of available light, water and nutrients more efficiently. It has been found that crop photosynthesis depends on the distribution of photosynthetically active radiation (PAR) among layers and on the amount absorbed by the canopy. Growth and yield were enhanced by the defoliation treatment, but the increment was not highly significant. Significant relationships among canopy reflectance, percentage defoliation, yield, and LAI were detected using linear regression. Per cent reflectance explained 15% and 12% more of the variation in yield and LAI, respectively, in Pusa Jaikisan compared to 16% and 14% in BIO 169-96.

The temperature at the ground (5 cm) level was lower in the debranched plots in the early hours because the relatively less crop density at the bottom layers facilitated radiation (from the ground) to escape into the atmosphere. But, as the day progressed, the temperatures were higher by about 2 ^{0}C to 3 ^{0}C in the debranched plots as compared to the plots where no debranching was done. A similar trend was observed at other heights (35 cm, 85 cm, and 135 cm above the ground in the crop canopy).

The relative humidity at the ground level in the early hours remained more or less the same (99%) in both the plots. But as the day progressed the relative humidity values were lower in the debranched plots as compared to those in the control plots. Removal of branches facilitated more radiation penetration to the bottom of crop by 6% to 25% after 10 days of debranching at 50 DAS. Radiation penetration reduced with time to a minimum of 2% to 10% in both the cultivars with no appreciable difference between debranching treatments. Percentage of radiation penetration from mid of the crop to bottom was more than that from top to bottom and

it got highly modified due to removal of branches. Air temperature at 5 cm and 35 cm was also lower in morning hour (7.30AM) but was higher during day time (10.00 AM onwards) by the magnitudes of 1 °C to 3 °C initially after debranching which later got diminished. Hence, debranching resulted in widening temperature range in field as compared to that in the control. Relative humidity was found to be lower by 10%-20% in debranched plots at 10.00AM onwards. Because of higher PAR penetration coupled with relatively higher wind speeds, there was more moisture loss from debranched plots (in both the cultivars and dates of sowings). Moisture content (in the 0-90 cm soil column in terms of depth units) in debranched plots was about 0.8-1.7 cm less than that of the control under different treatments.

5.5.3.2 A thumb rule for incidence of white rust

A new hypothesis was made for incidence of white rust disease on the basis of moving totals of hours with ambient air temperature between 10°C to 20 °C, relative humidity greater than 80% and the daily number of bright sunshine hours. Since the maximum and minimum temperatures, hours of continuous high relative humidity and sunshine hours were found to have been significantly correlated with the white rust severity, a model equation employing these weather parameters was developed after trying various combinations.

The thumb rule for incidence of white rust disease emerged from this study with the use of four years' consecutive data, is: "If the sum of hours in consecutive 10 days with temperature ranging from 10°C to 20°C is more than 150, the relative humidity more than 80% and actual bright sunshine hours are less than 10, then, it is quite likely that white rust disease would appear in the mustard crop" or "If there are rainy days during December and January with the total sunshine hours of past ten days less than 40, then white rust disease would appear."

For severity forecasting, the final equation (R^2 = 0.88) developed is

$$Y = 6.796 + 0.910\,Y^*_{(-1)} - 0.368\,Tmax^* + 0.81\,Tmin^* - 0.32\,SShrs^* + 0.47\,RH\,hrs^*.$$

(1.50) (0.072) (0.10) (0.21) (0.15) (0.17)

* : significant. $Y_{(-1)}$: disease severity of last week, Tmax: maximum temperature, Tmin: minimum temperature, SShrs: sunshine hours, and RH hrs: hours of relative humidity >80per cent. Value in parenthesis is standard error of corresponding coefficients in equation.

6. SOCIAL SCIENCES AND TECHNOLOGY TRANSFER

6.1 AGRICULTURAL ECONOMICS

6.1.1 Labour Migration and its Impact on Rural Economy of Indo-Gangetic Plains of India

Labour migration is an important factor affecting the course of socio-economic development in India. Large-scale labour migration obviously has raised a number of concerns in relation to the social and economic policy frame work in India. Concerns have been expressed over the economic, social and political marginalisation of migrant workers, especially unskilled people moving from relatively deprived and depressed areas in search of gainful employment and living. A survey of 800 respondent households, 400 (200 each from Bihar and Uttar Pradesh) from migrated families and 400 (200 each from Bihar and Uttar Pradesh) from non-migrated families, found larger families among resource poor households induced younger family members to migrate to other regions in search of income generating employment. In the migrant households, 44.22% members were illiterate while in the non-migrant households, 38.48% were illiterate.

Occupational pattern of migrant and non-migrant families depicted that non-migrant families mainly engaged themselves in farming and landless agricultural labour activities while migrant families engaged themselves in farming and non-farm wage labour. Here, it is clear that labours are substituting themselves from agricultural labours to non-farm wage labours. It can be assumed that in the study domain, owing to lower agricultural productivity, agricultural wages have not increased in consonance with those of the non-agricultural sector in urban areas or even in agricultural sector of other developed states.

6.1.2 Marketing Information Systems for Horticultural Commodities in India: Status, Constraints and Prospects

The farmers' share in the consumers' rupee in the case of fruits and vegetables varied from 20% to 30% and is said to be still low in the event of monopoly in the trade. In the existing situation, marketing information system in India is not sufficiently tuned to help the clientele. The study showed that market information can help the farmers in raising their returns above 20 per cent. At present, the market information in India is in its infancy. Traders reveal that late availability of market information causes lower price to the extent of 25% to 30%. Lack of market information, and market imperfection are the major causal factors for poor realization of prices from domestic as well as international markets. Stringent sanitary and phyto-sanitary standards (SPS) in developed countries are other deterrents for export promotion under Indian conditions.

6.1.3 Study on Peri-urban Agriculture and its Management in Delhi

To study the status and prospects of peri-urban agriculture, Delhi was targeted during the reporting period. Area, production and yield of wheat and paddy were found more stable than those of coarse grains, i.e., barley and maize, in Delhi. Gram was the most unstable crop among all crops. Vegetables cultivation and floriculture have potential in peri-urban areas of Delhi. Major vegetables grown in and around are cauliflower, cabbage, turnip, *palak*, and other leafy vegetables. Migration is the main factor, which affected land use pattern in favour of urbanization, and cropping pattern too. Easy access to transport and good network of roads, labour and capital, made it easier for farmers to bring their perishable crops in all the four markets (APMC) of Delhi. Total market arrivals of vegetables and fruits were 1359 thousand tonnes and 1633 thousand tonnes, respectively, during 2006. A wide fluctuation in wholesale prices and retail prices had been observed for tomato and onion during the last two years. There was only a small drop in market arrival of tomato in the month of June 2006. For onion, September 2006 registered a fall in market arrivals. Selling their perishable produce in Azadpur market, Delhi, on the basis of information collected from 30 farmers, net returns of farmers from two main crops, i.e., potato and onion, were estimated. These were (Rs. 1.8 to 2.0 lakhs/ha) for potato, and (Rs.40,000 - 53,000/ha) for onion.

Non-availability of seeds and fertilizer in adequate quantity and in time; and non-availability of electricity to run pump sets, which affects irrigation, were reported by 92 per cent of farmers as the main constraints for production of agricultural and horticultural crops.

6.1.4 Impact of Trade Liberalization on Indian Agriculture

Export plays a significant role in promoting economic

development, especially, in developing countries like India. Unfortunately, the share of India in world export of horticultural products is less than 0.3 per cent, which is far less compared to its share of production. It lags behind many countries both in value and quantity terms. In today's global market, quality has become a competitive edge for the enterprises producing quality goods and services. Increasing restrictions and sanitary and phytosanitary (SPS) measures limit the market access which results in significant loss of foreign exchange to India. Nominal protection co-efficients (NPCs) for export units were computed for fresh fruits and vegetables, to investigate India's competitiveness.

Average nominal protection coefficients (NPCs) for fresh fruits and vegetables

Fruits & vegetables	NPC
Fresh mango	0.69
Fresh grapes	0.85
Fresh banana	0.65
Fresh potato	0.86
Fresh onion	0.73
Fresh tomato	0.67

Average NPC for fresh fruits and vegetables varied from 0.65 for fresh banana to 0.86 for fresh potato. This shows that the country is competitive for export of mango, grapes and banana among fruits, and potato, onion and tomato among fresh vegetables.

To become a major exporter of food products in the world, the country would require a sustained policy programme, a genuine patronage from the central and state governments, technological inputs both in terms of process know-how and advanced processing machinery, and interest of large Indian corporate sector as well as the MNCs to venture into this field.

6.1.5 Adoption and Impact of Resource Conserving Technologies on Farm Economy in Indo-Gangetic Plains

A study of resource conserving technologies (RCTs) examined the adoption pattern and its impact on crop productivity, and fertility status of zero tillage and bed planting systems in Bihar, Haryana, Punjab, Rajasthan and Uttar Pradesh (Indo-Gangetic plains). The result showed that nearly 50 per cent RCT adopters in the entire region belonged to small category. It was observed that the farmers of Punjab had the highest average area (20.27 acres) under RCT followed by the farmers of Haryana (9.74 acres), Rajasthan (6.53 acres), Bihar (4.46 acres) and Uttar Pradesh (3.20 acres). It was observed that in the case of adopter category, more than 70 per cent of irrigation was done by tube well and less than 30 per cent by canal (27.35 per cent). In Rajasthan, the main source of irrigation was canal only.

Average area under RCTs in the study area (acres)

RCT	Bihar	Haryana	Punjab	Rajasthan	UP
Zero tillage	3.93	9.35	19.56	0.00	3.20
Bed planting	0.53	0.39	0.71	6.53	0.00
Total	4.46	9.74	20.27	6.53	3.20

Sources of irrigation of RCT adopters and non-adopters in the study area (acres)

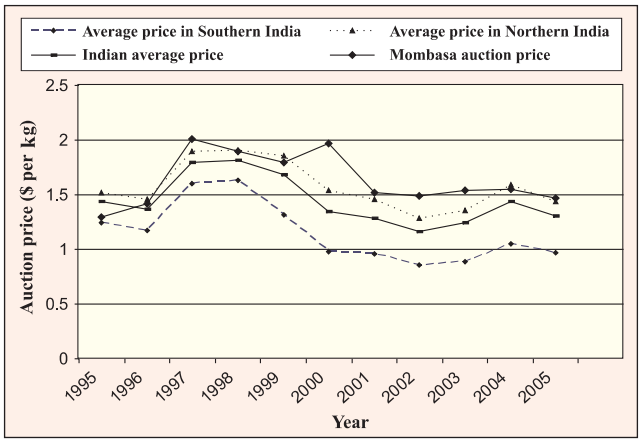
		Bihar	Haryana	Punjab	Rajasthan	UP	Average
Adopter	Total area	4.00	6.71	9.49	7.83	2.82	6.17
	Total irrigated area	3.97	6.69	9.49	7.78	2.76	6.14
	Canal per cent	15.72	5.04	7.89	98.73	9.03	31.45
	Tube well per cent	83.47	94.66	92.11	0.57	80.32	67.23
Non-adopter	Total area	3.66	6.47	6.98	5.24	2.17	4.90
	Total irrigated area	3.66	6.47	6.98	5.24	2.17	4.90
	Canal per cent	15.27	2.13	5.45	100.00	5.94	26.30
	Tube well per cent	84.73	97.87	94.55	0.00	94.06	73.70

It was further observed that the 100 per cent RCT adopters in Punjab and Haryana were using zero tillage technology for the production of wheat, while in Rajasthan the adopters were using bed planting for the cultivation of wheat crop. Overall, the respondent adopters of RCT showed more active involvement in cooperative, irrigation, marketing and self help group as compared to non-adopters of the study area. The average sizes of holdings in adopter and non-adopter categories were 6.17 acres and 4.90 acres, respectively.

6.1.6 Food Safety Measures and India's Horticultural Exports

6.1.6.1 Tea auction prices

India is the largest producer and consumer of tea in the world and accounts for around 27 per cent of world production and 13 per cent of world trade. Export of tea is around 20 per cent of domestic production. In recent years, however, India's long-standing predominance in the world market as the largest producer and exporter of tea has taken a beating. Falling prices of tea both in domestic and international markets added to the woes of the tea firms and farmers. Therefore, a comparative study of tea export price was made and the changing directions of Indian tea exports were analysed using Markov chain analysis. The fall in price of tea was observed both in India and the rest of the world. It was observed that the tea prices recorded in Mombasa (Kenya) in 2005 were the same as those recorded about a decade ago. Tea prices in India and all over the world have not shown an increasing trend.



Trend of tea auction prices recorded in India and Mombasa

Nevertheless immense variability in prices was observed in the past decade. Moreover, the Indian prices have always remained lower than those of Mombasa (Kenya). This phenomenon has effect on the profitability of the industry.

The government had made efforts to arrest the fall in prices by way of setting up a price stabilization fund, creating a separate fund for long term development, modernization of plantation sector, and other interventions. These efforts are showing signs of relief to Indian tea sector. However, in the long run, in order to make Indian tea sector more viable and competitive, emphasis needs to be given on improving the quality of the product, processing and market diversification.

6.1.6.2 Market loyalties of Indian tea

The structural changes in the direction of trade were quantified using Markov Chain analysis.

Transitional probability matrix of Indian tea exports

	Kazakhstan	Russia	UK	Iraq	UAE	USA	Iran	Pakistan	Japan	Others
Kazakhstan	0.431	0	0.021	0	0.411	0	1	0	0	0.048
Russia	0	0.327	0.556	1	0	0	0	0	0	0.040
UK	0	0.673	0	0	0	0	0	0	0	0.151
Iraq	0	0	0.115	0	0	0	0	0	0	0
UAE	0	0	0.307	0	0	0	0	0	0	0
USA	0.286	0	0	0	0.274	0	0	0	0	0
Iran	0.283	0	0	0	0.033	0	0	0	0	0
Pakistan	0	0	0	0	0	0	0	1	0	0.004
Japan	0	0	0	0	0	0	0	0	0	0.056
Others	0	0	0	0	0	1	0	0	1	0.701

The diagonal element of the transitional probability matrix measures the probability of the export share that a country will retain. Pakistan (1.00) and others group (0.70) of countries emerged to be highly stable markets, whereas Kazakhstan (0.43) and Russia (0.33) emerged as moderately stable markets. The other major importing countries, i.e., Iraq, UAE, USA, UK, Iran and Japan proved to be unstable markets for Indian tea. UK reinforces the market shares of Kazakhstan, Russia and UAE. Similarly, other group of countries also reinforces the market share of Kazakhstan and Russia. The markets of USA, UK and Iran became unstable leading to loss of market share. This could be attributed to two reasons: firstly, the production in Kenya, Sri Lanka, China and Vietnam moved to a higher plane from that of the mid-1990s prompting these countries to step up their export promotion on a substantial scale and secondly, the Indian tea exports, faced complacency, created by the steady surge in domestic demand which, unfortunately, started sagging from around 1997. A number of measures were taken by Iran and India to normalize the tea trade. Earlier, Iran had banned the import of Indian tea, because of their huge domestic stocks. The ban has now been lifted. Iran has reduced the tariff barriers to just 82 cents per kg and there is no restriction on the quantity of imports. The blending condition applicable, i.e., for every kg of Indian tea imported, two kg of Iranian tea was supposed to be blended into it, has been lifted now. India, on the other hand, is promoting orthodox tea production in Assam, which is preferred in the Iran market (Kohinoor, 2004). The UK has the highest per capita consumption of tea at 2.7 kg against 660 g in India, the largest consumer in the world. The UK consumption was estimated to grow at one per cent per annum. An equally significant aspect of the UK tea trade is its interest to re-export tea with value-addition. The UK market offers immense scope for the Indian tea industry (Sunder, 2002). To regain the market share in UK, efforts need to be made towards media publicity, product and logo promotion and developing market intelligence. Kenya (43 per cent) is able to meet a larger share of UK market than that of India (19 per cent) because of its concerted promotional efforts. Diversification of tea products, quality upgradation, and aggressive brand and logo campaign can get back the country its place among our traditional markets of Russia and other CIS nations. These efforts would also help in better realization of prices thus improving the competitiveness and profitability of our tea industry. Market diversification away from traditional markets offers great scope to boost Indian tea exports.

6.1.7 Cointegration of Horticultural Markets in India

Maharashtra, the leading onion-producing state, is known

as the onion basket of the country. Lasalgaon, near Nasik, is the biggest onion *mandi* in the whole of Asia. The two harvesting seasons are: March to May, and October to December. But the consumption is spread throughout the year. Inelastic demand and seasonal production of onion result in fluctuation of prices and uncertainty in the income levels of onion growers. The specific issues, studied are: trend in onion arrivals and prices, seasonal movements in onion arrivals and prices, and effect of arrivals on prices. Trend represents the general direction of change in arrivals and prices over a long period of time. Price trend is affected by adjustment in supply arising out of development of cold storage and marketing facilities, production technology and market arrivals over long period. The arrival trend is affected by production and price. The results showed positive trend in arrival and negative increasing trend in wholesale price of onion during 1996-2004 in Mumbai, Pune and Nagpur markets. The pattern of arrivals of onion in these three markets during the reference period showed increased arrivals of about 1480 t and 275 t per year, respectively, in Mumbai and Nagpur markets. However at pune market, the arrival decreased by 1670 t per year. Wholesale prices showed decrease at Mumbai and Pune markets by 0.68% and 0.69%, respectively. Thus, trend values for arrival were found to be increasing and those for prices were found to be decreasing. Seasonality in the arrivals, and prices are those changes, which occur regularly every year as a result of changes in season. High seasonal fluctuation affects the income of the grower adversely. The indices of seasonal price of onion in the markets were the lowest in May followed by those in the month of March. The seasonal price index for onion was below the average in the months of March to June and above the average in the remaining six months of the year. The price of onion starts increasing from the month of July and reaches its peak in the month of November. The main reason for the variation in prices was the pattern of market arrivals and the influence of previous months' price. Farmers may get a good return if they are able to retain and sell their product in the months of July to November. The highest index of arrivals was observed in May when fresh onion starts flowing into the markets in a big way. The arrivals of onion fall below the average in the months of August to December (lean period) as the supply was limited and remained above the average from January to July (fat season). The intra year price rise showed that the price movement for onion registered a considerable upward movement when compared with the lowest season price index. The coefficients of variation for prices and of arrivals conclude that onion arrivals were the main cause of fluctuation in onion prices and onion prices showed more variability than onion arrivals in Mumbai, Pune and Nagpur markets. Keeping such variations in demand in view, the growers can obtain better prices by matching supply to the market requirements during the period of high seasonal price index. Hence, there is a need to create cold storage capacity in areas where onion production and marketable surplus is high. Relationship between market arrivals and prices of onion was inverse, as usually observed in normal agricultural commodities. The current price of onion not only depends on its current arrivals but also on its linkage with the price in the previous months. The current wholesale price has a positive relationship with its price in previous period (one lag period) and a negative relationship with arrivals of onion in Mumbai, Pune and Nagpur wholesale markets. The results of these three markets show that an increase in arrival by one tonne would decrease the current price by Rs. 0.12, Rs. 0.54 and Rs. 0.59 per tonne, respectively, in Mumbai, Pune and Nagpur markets.

6.2 AGRICULTURAL EXTENSION

6.2.1 Farming Systems Research and Extension for Sustainable Development

A detailed survey of 100 farm families from selected village clusters in Delhi and Gurgaon was carried out, besides PRA exercises. The villages depicted different types of farming systems with different structural complexities and interrelationships. It was observed that the farming system in the area is a unique and reasonably suitable arrangement of family enterprises that the households manage according to

Important problems identified for interventions in action research villages

Farming problems	Action interventions
Soil and water degradation and receding ground water table	Irrigation management, crop diversification and conservation practices.
Low productivity of crops and dairy animals	Crop demonstrations, animal health and fertility camps, and training
Problem of fodder and fuel	Fodder based cropping pattern, agro-forestry, and training
Non-availability of quality inputs and their high cost	Quality seed production and distribution, use of bio-fertilizers, vermi-compost and bio-pesticides
Insect pests and diseases in crops	Integrated pest management, crop diversification, and training
Poor technological knowledge including post-harvest management	Demonstrations, training and education, SHG mobilization and information support
Unemployment and under-employment	Entrepreneurial development, SHG mobilization
Social, economic and environmental issues	Awareness camp, training and education, local capacity building, drudgery reduction

the physical, biological, economic and socio-cultural environment in accordance with the households' goals, preferences and resources. It is complex in related matrix of soil, plants, animals, employment, farm power, labour, capital and other inputs managed in part by farm family and influenced by social factors operating at different levels. The major farming systems were irrigated farming systems, rainfed and dry farming systems, mixed farming systems and urbanized farming systems.

The predominant crop components in Delhi villages were: rice, wheat, barley, mustard, vegetables and animal husbandry, whereas in the case of Gurgaon villages, these were: the *bajra*, pigeon pea, wheat, mustard, vegetables and animal husbandry.

PRA exercises were conducted at Rajapur and Naropatti villages of Muzaffarpur district, Bihar to understand the structural complexity of farming systems, and interrelationships in terms of resources. The data were collected from 100 farm families to design a methodology of viable farming systems.

The major problems identified were non-availability of assured irrigation facility at affordable rate, non-availability of agricultural inputs at proper time, lack of market infrastructure and increasing rate of labour migration. Cultivation of traditional low yielding wheat varieties was one of the major factors for poor wheat production. There were positive attitudes of the farm families towards agricultural diversification and entrepreneurship development in agriculture. Women SHGs are also working in the villages.

The crop components in Muzaffarpur (Bihar) were: rice, wheat, moong, tobacco, maize, mustard, vegetables, oat, potato and animal husbandry. Demonstrations on rice and vegetable based cropping systems and seed production were carried out besides training and education camps on improved farm management practices and entrepreneurship development.

Communication behaviour of farmers. In order to develop communication materials for transfer of technology, the communication behaviour of farmers, and the extent of adoption of modern technologies were analysed through Rapid Rural Appraisal along with focus group interviews among the farmers of selected villages. The study revealed that the major sources of farm information for the farmers were television and radio (1st rank), followed by neighbours and friends (2nd rank), input dealers (3rd rank), village level workers (4th rank), agricultural officers (5th rank) and farm magazines and newspapers (6th rank). With regard to farm inputs, the main source of improved seeds was government agencies (50%) followed by private dealers (40%). Fertilizers were purchased mainly through private dealers (80%) and co-operatives (20%). Pesticides were purchased through private dealers (100%). As many as 80% farmers faced problem with the availability of quality seeds of high yielding varieties of crops. None of the farmers reported any problem with the availability of chemical fertilizers or pesticides. However, farmers faced problems with regard to the availability of farmyard manure and information on modern farm practices.

Adoption of improved methods of cultivation. The investigation revealed that all farmers (100%) cultivated improved varieties of wheat. The varieties cultivated were: PBW 343, WH 711, WH 283, WH 147, and Raj 3765. However, the farmers were not aware of the improved varieties of wheat, viz., which can increase their yield: HD 2687, HD 2733, PB 502, HD 2643 and WR 544. The farmers used a higher level of seed rate (an average of 50-60 kg/acre) than the recommended one (40 kg/acre) because of the problem of termites in the field. About 90% of the farmers had sprinkler irrigation system, as they had the problem of undulating land. Since the soil type of the village was found to be sandy, the farmers gave more number of irrigations to the crop (7-8 irrigations) as against the recommended practice (5-6 irrigations). The quality of irrigation water was poor owing to increased salt contents. None of the farmers applied fertilizers, based on soil test. The average basal dose of nitrogen applied per acre was found to be 10-12 kg/acre against the recommended dose of 25 to 30 kg/acre. However, the farmers applied about 20-25 kg nitrogen as top dress as against the recommended dose of 25-30 kg per acre. The amount of phosphorous applied by the farmers was 23 kg/acre as against the recommended dose of 24 kg/acre. The farmers did not apply any potash to the field, which should be based on the results of soil test. One of the major problems faced by the farmers was a higher level of weed infestation in their fields. However, owing to high cost of herbicides and lack of knowledge, only about 20% of the farmers sprayed herbicides (1-2 times) to control weeds. The major pest problem faced was related to termites. However, none of the farmers followed the pre-sowing treatment (with endosulphan) of seeds for termite control. On an average, the farmers received a yield of about 1.5-1.7 t of wheat per acre as against the potential yield of 2.2-2.4 t per acre.

Empowerment of farm men and farm women to enhance their skills. The programme aimed at capacity building and inculcation of entrepreneurial skills among farm men and farm women to take up agripreneurship for sustainable livelihood in rural areas. A survey was conducted with the focus on entrepreneurial skill development. Matrix ranking of potential enterprises was conducted and knowledge test developed and administered. Intervention on enhancing moderate risk taking ability of farmers was also conducted. The farmers

perceived that the growth in agriculture is poor because of the decline in quality of water, that is turning saline, and poor supply of electricity to the village. Ninety per cent farmers were having diversified agriculture, growing flowers and peas along with cereals in the ratio of 1:1:2. Vegetable and fruit cultivations were the most preferred entrepreneurial ventures perceived by the farmers followed by polyhouse nursery raising, mushroom cultivation, beekeeping, poultry, vermin composting and fisheries.

6.2.2 Assessment of Socio-economic and Environmental Impacts of Agricultural Technologies

6.2.2.1 Socio-economic and ecological implications of transgenic agriculture

A survey was conducted in the villages of Abohar, Fazilka, Bhatinda, Bhuchho and Mansa blocks of Punjab. Among the several Bt. cotton varieties recommended, viz., MRC 6301, MRC 6304, RCH 134, RCH 317, Ankur 651 and Ankur 2534, RCH 134 Bt. cotton variety was observed to be most popular among the farmers. High cost of the seed (Rs. 1395/- per 450 g as against Rs. 300-600/- of unapproved Bt. varieties) was the most important limiting factor for adoption of approved varieties of Bt. cotton. Farmers reported reduction in the frequency of sprays to 2-4 in Bt. varieties as against 10-12 sprays in hybrid cottons because of low or no incidence of American bollworm. RCH 134 Bt. cotton fetched Rs 500-600/- extra per tonne as against hybrids and unapproved Bt. varieties. Adoption level of approved Bt. varieties was low in the first year. About 11 per cent of farmers had put about 25 per cent of their cotton acreage under approved Bt. varieties. Farmers preferred unapproved Bt.varieties because of their low cost and capacity for early development of boll. Their yields are also almost on a par with those of approved Bt. varieties. Pattern of adoption raised critical issues about poor bio-safety measures, use of F_2 seeds and over-use of seed rate.

About 37 per cent of farmers reportedly practised refuge lines of non-Bt. variety along the periphery of Bt.variety plot. They lacked knowledge about the importance of refuge lines as a bio-safety measure to check pest resistance and genetic pollution. A study on farmers' perception about Bt. cotton was conducted. The farmers realized that Bt. varieties were eco-friendly, required less pesticide, produced high yield, checked pesticidal pollution and health hazards but at the same time jeopardized farmers' seed autonomy. They were undecided about Bt.varieties' impact on soil and living beings. However, they were strongly averse to the introduction of Bt. technology in food and fodder crops. A majority of the farmers declined to endorse the view that Bt. varieties would be catalytic for agricultural revolution in future, and hence Bt. technology should be applied even in food, fruit and vegetable, and fodder crops.

6.2.3 Enhancing the Efficiency of Extension Organization

The study aimed at assessing the knowledge level of extension managers and their training needs in management skills and practices which will be the basis for developing computer based interactive self-learning modules (SLM) on major functions of development management. Based upon the data collected from 100 extension personnel of *krishi vigyan kendras* (KVKs), the knowledge level and training needs were assessed. Further the organizational climate and job satisfaction level of extension personnel of KVKs were also studied.

Knowledge level of extension managers in different components of management functions. The knowledge level was assessed through a knowledge test developed for the study. The mean level of knowledge on different aspects of management functions was found to be 40.6 per cent. Thus, the overall knowledge gap with regard to management skills and practices works out to be 59.4 per cent. The highest gap was found in the area of training management (67.3%), followed by leadership (65.5%), team building (65.4%), project management (62%), evaluation (53%) and entrepreneurship development (43.2%).

Training needs of extension managers. The training needs of extension managers of *krishi vigyan kendras*, in management competency were assessed based upon their perceived needs on a five point continuum which ranged from 'very much needed' to 'not at all needed', with a score level ranging from 5 to 1. The combined average score received by the different areas of management competency was used to rank areas of training needs. The investigation revealed that the most important areas of training need in management competency were: modern communication technology with a score level of 4.38, leadership (4.16), time management (4.02), creativity (3.94), motivation (3.83), team building (3.81), co-ordination (3.79), stress management (3.78), project management (3.70), planning (3.69), monitoring (3.65), evaluation (3.65), training management (3.63), entrepreneurship development (3.6), personal effectiveness (3.59), and performance appraisal (3.54).

Organizational climate. The existing organizational environment of *krishi vigyan kendras* (KVKs) was assessed on ten dimensions. The organizational dimensions which were perceived to be 'below average level' were 'innovation', 'team work', 'personal development', 'performance', 'recognition' and 'structure'. The dimensions which were perceived to be 'above average level' were: 'decision making', 'supervision',

'managing problems' and 'communication'. The investigation revealed that the extension personnel of KVKs had a higher level of expected or desired climate for all the dimensions. The overall gap between the existing and desired organizational environment dimensions had the highest gap of 39.6 on a 0-100 scale for the dimension, 'innovation' followed by 'performance' (34.20), 'personal development' (33.2), 'recognition' (29.20), 'team work' (24.80), 'structure' (24.20), 'managing problem' (22.00), 'communication' (18.20), 'supervision' (17.20) and 'decision making' (11.60).

Job satisfaction level. The job satisfaction of extension personnel of *krishi vigyan kendras* was measured on an 11-point continuum with a score level ranging from 1 to 11. The study revealed that the overall job satisfaction level was below average with a score level of 5.90. The highest level of job satisfaction was on importance value of work to farmers' welfare (7.38) and the least level was on policy regarding transfer, promotion, etc. (4.23). The study further revealed that the extension personnel had above average level of satisfaction with regard to professional rewards and supervision. However, the satisfaction with working environment, personal growth and management practices was perceived to be below average level.

6.2.4 Development of Participatory Extension Methodology and Intersectoral Micro-plans

6.2.4.1Developing a model of sustainable extension system through rural institution

The project is being undertaken in selected villages at three locations, namely, Bulandshahr District (UP), Alipur block, Delhi, and Sonepat district (Haryana).

Progress of work in Bulandshahar district (UP). Farmers were organized to form a cooperative society with a total of 60 members identified from a cluster of ten villages of Bulandshahr district (UP). The proposed name of the society is Samagra Chhetra Vikas Sahkari Samiti Ltd., Nekpur, Bulandshahr, UP. It was decided that a membership fee would be collected @ Rs. 100/- and a share money @ Rs.1000/ per member. The byelaws of the cooperative society were developed. A total of 2.6 t of wheat seed (PBW 3243-1.0 t, PBW 373-1.0 t and PBW 502-0.6 t) was procured from the Integrated Agriculture and Marketing Cooperative Society Ltd., Palla, and given to the members of the newly formed society. In addition, the Division of Seed Science and Technology of IARI identified this village as a seed producing village during *rabi* 2006 and provided 1.6 t of breeder seed of wheat: HD 2687 (0.1 t), HD 2329 (0.1 t), HD 2851(0.3 t), HD 2824(0.3 t), HD 2643 (0.4 t), HD 2733 (0.3 t), WR 544 (0.1 t).

A meeting was organised in Nekpur village, Bulandshahr (UP) in which more than 400 farm men and farm women from the cluster of identified ten villages participated. The farmers reported about the non-availability of inputs; problems in marketing their produce; and low selling price for their products. A guideline was developed for organizing the farmers. The steps of society formation were discussed in detail with the identified executive members to initiate and carry forward the process. The common factors for which farmers may come together were identified. In order to address the immediate felt needs of farmers and to keep their interest in the participation process, 5 kg seed of bottle gourd (Pusa Naveen) and 33 kg seed of *bhindi* (A-4) were provided for the demonstration of these varieties to the members in the identified project villages.

Progress of work in Alipur block, Delhi. A cluster of ten villages was identified for the project work in Alipur block of Delhi. The Institute scientists coordinated with various relevant agencies for the formation of a cooperative society and issue of Kisan Credit Cards to farmers.

Progress of work in Sonepat district, Haryana. A cluster of ten villages was identified in Sonepat district of Haryana. A meeting with farmers was held in Atterna village of Sonepat, Haryana on April 29, 2006 to discuss their agricultural problems and to find solutions. The meeting was held in the village *chaupal* where about 50 farmers were present. The farmers faced a number of problems in this village such as non-availability of quality seeds and fertilisers in time at reasonable rates; difficulty in the marketing of their farm produce, particularly, baby corn; non-availability of electricity; etc. The project team motivated the farmers to organize themselves through formation of a cooperative society to solve their problems on a sustainable basis.

6.2.5 Impact Analysis of Training Programmes Conducted under CAS in Agricultural Extension

The post evaluation of training programmes conducted under CAS in Agricultural Extension revealed that the participants considered the CAS programmes as excellent (43.8%) and good (38.2%). Data on content exposure before training for 'Capacity Building' showed that only 36% participants had exposure to the content before the training, whereas it was 61.9% for the training on Extension Management. Twenty-six per cent participants reported that the extent of capacity building on the organization as a result of training would be very high and 39.9% responded moderate impact. In the case of extension management training, the extent of extension augmentation for agricultural and rural development was considered as very high by 47.5% participants and moderate by 33.3% participants.

Data on usefulness of training on professional development revealed that for the training on 'Extension Management for Agricultural and Rural Development, 'the usefulness was 72.7% for research and 100% for teaching, whereas, in the case of training programme on 'Capacity Building for Organizational Development' it was 80% for extension and 60% for research. Suggestions for better training include: improvement in planning, timings of sessions, boarding and lodging, field visit and providing the manual for training before the training.

6.2.6 Evaluation Capacity Building in Rural Resource Management: A Pilot Action Research on Programme Evaluation

The main objective of the project is to build programme evaluation capacity among rural resource management programme staff in India through development of a cadre of evaluators who will be willing and able to conduct evaluation of educational and/or developmental programmes through 'train the trainer' approach. Specifically the project aimed at undertaking workshops on evaluation to enhance the participant's knowledge and skills in determining the impacts/ outcomes of educational programmes.

The study revealed that the extent of change due to workshops on evaluation was perceived to be very high for all the areas of evaluation. The average overall change score obtained by the participants was 4.12 out of the maximum obtainable score of 5. The greatest changes occurred in the area of "planning of evaluation" (score 4.6) followed by "preparing and presenting evaluation report" (score 4.22), "approaches to evaluation data collection" (score 4.1), "construction of questionnaire" (4.05 score) "understanding evaluation concept" (4.01 score), "statistical analysis of data" (3.96 score), and "drawing sample for evaluation" (3.9 score).

The study showed that all the participants had acquired several new skills due to evaluation workshop. The participants perceived that new skills were acquired in the following areas in the order of importance: "use of SPPS package in analysis of data", "planning evaluation", "focus group method", "different models and approaches of evaluation", "report preparation", "analysis of data", "understanding evaluation concepts", "presentation skills", "data collection methods", "questionnaire preparation", "sampling technique", "study of impact", "ethics in evaluation research", "planning the field work", "drawing conclusion and implication", "preparation of project plan and budget", "writing research papers", and "computer operation skills".

6.2.7 Reaching Un-reached Areas and Checking Rural Migration from Tribal Areas

Tribal-dominated Jhabua district. Front line demonstrations (FLDs) in the tribals dominated Jhabua district of Madhya Pradesh are being conducted for the past three years in order to ensure food and feed security to the tribal farmers, and to check rural migration to cities. During 2005-06, 66 FLDs of 12 newly evolved IARI-wheat varieties (including five *durum*s) were conducted in 12 villages covering an area of 25 hectares. On an average, 45% increase in wheat yield was recorded in these demonstration plots over those of 'check' varieties. Overall, the average return per rupee invested was Rs. 3.5 for test varieties and Rs. 2.9 for check varieties. These efforts have resulted in building up confidence among the farmers of the region and in checking their migration to a considerable extent. Impact analysis showed that in some of the villages, new wheat varieties had covered almost 75% of the cultivated wheat areas.

Eastern M.P. Despite abundant agricultural resources, improved wheat varieties and cultivation technology are yet to reach the eastern part of M.P., where >90% area is planted by outdated wheat variety 'Sujata' mostly under late to very late conditions (Mid Nov. – Mid Dec.) with an average yield of 1.5 t/ha, which is only about 50% of the yield of the timely planted improved wheat cultivars, viz., HW 2004, HI 1500 and HI 1531 which give 3.0 - 4.0 t/ha under just one supportive irrigation. Thus, the Institute has planted in 55 frontline demonstrations of 9 improved wheat varieties covering 28 hectares area during the current (2006-2007) crop season.

Marginal farmers of Dewas district. In all, 21 demonstrations of 12 varieties were conducted in 11.5 hectares area in 11 villages targeting marginal farmers in Dewas district, under varying irrigation availability. The average increase in yield was 64% over those of the checks. The overall average return per rupee invested was Rs. 3.7 for the test varieties and Rs. 2.2 for the check varieties.

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 agro-eco region–Jhunjhunu and Churu districts, Rajasthan (*rabi* 2005-2006)

Management of Orobanchae weed in mustard crop. A modified sowing method, which included pre-sowing irrigation - ploughing - Pata - drying of upper 3 inch layer of

the field followed by mustard sowing at 5-6 inch depth, could reduce germination of Orobanchae weed by 30%. Cluster bean, onion, and sesame crops during the preceding *kharif* season reduced Orobanchae weed infestation in mustard crop by about 10-15%.

Integrated insect pest management in gram crop. Integrated pest management, which included putting 2 to 3 pheromone traps per acre before or at the time of flower initiation, light traps during night, spray of nuclear polyhedrosis virus (NPV) at appropriate time along with spray of monocrotophos @ 400 ml in 200 l of water per acre at the time of pod formation and pod filling stages, was found very effective for controlling the pest damage in gram crop with almost double the yield of gram crop.

Evaluating suitable crop rotations. *Guar* (cluster bean) - wheat or mustard, *lobia* - wheat or mustard, moong - mustard or wheat, *bajra* - gram and sorghum - gram proved to be suitable crop rotations for semi-arid agro-eco region.

Assessment and promotion of improved crop varieties (rabi 2005-2006). In field trials on 11 mustard varieties, Pusa Bold gave the highest yield of 1.72 t/ha giving an increase of about 23% over those of local check varieties. In gram demonstrations, BG 372 gave the highest yield of 1.48 t/ha giving about 30% increase in yield over that of the local check varieties. Among barley demonstrations, the variety RD 2552 gave the highest yield of 5.4 t/ha giving about 17% increase in the yield over that of local check variety. In wheat demonstrations, variety PBW 502 outperformed all other varieties giving an average yield of 3.84 t/ha with 20% increase in yield. Pea Azad 1, Tomato PH 2, Brinjal Pusa Uttam, Cabbage Pusa Hybrid and Cauliflower PSB 1 were introduced as new crops to the area.

Assessment and promotion of improved crop varieties (kharif 2006). *Bhindi* variety A-4, cotton variety AA/H-1, moong variety Pusa Vishal, *Bajra* variety P 383, cluster bean HG 365, brinjal Pusa Uttam, bottle gourd Pusa Naveen and sponge gourd Pusa Sneh gave average per hectare yields of 7.5 tonnes, 1.24 tonnes, 0.55 tonnes, 2.0 tonnes, 1.50 tonnes, 11.00 tonnes, 11.5 tonnes, and 8.7 tonnes, respectively, with corresponding increase in per cent yields of 10.3, 14.8, 10.0, 42.8, 7.1, 4.76, 15.0, 2.35, respectively, as compared to those of control varieties. Maize PEMH 2, amaranthus P. Red and P. Kiran and *arhar* P 991 were introduced as new crops/varieties to the area.

Assessment and promotion of improved crop varieties (*kharif* 2006)

Crop	Variety	No. of dem.	Area (ha)	Av. yield (t/ha)	Local yield (t/ha)	Increase in yield (%)
Bhindi	A-4	37	2.26	7.50	6.80	10.30
Cluster bean	HG 365	32	12.22	1.50	1.40	7.10
Cotton	AA/H 1	4	2.40	1.24	1.08	14.80
	H 117	3	0.96	1.10	1.08	1.85
Moong	P. Vishal	7	0.72	0.55	0.50	10.00
Lobia (cowpea)	C 152	41	1.20	0.52	0.50	2.00
Bajra	P 769	3	1.20	1.52	1.40	8.57
	P 751	4	1.60	1.48		5.71
	P 768	4	1.60	1.40		-
	P 383	1	0.40	2.00		42.80
Brinjal	P. Uttam	3	0.70	11.00	10.50	4.76
Bottle gourd	P. Naveen	24	4.15	11.50	10.00	15.00
Sponge gourd	P. Sneh	3	0.30	8.70	8.50	2.35
Moong	P. Vishal	44	23.50	0.50	0.50	-

6.3.1.2 Sustainable rice-wheat based production system in irrigated areas (Patiala District, Punjab; and G. Budh Nagar and Bulandshahr Districts, UP)

Seed production. At Patiala in 19 seed production plots of one acre each of improved wheat varieties, HD 2851 (4 plots), WR 544 (6 plots), HD 2864 (3 plots) and HD 2643 (6 plots) in farmers' fields yielded 5.8 tonnes, 8.7 tonnes, 4.3 tonnes and 8.7 tonnes, respectively, of quality wheat seed for promotion of these varieties in Punjab during *rabi* 2005 - 06. At KVK Lakhaoti (Bulandshahr), UP, 12 seed production plots of wheat (11 of HD 2733 and one of HD 2643), yielded 20.24 tonnes and 1.8 tonnes of quality seed, respectively.

During *kharif* 2006, 15 paddy seed production plots of one acre each (10 of Pusa 44 and 5 of P 1121) were put under seed production, which yielded 7.5 tonnes and 2.2 tonnes of paddy quality seed, respectively. Seed production of *jowar* (PC 9) was also taken up at KVK, Lakhaoti, and 0.8 tonne of seed was produced.

Introduction of improved varieties. The main emphasis in Gautam Budh Nagar district of UP was on introduction and promotion of improved varieties of *rabi* & *kharif* crops. During *rabi* 2005-06, a total number of 26 demonstrations (24 of HD 2733 and 2 of HD 2643) were laid which resulted in average yields of 4.7 tonnes and 4.0 tonnes per hectare, respectively. Five demonstrations of *methi* (Pusa Early Bunching), three of caulifilower (Pusa Snow Ball K-1) and four of onion (Agri Found Light Red) gave average yields of 7.75 tonnes, 2.4 tonnes and 19.1 tonnes per hectare, respectively. In addition, three demonstrations, one each of *methi* (P. Early Bunching), cauliflower (P. Snowball K-1) and onion (ALR) were conducted in farmers' fields at Rakhra (Patiala) as new crop introduction giving average per hectare yields of 7.5 tonnes, 25.0 tonnes and 20.0 tonnes, respectively.

During *kharif* 2006, a total of 51 demonstrations on paddy (27 of P 2511, 23 of P 1121 and 1 of PRH 10 number) yielded on an average 5.15 tonnes, 4.55 tonnes and 6.00 tonnes per hectare, respectively. Sixteen demonstrations conducted on *arhar* (Pusa 992) resulted in an average yield of 1.53 t/ha. The average yields of four demonstrations of bottle gourd (Pusa Naveen) and six demonstrations of *bhindi* (Pusa A-4) were to the tune of 16.5 tonnes and 15.2 tonnes per hectare, respectively.

6.3.2 Joint Bio-fertilizer Extension Programme (IARI-NFL)

During *rabi* 2006-2007, a total of 60 demonstraions on use of bio-fertilisers in mustard (18), wheat (24), pea (12) and gram (6) were laid in Gurgaon district of Haryana, Jhunjhunu district of Rajasthan and National Capital Region of Delhi.

6.3.3 Front Line Demonstrations

During *rabi* 2005-2006, forty-six front line demonstrations (FLDs)on wheat were laid on the latest variety (22), application of bio-fertilizers (16) and zero tillage (8) in Gurgaon district of Haryana. The wheat variety HD 2687 gave 8.62 per cent more yield than control with a benefit : cost (B:C) ratio of 2.02. Use of *Azatobacter* and PSB in wheat crop gave 6.53% more yield that that of the control with a B:C ratio of 2.08. Zero tillage for sowing of wheat crop also gave 4.16% higher yield with a B:C ratio of 2.38.

Frontline demonstrations: *rabi* 2005-2006

Name of the demonstration	No. of dem.	Average yield (t/ha)	Per cent increase in av. yield of variety	Total cost (Rs./ha)	Net return over operational cost (Rs./ha)	B:C ratio
Latest variety	**22**					
Control (PBW 343, WH 711, HD 2285)		4.29	-	21233	19215	1.90
HD 2687		4.66	8.62	21520	22158	2.02
Application of biofertilizer	**16**					
Control		4.52	-	21430	19963	1.93
Use of *Azatobacter* & PSB		4.81	6.42	21558	23297	2.08
Zero tillage	**8**					
Control		4.56	-	21015	20708	1.98
Use of zero tillage		4.75	4.16	18298	24350	2.38

The IARI Regional Station, Pusa conducted twenty-four front line demonstrations (FLDs) of wheat in Samastipur, Muzaffarpur, Vaishali, Madhubani, Nalanda and Shivhar districts of Bihar. The FLDs were made on zero tillage (8), use of bio-fertilizers (6) and use of newly released varieties (10).

The regional station at Wellington successfully conducted a 22 ha FLD during 2006-2007 to popularize newly released wheat varieties CoW(W)1 and HD 2833 in non traditional areas. It also conducted two state-level training courses for the personnel of the state departments of agriculture of Karnataka and Tamil Nadu.

Front line demonstrations on wheat and barley were conducted in 10 villages in Shimla, Bilaspur, Kullu and Mandi districts of Himachal Pradesh by the Institute's regional station at Amartara Cottage (Shimla). Performance of the new wheat variety, Shivalik, was very good under late sown conditions with a mean yield of 3.0 t/ha, and 15% to 35% increase over local checks. Barley variety, BHS352 has shown average yield of 2.1 t/ha with an increase of 16% over local checks.

To evaluate the on-farm profitability of the soil test-based fertilizer recommendations, a frontline demonstration was conducted during *rabi* 2005-2006 in a farmer's field in Chhawala village of the National Capital Territory of Delhi. The grain yield obtained in soil test-based fertilizer recommendations was 4.76 t/ha with a net profit of Rs. 19132/ ha as against the grain yield of 4.32 t/ha with a net profit of Rs. 16180/ha in general recommended dose and 3.41 t/ha with a net profit of Rs. 10779/ha in farmer's practice. The benefit cost ratio (rupees/rupee spent on fertilizers) obtained was 6.4, 5.6 and 5.7 in soil test based recommendations, general recommended dose and farmer's practice, respectively. This shows that higher yield and profit can be obtained by adjusting the fertilizer dose according to the nutrient requirement of the crop as per targeted yield and soil fertility status of the field.

6.3.4 Transfer of Technologies (TOT) Programme

During *rabi* 2005-2006, demonstrations were carried out on mustard, timely and late sown wheat, gram, vegetable pea, fodder *berseem* and oat in villages of Jhajjar, Sonepat, Gurgaon, Mahendergarh and Faridabad districts of Haryana, National Capital Terrtory of Delhi, and Ghaziabad, Bagpat and Bulandshahr districts of UP. In mustard demonstrations, Pusa Jagannath outperformed and gave 30.71% higher yield than that of the control plot with B:C ratio of 2.42 followed by Pusa Bold with 28.57% increase in yield and 2.40 B:C ratio. In the case of timely sown wheat, HD 2733 outperformed all other varieties with an average yield of 5.21 t/ha followed by PBW 502 with 4.92 t/ha as against 3.80 t/ha of the control plot. Among late sown wheat varieties, PBW 373 yielded 4.44 tonnes with 26.85% increase over that of the local variety. In gram, variety BG 362 gave an increase of 0.92 t/ha over that of the local check. Increase in yield of vegetable pea (Azad P-1), *Berseem* fodder (Maskavi) and oat (Kent) was to the tune of 5.71%, 8.75% and 19.78%, respectively, over that of the control varieties.

H.E. Michael Johanns, Secretary, US Dapartment of Agriculture during a visit to Badshahpur (Faridabad district, Haryana), an adopted village under the outreach extension programme (OEP) of IARI (centre) with Dr. S.A. Patil, Director, IARI (right) and a progressive farmer

Under TOT programme during *kharif* 2006, in Mahendragarh, Jhajjar, Rohtak, Sonepat, and Faridabad districts of Haryana and Ghaziabad, Bulandshahr and Baghpat districts of UP, and National Capital Territory of Delhi, a total of 362 demonstrations were conducted on improved varieties of paddy, *bajra, jowar*, bottle gourd, *arhar, guar*, *moong, bhindi*, brinjal, sponge gourd and *urd*. All the demonstration plots of improved varieties of different crops gave higher average yields as compared to those of their respective local check varieties. Among paddy varieties, PRH 10 gave the highest yield followed by Pusa Sugandh 5, PB 1 and Pusa Sugandh 4. Though there was a negative trend in the yield of variety HBC 19, it enjoyed high market price.

The average yield of *jowar* variety PC 9 was 29.51 t/ha, which was 5% more than that of the local check. Pusa Naveen variety of bottle gourd and P 992 variety of *arhar* produced 30% and 65 % more than the produce of the local variety. The average yields of *bhindi* (Pusa A- 4), brinjal (Pusa Uttam) and sponge gourd (Pusa Sneha) were 12.92 tonnes, 15.39 tonnes and 8.92 tonnes per hectare, respectively. T 9 and Azad 2 variety of *urd* yielded 55% and 54% more than the yield of the local check variety, i.e., 0.56 t/ha.

TOT programme: *rabi* 2005 - 2006

Crop	Variety	Average yield (t/ha)	Per cent increase in av. yield over that of local check	Total return (Rs./ha)	B:C ratio
Mustard	Local	1.40	–	25010	2.15
	JD 6	1.48	5.71	26296	2.16
	Pusa Bold	1.80	28.57	31819	2.40
	Pusa Jaikisan	1.59	13.57	28217	2.12
	Pusa Jagannath	1.83	30.71	32299	2.42
Wheat (timely sown)	Local	3.80	–	36000	1.81
	HD 2733	5.21	37.10	47810	2.32
	PBW 343	4.57	20.26	42268	2.10
	WH 711	4.28	12.63	39630	1.99
	PBW 502	4.93	29.73	45695	2.26
	HD 2824	5.13	35.00	47188	2.24
Wheat (late sown)	Local	3.50	–	32500	1.72
	Raj 3765	4.38	25.14	40623	2.02
	PBW 373	4.44	26.85	40823	2.00
	WR 544	4.25	21.43	39375	2.05
Gram	Local	0.75	–	12000	1.19
	BG 372	0.84	12.00	13360	1.16
	BG 362	0.92	22.67	14720	1.30
Vegetable pea	Local	7.00	–	35000	1.80
	Azad Pea 1	7.40	5.71	36990	1.81
Fodder *berseem*	Local Maskavi	75.00 81.57	– 8.75	37500 40783	1.43 1.45
Oat	Local	25.00	–	12500	1.14
	Kent	29.94	19.78	14972	1.21

TOT programme: *kharif* 2006

Crop	Variety	No. of demons-trations	Area (ha)	Av. yield (t/ha)	Per cent increase in av. yield over that of local check
Paddy	Local	—	—	3.44	—
	PS 4	102	37.30	4.35	26
	PS 5	58	24.58	5.17	50
	PRH 10	16	4.20	6.14	78
	HBC 19	2	0.80	2.52	-27
	IET 1401	5	2.00	3.91	14
	PB 1	23	9.20	4.59	33
	Total	2.6	78.08	—	—
Bajra	Local	—	—	2.00	—
	HHB 67	7	4.80	2.54	27
Jowar	Local	—	—	28.21	—
	PC 9	14	4.50	29.51	5
Bottle gourd	Local	—	—	18.70	—
	Pusa Naveen	22	8.16	24.30	30
Arhar	Local	—	—	1.20	—
	P 992	29	11.52	1.98	65
Guar	Local	—	—	1.30	—
	HG 365	5	2.00	1.59	22
Moong	Local	—	—	0.45	—
	P. Vishal	2	0.20	0.68	51
Bhindi	Local	—	—	10.17	—
	Pusa A-4	27	9.24	12.92	27
Brinjal	Local	—	—	12.00	—
	Pusa Uttam	7	1.00	15.39	28
Sponge gourd	Local	—	—	8.00	—
	Pusa Sneha	4	0.20	8.92	12
Urd	Local	—	—	0.56	—
	T 9	19	7.24	0.87	55
	Azad 2	20	6.94	0.86	54
Total	—	362	133.88	—	—

On-farm trials/demonstrations in North Bihar on high yielding wheat varieties were conducted to reduce the technological and yield gap in the farmers' fields in rice-wheat cropping system. *Kisan Divas* and *Arhar Divas* were organized at the station as well as neighbouring villages in Muzaffarpur District to initiate interventions for utilization of modern agricultural production technology.

The Regional Station, Katrain conducted nine field demonstrations on capsicum, 12 each on brinjal, tomato and squash and one on radish at farmers' fields of 17 villages during *kharif*, 2006. Similarly, during *rabi*, 2006, five demonstrations on onion and two on cauliflower were conducted in two villages.

6.3.5 *Pusa Krishi Vigyan Mela*-2006

The three-day *Pusa Krishi Vigyan Mela* (February 23-25, 2006), on the theme "IARI's March Towards Second Green Revolution" was inaugurated by Shri Kanti Lal Bhuria, Hon'ble Minister of State for Agriculture, Government of India. Dr. Mangala Rai, Secretary, DARE and Director-General,

The farmers and other visitors arriving at the *Pusa Krishi Vigyan Mela* held from February 23 to 25, 2006

Indian Council of Agricultural Research presided over the function and Dr. A.K. Singh, Director, IARI gave the welcome address.

Farm literature brought out by the Institute on this occasion was released for the use of farmers. The best performing four farmers in IARI-AIR : Rice and Cotton *Pathshala* 2005-2006 were given away the prizes. Dr. B.S. Hansra, Joint Director (Extension) proposed the vote of thanks.

The *mela* provided a unique opportunity, particularly, to the farmers to have a glimpse of the latest agricultural technologies by visiting live demonstrations on major *rabi* crops like wheat, mustard, chickpea, lentil, pea, vegetable, flowers and horticultural crops, etc. The other major attractions of the *mela* were: direct scientists-farmers' interaction in *kisan goshthi*, agri-based educational workshop for farmers, operational farm machinery demonstrations, video film show on the latest agricultural technologies, farm women empowerment workshop and experience sharing on the latest agricultural technologies by experienced progressive farmers for enhancing production, income and employment on their farms, etc.

More than 26,000 persons (farm men, farm women, students, extension workers and officials from all over the country covering 11 states and union territories visited the *mela*. One hundred one organizations including research institutions, public/pvt. sector companies, NGOs, etc. participated to display and demonstrate their exhibits.

6.3.6 Off-campus Exhibitions/Field Days

The CATAT and ATIC staff participated in the following off-campus exhibitions for display of IARI technologies, products, services and publications.

Off-campus exhibitions

Name of event	Place of exhibition	Period
93rd Indian Science Congress Hyderabad	Acharya N.G. Ranga University, Rajender Nagar,	3-7 January, 2006
Transfer of Hi-tech Horticultre Production Technology	IIT, Rurki, Haridwar	19-20 Janaury, 2006
Krishi Expo 2006 - Mission for Increasing Productivity of Agriculture	Pragati Maidan	8-12 March, 2006
Krishi Mela	KVK, Shikohpur	14 February, 2006
Field Day on Paddy cum *Kisan Goshthi* and Exhibition	Village Asanda, Jhajhar (Haryana)	15 September, 2006
Krishi Kumbh	GBPUAT, Pantnagar	11-14 October, 2006
Kisan Mela and *Pashu Vigyan Pradarshani*	IVRI, Izzatnagar	28-30 October, 2006

Field days

Name of event	Place of exhibition	Period
Paddy Field Day	Baghpat and Ghaziabad Districts	17 August, 2006
Paddy Field Day	Faridabad (Haryana) and Gautam Budh Nagar (UP),	27 September, 2006
World Food Day	IARI	16 October, 2006
Kisan Samman Diwas	Department of Agriculture, Ghaziabad (UP) Hapur, Ghaziabad	23 December, 2006
Animal Health Camp	Village Sandhal Khurd, Sonepat district	9 November, 2006
Field Day on Paddy cum *Kisan Goshthi*	Village Kannoja, Ghaziabad (UP)	3 October, 2006

6.3.7 Agricultural Technology Information Centre (ATIC) - A Single Window Delivery System

The ATIC working as a 'Single Window Delivery System' is effectively providing products, services, technologies and information to different stakeholders. Besides farm advisory services at ATIC, farmers are given farm advice through Pusa Helpline (011-25841670), exhibitions, farm literature and letters. A level of Kisan Call Centre (1551) is also working at ATIC for the remedial measures of the problems/queries of farmers of Delhi and Haryana states. Live demonstrations of *dhaincha* for green manuring in *kharif* 2006 and Pusa Jai Kisan, Pusa Karishma, JD 6 and Pusa Bold of mustard, L 4147 of lentil, and HD 2894, HD 2643 and HD 2824 of wheat in *rabi* 2006-2007 were demonstrated in crop cafeteria for information and knowledge of the visitors. A nutritional garden was developed in crop cafetaria, and summer and winter vegetables were grown for demonstration for visiting farmers/students/ entrepreneurs. High density fruit tree orchards planted with lemon (Kagzi Kalan), guava (Allahabadi Safeda and Lucknow 49), and *ber* (Banarasi Karaka), and a new plantation of *aonla* and one herbal garden, were developed for catering to the growing information needs of farmers in fruit and medicinal plants. Information and advisory needs of the visitors were also met through information museum, plant clinic, farm library, and exhibits related to agriculture implements, seed samples, and bio-fertilizers are displayed in the Centre.

A Price Ticker Board by NCDEX, Bombay installed in ATIC displays current and future rates of agricultural commodities in major agricultural markets/*mandies* of the country. It helps the visiting farmers and agricultural entrepreneurs in decision making for sale of their farm produce.

About 12310 farmers/entrepreneurs, development department officials, students, NGO representatives, etc. from 23 states and one union territory of India visited ATIC during the year under report for farm advisory, diagnostic services, purchase of technological inputs/products and trainings. Purpose-wise, maximum number of farmers visited ATIC for purchase/enquiring about seeds/varieties (4260), followed by horticultural and medicinal plants related information (4220), plant protection (4160), agro-based enterprises (1565), farm literature (2635), dairy (430) and agricultural implements (205). State-wise, out of total farmers visited ATIC, UP (26%) ranked first followed by Haryana (23%), Delhi (19%) and Rajasthan (10%). One thousand one hundred twenty farmers/ entrepreneurs from 11 states were able to get information on various aspects of agriculture through Pusa Helpline and Kisan Call Centre (II level). Purpose-wise, maximum calls were made by the farmers related to seed availability (468) followed by production technology (405), plant protection (398), agro-based enterprises (178) and others (355). Seeds, publication, etc., of worth about Rs. 368 061 were sold by ATIC during the period.

Two issues of the six-monthly magazine "Prasar Doot" were published. Twelve pamphlets on cereals, pulses, oilseeds and vegetables were also printed and distributed free to visiting farmers. Besides, more than hundred farmers got farm advisory services through letters during the period.

The ATIC is providing a mechanism for getting direct feedback from the technology users to the technology generators. The feedback strengthened the ATIC activities and provided a ground for need based technologies. The ATIC also developed functional linkages with various agencies working for the farming community to effectively cater to the information needs of different stakeholders.

6.3.8 Farmers' Day

A farmers' day was organized on the occasion of 'Himachal Day' by the Institute's regional station at Tutikandi (Shimla), at Bhajwani Village of Bilaspur district (HP). Farmers as well as Agricultural Officers of HP State Agricultural Department took keen interest in newly evolved wheat and barley varieties (mainly Shivalik and Himadri) during a field demonstration. A farmers-scientists-agricultural officers' interaction was also held to discuss the problems and prospects of wheat and barley cultivation in the hills.

6.3.9 On-farm Studies

Participatory varietal selection (PVS) trial-cum-demonstration was conducted at farmers' fields in UP during 2006. Farmers actively participated, and farmer to farmer interaction meetings were organized at different stages of crop cycle. Among the 15 varieties evaluated in the PVS trial, farmers selected Proagro 6111, Pusa Rice Hybrid 10, Apo (IR55423-01) and Pusa Sugandh 3 based on their yield in aerobic conditions and grain fineness, as fine grain varieties fetch higher market price. Farmers who visited the PVS trial are willing to take up aerobic rice system in a big way because in large part of this area, canal irrigation is not available and farmers have to depend on unpredictable electric supply/ high cost diesel to pump ground water for irrigating the rice crop.

6.3.10 Training Programmes Organized for Farmers and Extension Workers - 2006

The following training programmes were organized by the institute during the year.

Training Programmes

Topic of training	Date
Training-cum-visit programme for officers of military farm, Meerut	31 Dec., 2005- 2 Jan., 2006
Motivation of farmers for adopting the latest technology, its monitoring and evaluation	7 January
Diversification of crops and promotion of entrepreneurship and agro-based industries	14 January
Pesticides residues on foodstuff, its testing and certification	21 January
Hi-tech agriculture for the farmers and officials of Sikkim Govt.	23-28 January
Various organic manure, organic farming and its certification	28 January
Post-harvest technology and preservation of fruits and vegetables	2 February
Training-cum-visit programme for officers of military farm, Meerut	31 March - 3 April
Pre-*kharif* training programme	27 and 28 April
Seed treatment technology at Badshahpur, Dadisiya and Atali (Faridabad)	26 May
Seed production technology in *kharif* crops	16-19 May
Operational knowledge on leaf analysis, plant health clinic and disease forecasting unit	22-27 May
Nursery management practices in paddy at Sabota (G.B.Nagar)	2 June
Seed treatment technology at Duriyai and Rupbas	13 June
Balanced use of fertilizer at Moondibakapur, Bulandshahr (UP)	4 July
Pest and disease management practices in paddy at Dadisiya and Badshahpur (Faridabad)	25 July
Pest and disease management practices in paddy at Durai and Rupbas (G.B. Nagar.)	26 July
Organic farming and integrated pest management in *kharif* crops	6 September
Pre-sowing training programme on *rabi* crops	13 & 14 September
Vermi compost, organic farming and integerated pest management in *rabi* crops	5 October
Joint bio-fertilizer extension programme of IARI and NFL for farmers of Sonepat and Gurgaon districts of Haryana	19 October
Integrated nutrient management in *kharif* crops	27 October
Dryland farming	12 December
Capacity building training programme for farm women at Sandhal Khurd village, Sonepat district	9 November

6.3.11 Krishi Vigyan Kendra (KVK), Shikohpur, Gurgaon

The Institute's Krishi Vigyan Kendra at Shikohpur, Gurgaon is playing a vital role in combating 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 demonstrations

FLDs on oilseeds, pulses and cereal crops are playing a catalytic role in transferring and disseminating location specific crop technologies in the area. During *rabi* 2005-2006 and *kharif* 2006, eighty demonstrations (covering an area of 45.20 ha) on oilseeds, pulses and cereal crops were organized in farmers' fields of seven villages in three blocks of Gurgaon district. Out of 80 demonstrations, 37 demonstrations on mustard (Pusa Jagannath), 7 demonstrations on gram (BGD 72, Pusa 256, Pusa 1103 & Pusa Pragati), 9 demonstrations on lentil (DPL 62), 13 demonstrations on wheat (HD 2824, HD 2643, HD 2851), 10 demonstrations on *arhar* (Pusa 992) and 4 demonstrations on *moong* (Pusa Vishal) were laid out in farmers' fields.

A bumper crop of mustard (var. Pusa Jagannath) under front line demonstration at Teekli village, Gurgaon district, Haryana

The average yields of mustard, gram, lentil, wheat, *arhar* and *moong* were 1.86 t/ha, 1.75 t/ha, 1.07 t/ha, 4.84 t/ha, 1.83 t/ha, and 1.09 t/ha, respectively. The comparative results revealed that average yields of mustard, gram, wheat, *arhar*, and *moong* were increased by 6.34%, 10.24%, 4.12%, 8.78%, and 28.70%, respectively, over those of farmer's practices. Lentil crop was introduced first time in the FLD villages.

A subject matter specialist (plant protection) demonstrating the use of light trap in checking the insect population in gram crop at Teekli village, Gurgaon district, Haryana

During *rabi* 2005-2006, the KVK organized 25 FLDs covering 10 ha (sponsored by DWR Karnal) on different components, viz., newly released variety, application of bio-fertilizers and zero tillage, and compared with the local farmers practice at check plots.

Comparative results of treatments and check plots (component wise)

Component	Treatment plot				Check plot				Yield increase over that of check plot (%)
	Variety	No. of dem.	Area (ha)	Av. yield (t/ha)	Variety	No. of dem.	Area (ha)	Av. yield (t/ha)	
Newly released variety	HD 2687	10	4.00	4.81	HD 2643, PBW 343	10	4.00	4.70	2.14
Application of bio-fertilizers	HD 2687	10	4.00	4.77	HD 2687	10	4.00	4.60	3.58
Zero tillage bio-fertilizers	HD 2687	05	2.00	4.71	HD 2687	05	2.00	4.67	0.96

6.3.11.2 Trainings for different target groups

The major objectives of on-campus and off-campus trainings are to generate the opportunities for income and employment, to provide technical know–how to the practising farm men and farm women and to update the knowledge of in-service personnel.

Vocational trainings for rural youth and girls. In all, twelve vocational training courses on the subjects, viz., bee keeping (1), dairy farming (1), dress designing and tailoring (2), landscaping and beautification (1), tractor repairing and maintenance of farm implements (1), motor winding (1) custom service in plant protection (1), establishment and management of high density orchards (1), vermi compost technology (1), preservation of seasonal fruits and vegetables (1), and production of commercial vegetables (1) were organized. Through these trainings, 207 youths (112 male and 95 female) were benefited.

A professional tailor providing skill training to the girls during a vocational training course on "Dress Designing and Tailoring" held at Seehi village, Gurgaon district, Haryana

In-service (refresher course) trainings. One in-service training (refresher course) on integrated pest management (IPM) was organized for ten Agricultural Development Officers (ADOs) of Haryana Agriculture Department, Gurgaon during the year 2006.

Day long training programmes. During the period, 42 day-long on-/off-campus training programmes for the practising farm men 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, 1115 farmers (898 male and 217 female) were benefited.

On-/off-campus trainings organized during 2006

Training areas	No. of trainings	No. of beneficiaries		
		Male	Female	Total
Crop production	06	84	-	84
Crop protection	12	373	62	435
Animal science	08	214	33	247
Bee keeping	02	84	12	96
Horticulture	08	76	35	111
Agril. engineering	03	67	-	67
Home management	03	-	75	75
Total	42	898	217	1115

Sponsored trainings. Two sponsored training programmes were organized on preparation of vermicompost, and preservation of seasonal fruits and vegetables during the year, 2006. Through these sponsored trainings, 60 members (female) of self help groups (SHGs) of BPL categories were benefited. These trainings were sponsored by DRDA, Gurgaon.

Collaborative trainings. During the year, 2006, three trainings (two-week long) on motor winding were organized in collaboration with Nehru Yuva Kendras, Sonepat and Narnaul (Haryana), Alipur (Delhi) and, the Division of Agricultural Engineering, IARI. Forty-five un-employed rural youths of different villages were benefited through these collaborative training programmes.

6.3.11.3 On-farm testing

By adopting the tested technologies and recommendation in their farming, the farmers are getting more profit. The direct beneficiaries of this programme are playing a catalytic role for other fellow farmers of the village and neighbouring villages.

Major field problems, number of trials, treatments and comparative yield performances during *rabi* 2005-2006

Field problem	Technology tested			Control (farmer's practice)			Increase in yield over that of farmers' practice (%)
	No. of trials	Treatment(s)	Average yield (t/ha)	No. of trials	Treatment(s)	Average yield (t/ha)	
Weed management in wheat (HD 2824)	04	Sulpha sulphuran @ 25 g/ha	5.00	04	2-4,D (Na salt) @ 750 g/ha	4.97	0.60 %
Effect of zinc sulphate in wheat (HD 2643)	03	Zinc sulphate @ 25 g/ha at sowing time	4.88	03	Control plot (without zinc sulphate)	4.31	13.22%
Management of nematode in wheat (HD 2643)	04	Soil treatment with carbofuran (3G) @ 33 g/ha & neem cake @ 500 g /ha	4.94	04	No use of any chemical	4.20	17.61%
Management of pod borer in gram (HC 1)	04	• Use of tight/ pheromone trap • Use of Bt. @ 1g/l of water • Endosulphan+Quinalphos @ ½ ml/l of water • Spray of neem seed powder extract	1.89	04	Endosulphan @ 2 ml/l of water Dichlovas @ 1 ml /l of water	1.50	26.00%
Management of nematode in chilly (Pusa Sadabahar)	03	• Seed treatment with phorate (10G) @ 10 g/ha & neem cake @ 500 g/ha • Seedling treatment by dipping of roots for ½ hr in trizophos solution @ 2.5 ml /l water	1.78	03	Two sprays of dimethiote (30 EC) at 30 and 40 days after transplanting	1.34	32.83%

Tailor-made recommendations for farmers

- For weed control in wheat, the application of sulpha sulphuran @ 25 g/ha is effective in comparison to the use of 2,4D (Na salt)
- Zinc deficiency can be removed by the application of zinc sulphate in wheat crop @ 25 kg/ha at the sowing time
- Nematode problem in wheat crop can be minimized by the application of carbofuran (3G) @ 33 kg /ha and neem cake @ 500 kg /ha for soil treatment
- Pod borer in gram crop can be managed by using Bt.@ 1g/l of water and endosulphan + quinalphos @ ½ ml/l of water, and spray of 5% neem seed powder extract
- Nematode in chilly crop can be managed by soil treatment with phorate (10G) @ 10 g/ha and neem cake @ 500 g/ha and seedling treatment by dipping the root for ½ h in trizophos solution (2.5 ml/l of water)

6.3.11.4 Agricultural extension activities and farm advisory services

For speedy dissemination of technologies in farmers' fields, the KVK celebrated/ organized various extension activities in villages and at KVK campus. During the reported period, 591 activities were organized. Out of 591, 1 *kisan mela*, 5 field days on different crops, 1 women in agriculture day, 3 animal-health days, 1 honey day, 52 method demonstrations, 5 camps/campaigns on plant protection and animal health care, 64 lectures (delivered by the SMS of KVK in the meetings/training of Kisan clubs/organized by the line departments) 2 programmes on TV/Radio were the major activities. Four hundred forty-nine animals were also treated for different types of ailments through animal health camps.

Krishi Vigyan Patrika, a quarterly newsletter of KVK in Hindi, continues to provide the latest and newer technologies to the farmers at proper time at their doorsteps. It provides relevant technical know-how related to the production technologies of field crops, fruits, vegetables, home and dairy management. During the period, 10530 (8237 male and 2293 female) members of different farming communities were benefited through these programmes. Among the beneficiaries, 69% belonged to OBC, 10.50% to SC and 20.50% to the other categories.

7. EMPOWERMENT OF WOMEN AND MAINSTREAMING OF GENDER ISSUES

7.1 GENDER EMPOWERMENT AND FARMING SYSTEM DEVELOPMENT: AN ACTION RESEARCH STUDY

7.1.1 Farming System Development

Six villages, namely, Banspadamka, Mumtajpur and Safedarnagar of Pataudi block and Jamalpur, Johari Khurd and Sampka of Farookhnagar block were selected for project interventions.

Participatory rural appraisal and survey method were employed in the project villages for the assessment of technological gaps in quality production and assessment of training need, involvement of rural women in farming and drudgery reduction, pattern of livelihood management, status of institutional efforts for group action for livelihood security, pattern of marketing and utilization of farm produce, level of achievement and entrepreneurial orientation as well as delineation of expectations and concerns of farmers.

Wheat-millets-vegetable and livestock are the predominant components of farming system. Farmers lacked technical knowledge about bio-fertilizers, integrated pest management practices, minimum tillage, post harvest handling of produce, minimal processing of vegetables, and production of processed products for marketing. The awareness about vermicomposting and other organic practices and their level of adoption was very low.

Village seed bank. As the farmers' stated lack of knowledge of superior seeds, and the unavailability of seeds were some of the most important constraints in quality production of crops, interventions of laying out crop demonstrations of superior varieties, particularly from IARI and mobilization of households to develop village seed banks were made. The demonstrations were laid out in an area of 23.2 ha of plots of farmers' groups formed for seed production. Women were sensitized to play an important role in evaluation of appropriate varieties and their multiplication and exchange.

Organic production. Findings revealed that the farmer's knowledge about organic production was limited to just application of farm yard manure, the practice of which also had become unpopular because of the over reliance on chemical fertilizer for sustaining the yield potential and the practice of lease-in cultivation or share cropping, in which the care of land is grossly neglected by the contracting partner. Over 350 farmers participated in the farmers' meet organized at Jamalpur village for promotion of organic cultivation. Farmers-scientists' interface sensitized the farmers about organic production system. Demonstrations on the use of *Azatobactor* and *Phosphotica* bio-fertilizers were laid out in 8 acres. Farmers were mobilized for inventorization and on-farm assessment of various organic production systems like vermicomposting and biodyanamic farming.

Integrated pest management. A farmers' meet was organized at Banspadamka village. About 200 vegetable growers participated and learnt about integrated pest management practices like summer ploughing, mulching, green manuring and the use of trichoderma, soil solarization of vegetable beds with the use of polythene, application of neem cake 950-1000 g/m^2, agro net based nursery, neem based formulations and pesticides, safety net for bio-agents and pollinators, crop rotation, and punctuality in sowing operation as well as prudence in cultural practices management.

7.1.2 Gender Empowerment

Lack of education and self confidence, social discrimination between boys and girls for education and other developmental opportunities, lack of social participation, lack of capital and opportunity, lack of freedom and facility to take loans for economic activity, and lack of technical skills and accessibility for capacity building programmes of institutions for entrepreneurial activities and cultural traditions were identified as the impediments for female gender development. Matrix ranking conducted among women groups revealed goat rearing as the most preferred enterprise to initiate among the landless households of weaker sections. This was followed by a preference for processing (preparation of *dalia*, dairy products, *papad, badi,* pickle, etc.), tailoring and stitching, and candle making.

Motivational sessions were held with family members for allowing women to join the training and other capacity building programmes, including farm demonstrations and evaluation of crop varieties. Initially, women did not turn up to interact with male staff of the project. However, after the pursued sessions on motivation and entrepreneurial orientation, and organization of awareness camps and farmers'

meet they showed a high level of enthusiasm in organizing themselves and in actively participating in the project activities.

Goat keeping. Woman of landless agricultural labourers and from households of weaker sections, who had shown interest to take up goat keeping as enterprise for their livelihood security, were mobilized to form groups of 15-20 members each in the villages of Jamalpur, Johari Khurd and Banspadamka. A total of 18 women of landless house holds of weaker sections with five women each from the villages of Johari and Banspadamka and 8 women of the village, Jamalpur, were provided with stall fed goat breed (Barberry) with the condition that subsequent progenies would be distributed among the group members till all the members have at least one unit and later the capacity to develop and rear a viable stock strength. Three groups for goat rearing were formed at the villages of Banspadamka, Jamalpur and Johari Khurd.

Tailoring and candle making. Employment opportunities for farm women in non-farm sectors like tailoring and candle making were promoted to provide fillip to the local initiative for development. Three groups of twenty-five women each of the villages Jamalpur and Johari Khurd were trained in tailoring to take it up as an enterprise. Two other groups are being formed for training in candle making.

Drudgery reduction. Weeding is an acutely drudging operation. Manual weeders developed at the Central Institute of Agricultural Engineering (CIAE), Bhopal and Punjab Agricultural University, Ludhiana, and multiple threshers of CIAE were identified to reduce the drudgery among farm women.

8. POST-GRADUATE EDUCATION AND INFORMATION SYSTEM

8.1 POST-GRADUATE EDUCATION

8.1.1 Admission during the Academic Session 2006-2007

The Institute admitted 95 students to the Ph.D. programme on the basis of written examination, academic record and interview. In order to attract students from all over the country, the entrance test was conducted at 5 different centres, namely, Bangalore, Delhi, Kolkata, Nagpur and Varanasi. The admission of 77 students to the M.Sc. courses at this Institute was made by the Indian Council of Agricultural Research (ICAR) through a combined all India competitive examination for Junior Research Fellowship and Master's degree programme of deemed universities of ICAR and state agricultural universities. It goes to the credit of the Institute that, in all the subjects, toppers of the entrance test sought admission to IARI.

Category-wise number of students admitted to M.Sc. and Ph.D. courses

Category	M.Sc.	Ph.D.	Total
Open competition	77	95	172
Foreign students*	3	3	6
Total	80	98	178

**Foreign students were from four countries, namely, Egypt, Ethiopia, Iran and Sri Lanka*

8.1.2 Convocation 2006

The 44th convocation of the Indian Agricultural Research Institute (IARI) was held on February 10, 2006. Prof. M.G.K. Menon, Advisor, Department of Space, ISRO, was the chief guest. In his convocation address, Prof. Menon emphasized that agricultural education has to cover not only the technical aspects of Agriculture but also a vision that covers its relationships with various aspects of the working society – such as land holding patterns, inheritance, legal frameworks, social structures, financing and so on. The chief guest also highlighted the priorities and issues in the development of agriculture in the changing national and international scenarios.

Dr. A.K Singh, Director, IARI, highlighted the research achievements of the Institute during the year 2005. Dr. R.C. Gautam, Dean & Joint Director (Education), IARI, highlighted the important role being played by the Institute in human resource development in terms of post-graduate teaching and short-term training courses in the field of agricultural sciences. A series of IARI publications including the Volume 28 of the *Journal of IARI Post Graduate School*, 2005 and a number of IARI seed varieties were released during the convocation.

At this convocation, 67 M.Sc. and 81 Ph.D. students were awarded degrees. Mr. P.P. Thirumalaisamy (Plant Pathology) and Ms. Sunaina Singh (Plant Genetic Resources) were awarded the 'Best Student of the Year 2005' award for Ph.D. and M.Sc., respectively. Five recipients of Ph.D. degrees, namely, Ms. Thulasi V. (Soil Science & Agricultural Chemistry), Mr. D. Vijay (Seed Science & Technology), Mr. Rajib Karmakar (Agricultural Chemicals), Ms. Y.Amravathi (Molecular Biology & Biotechnology) and Ms. Mahua Banerjee (Agronomy); and 5 recipients of M.Sc. degrees, namely, Ms. Surya Kalyani S. (Microbiology), Mr. Kaushik Majumdar (Agricultural Chemicals), Mr. S.S. Dey (Horticulture), Mr. Thomas A. Johnson (Environmental Sciences) and Ms. Betsy J. (Molecular Biology & Biotechnology) were awarded the 'IARI Merit Medals' for their outstanding academic performance.

Five faculty members, namely, Dr. A.K. Singh (Water Science & Technology), Dr. (Mrs.) V.G. Malathi (Plant Pathology), Dr. A.P. Srivastava (Agricultural Engineering), Dr. (Mrs.) Shashi Bala Singh (Agricultural Chemicals) and Dr. Sanjay Kumar Singh (Fruits & Horticultural Technology) were awarded 'Best Teacher Awards' for their outstanding contribution to teaching.

The 36th Lal Bahadur Shastri memorial lecture was delivered on February 8, 2006 by Dr. G. Madhavan Nair, Chairman, ISRO & Secretary, Department of Space, Government of India, on the topic "Technology Convergence for the Next Green Revolution". The function was presided over by Dr. Panjab Singh, Vice-Chancellor, Banaras Hindu University, Varanasi.

The 6th Hari Krishna Shastri Memorial Award for the year 2005 consisting of a cash prize of Rs.25,000/- and a commendation certificate was awarded to Dr.B.S. Prakash, Professor & Head, Division of Dairy Cattle Physiology, National Dairy Research Institute, Karnal, Haryana for his outstanding research contribution to animal reproductive physiology using biotechnological approaches.

The 10th B.P. Pal Memorial Award for the year 2005 consisting of a cash prize of Rs.10,000/-, a gold medal and a commendation certificate was awarded to Dr. S. Chowdhury, Head, IARI Regional Station, Pusa, Bihar for his outstanding research contribution to the development of new varieties of wheat.

The 14th Sukumar Basu Memorial Award for the biennium 2003-2004 consisting of a cash prize of Rs.10,000/- and a commendation certificate was awarded to Dr. Gouranga Kar, Scientist (Senior Scale), Water Technology Centre for Eastern Region, Bhubaneswar, Orissa for his outstanding research contributions to drought management under rainfed situation through land use planning, water harvesting and crop diversification.

Training programmes organised during the year 2006

Training programme	Period
Division of Agricultural Chemicals	
• Analytical techniques in pesticide residue analysis	December 1 – 30, 2006
Division of Agricultural Engineering	
• Interaction-cum-training for rural artisans in manufacturing technology of agricultural implements	March 28 – April 1, 2006
• Manufacturing technology of agricultural implements	November 19 – 25, 2006
Division of Agricultural Extension	
• Monitoring and evaluation of programmes	January 27 – February 3, 2006
• Extension management for agricultural and rural development	February 27 – March 20, 2006
• Mass media in agricultural development	September 8 – 18, 2006
• Participatory extension approaches for commercial agriculture	November 7 – 27, 2006
Division of Agricultural Physics	
• Winter school on remote sensing applications with special emphasis on linkage of remote sensing with simulation models for agricultural production estimates and land use planning	March 22 – April 15, 2006
Division of Agronomy	
• Crop diversification for sustainable farming	August 5 – 25, 2006
Division of Biochemistry	
• Construction of cDNA library and its screening	January 5 – 25, 2006
• Advanced biochemical and molecular biology techniques	March 1 – 21, and October 26 – November 15, 2006
• Recombinant DNA techniques	December 1 – 21, 2006
Division of Floriculture and Landscaping	
• Entrepreneurship in floriculture and landscaping	December 11 – 20, 2006
Division of Plant Pathology	
• ELISA and PCR based viral diagnosis	December 12 – 16, 2006
• Advanced techniques in plant disease diagnosis and management	September 5 – 25, 2006
• Mushroom cultivation	September 25 – 30, 2006
• Molecular biology and detection techniques for diagnosis of phloem - restricted organisms and viruses in citrus	December 4 – 19, 2006
Division of Seed Science and Technology	
• Seed testing	May 22 – June 3, and October 27 – November 4, 2006
• DUS testing for EDV's and special purpose varieties	September 5 – 14, 2006
Division of Soil Science and Agricultural Chemistry	
• Soil testing, plant analysis, and water quality assessment	November 22 – December 12, 2006

	Water Technology Centre	
•	Water management for sustainable agricultural production in canal commands	March 2 – 8, 2006
•	Water saving technologies for sustainable crop production	November 15 – December 5, 2006
	Unit of Simulation & Informatics	
•	Emerging trends in agri-informatics	February 13 – March 5, 2006
•	Computer basics with application in office automation	August 1 – 5, 2006
	Centre for Protected Cultivation Technology	
•	Modern nursery raising technology for horticultural crops	December 18 – 20, 2006
	IARI Regional Station, Kalimpong	
•	Production of disease-free planting materials of orange	September 19 – 20, 2006

8.2 INFORMATION AND DATABASE

8.2.1 Agri-informatics

Agri-informatics work for relational database layers of bio-physical aspects with decision tools (simulation models) for Orissa is going on which will subsequently lay the foundation for land use planning and agro-advisory. Limited weather station daily rainfall was collated from different sources. Data on solar radiation are limited and are being collected. The spatial information on basic soil properties such as soil class, surface texture, soil depth, soil reaction, including salinity/alkalinity, flooding, etc. was collated and placed in GIS platform. Currently work is in progress on developing suitable state-wise zones for different crops. The agro-climatic zones-wise crop and cropping system information was collected, and parameterization for commonly used crop models like INFOCROP, Oryza, Wofost is being done. The spatial maps for the derived soil parameters are being prepared on district level scale, which can be used for simulation of crop yield in different bio-physical units. This information system would help different users to access site-specific information for Soil Quality Quotients of the AEZ and districts.

8.2.1.1 Web based wheat information retrieval system

An attempt was made to develop a framework of an agricultural decision support system by integrating agriculture, expert knowledge and information technologies. The proposed system aims at improving agriculture productivity by helping farmers to take timely decision.

This software has a three-layered architecture consisting of Client Side Interface Layer implemented in markup and scripting languages and some front end design tools. Server side application implemented in Active Server Pages and Database Layer is implemented in Microsoft Access 2000. This package can be updated as and when new information on these aspects arises. The software can be useful for accessing the information about parentage of different varieties of India, classification, susceptibility to various biotic and abiotic factors and management practices. Pedigree of rice and wheat cultivars has been prepared which is being used for simulation work for various agro-ecologies. There is a provision to search for relevant information with regard to morphological, agronomic and pedigree related information.

WIS-Wheat information retrieval system

8.2.1.2 Chickpea decision support system

A framework for chickpea crop agricultural information system, to disseminate expert agricultural knowledge to the farming community and researcher was developed. It gives information on classification, origin, morphology, types, ecosystem, varieties, yield and economics, residues, cultural practices, uses, germplasm, pedigree, informatics, environmental requirements, production and neutralization, growth stages, national and international trades, special practices, industrial uses, and many more. In addition, database and data warehousing technologies can be used to store and retrieve large amounts of information, which can be coupled with internet technology to deliver information instantaneously to the user. It was developed using client-

server approach, in which MS-Access was taken as back end to store data. Front end was designed using ASP 3.0, HTML and Java-Script.

8.2.1.3 Rice informatics

Informatics on various crops in general and rice in particular, got impetus with the advent of the twin revolution in biotechnology and ICT (Information and Communication Technology). Different aspects of rice informatics such as weather, crop parameters, agro-techniques, water and nutrient management, insect and pest management practices and post production techniques of different agro-climatic zones were used for developing the modules. These modules have attempted induction and extraction of dynamic relationships among growth characteristics, variety type, farming system, ecological conditions and simulation models under varied environments through knowledge engineering and system analyses.

8.2.1.4 AgProtect - an information technology based information dissemination system for crop protection

AgProtect is a web-based Information Dissemination System that uses internet to bridge the gap between the end-users and the experts. AgProtect helps the farmers directly by providing the crucial expert information at the right time. It provides a broader platform for end-to-end information in pest management through cost-effective remedial steps provided by the experts and knowledge bank.

8.2.2 Bioinformatics

8.2.2.1 MicroRNA designer

A tool for designing MicroRNA for cDNA/mRNA sequence was developed. In this tool, we can create mRNA after pasting cDNA/mRNA sequence. This is based on the defined parameters and the existing rules. The validation of this tool is under process.

8.2.2.2 Prediction of microRNA

A tool developed at the Institute can predict the possible microRNAs present in the query sequence. The software is useful for possible prediction of microRNAs before starting the wet lab experiments for microRNA work.

8.2.2.3 Comparative study between glycophytes and halophytes

Studies were carried out for comparing proteins of glycophytes and halophytes using *in-silco* approach. Salt stress is one of the most serious abiotic stress factors limiting the crop productivity. Accordingly, a few halophytes (salt tolerant) and glycophytes (salt sensible) were chosen to study the salt stress gene and their phylogenic relationship. The 3D structures of all proteins were generated and superimposed to know their phylogenic relationship. It was observed that though the mechanism of salt tolerance is somewhat similar in both categories, but the difference lies only in their gene expression. It was also observed that there is cent percent similarity between the proteins of glycophytes and halophytes.

8.2.2.4 Prediction of structure and function of hypothetical proteins

In-silco work on hypothetical proteins of rice (*Oryza sativa*) was done to predict the structure and function of hypothetical proteins. In rice, there are about 40,000 to 50,000 genes present in its genome (430Mb). Majority of proteins are still unannotated and have been termed as unknown or putative or hypothetical. Through *in-silco* methods, an attempt was made to predict the structure and function of hypothetical proteins such as a new domain found in the protein BAC78599 with similarity to SAD1/UNC-84 domain. However, the prediction requires a wet lab validation for confirmation.

8.2.2.5 Missing gene identification in thiamine biosynthesis pathway

An attempt to form signature molecules of all enzymes involved in thiamine biosynthesis pathway, showed many missing genes in various genomes. Accordingly, efforts were made to fill these gaps by generating enzymes specific profiles. Further, these profiles were used to find missing link in the genomes of *Thermotoga maritime* MSB8, a eubacteria. This genome shows evidence of the presence of thiamine biosynthesis pathway as all enzymes except thiD and thiG are present in the genome. This genome was searched for enzyme phosphomethyl pyrimidine kinase (thiD activity) using profiles generated by MEME and MAST to search this genome. Two significant hits, which have phosphomethyl pyrimidine activity in the genome, were obtained. Similar results in a few other organisms were also obtained.

8.2.3 Internet Activities

Internet Leased Line connectivity has been increased from 2 mbps (1:4) to 4 mbps (1:4) since October 2006. Backstopping and additional internet connectivity is supported through ERNET (2 mbps (1:3). During the year under report, more than 1000 internet users awailed these facilities for various applications. IARI website is being maintained and updated regularly. Internet services are being provided to the scientists, staff and students of the Institute.

8.3 LIBRARY SERVICES

IARI Library is one of the largest and the finest agrobiological libraries in South East Asia housing a total of 6 lakh publications including 1 lakh books/monographs, 3,50,000 journal volumes, 45,000 bulletins, 15,000 post graduate theses, 10,000 pamphlets, 30,000 news clippings, 30,000 reports, and other reference materials. The Library has, on its role, 2000 members, viz., students, scientists and technical staff. It also serves about 8,000 visitors every year. The Library functions as the depository of FAO, IDRC and AVRDC publications and also as the National Depository for CGIAR institutes' publications.

8.3.1 Acquisition Programme

8.3.1.1 Books

During the year, the Library procured 583 publications, which included 310 in Hindi and 273 in English costing Rs.1,14,138. The Library also acquired 205 gift publications, 165 IARI theses, 7 ICAR/RFT theses, and 214 ICAR award winning theses documents.

8.3.1.2 Serials

The Library procured 806 journals/serials through subscription, gifts and exchanges. It subscribed to 86 foreign journals (out of which 45 had online access) and 252 Indian journals and 54 advances/annual reviews. Exchange relationship was maintained with 67 institutions/parties globally and nationally by sending annual reports/ Indian journals and society publications.

One hundred fifty-seven (157) annual/scientific/technical reports of different institutions and 137 bulletins were received in the Library. The expenditure on Serial Acquisition Programme from Plan was Rs.78,57,421.

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, 434 articles were scanned, processed and sent to DIPA, ICAR for inclusion in AGRIS Index.

8.3.2.2 Development news in agriculture

Four thousand six hundred eighty (4680) news papers were scanned and 28 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, 1326 documents consisting of books, bulletins, IARI post-graduate theses and Hindi books were processed (classifying and cataloguing).

8.3.3 Resources Management

8.3.3.1 Binding of publications

In all, 4850 volumes consisting of 80,000 loose issues of journals, reports and bulletins were bound and 4000 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, 18000 publications were issued to its members. In all, 150 documents were issued under Inter Library Loan System to various institutions including NISCAIR. Two hundred and fifty-two No Due Certificates were issued to staff, including scientists, after checking relevant record.

8.3.3.3 Reprography services

During the period, the Library provided 32,572 pages of photocopies of scientific and technical literature officially. One key cord counter for updating of Resograph GR 1750, one Toshiba Color Photocopier Model Studio 351C and one Toshiba Studio 452 digital photocopier were purchased during the period.

8.3.3.4 CD-ROM workstation

In all, 89,048 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 29,499, which generated revenues amounting to Rs.68,874. The scientists of IARI accessed through the Intranet (Local Area Network).

8.3.3.5 C-DAC Project

A memorandum was signed with C-DAC (Ministry of Information Technology) on 4th September 2004 to digitize old documents. During the period, 17,93,213 pages of 2673 publications published before 1950 and not covered under copyright Act were scanned. They can be accessed through software developed by C-DAC.

8.3.4 National Agricultural Library Activities under Agricultural Knowledge Initiative (AKI) Programme

A meeting was organized on July 27, 2006 under an Indo-US Agricultural Knowledge Initiative (AKI) for cooperation

between USDA, and the National Agricultural Library for (A) exchange of online information, (B) document delivery services, and (C) exchange of professional experts in the field between the countries.

Mr. Ryan Moore from USDA NAL, USA attended the meeting for chalking out the various steps for the library partnership between the countries.

A brain storming session under AKI programme was organized at G.B.Pant University of Agriculture & Technology, Pant Nagar from November 4 to 5, 2006 to discuss various aspects of the programme. The following rcommendations/ suggestions were given for successful implementation of the programme:

1. Compilation of Union Catalogue: (a) constitution of a Technical Advisory Committee having expertise from Library and Information Technology to set up standards and formats for exporting and importing of data from different libraries to NAL to develop Web enabled Union Catalogue, (b) purchase compatible software for the development of Union Catalogue, (c) experts from organization like DELNET, INFLIBNET, NIC, C-DOT and other organizations, ought to be included in the Technical Advisory Committee, and (d) development of Union Catalogue may be completed through outsourcing.
2. Exchange of on-line information
3. Document delivery services
4. Exchange of professional experts in the field between the countries particularly the USA
5. Holding of workshops/seminars at different locations
6. Creating Web-enabled OPAC with the existing database by providing the necessary infrastructure
7. Publishing an "Indian Agricultural Library Information Newsletter" on the activities of agricultural libraries
8. Development of a portal on Gateway of Indian Agricultural Newsletter" on activities of agricultural library Information pertaining to information/services/ resources available in National Agricultural Library under AKI programme

8.3.5 Training Activities

A Training Cell was developed with the financial support from LIS-NATP.

The following trainings were organized by the Cell during the period under report:

1. Scopus demonstration for scientists of IARI
2. OVID database user Training Awareness Programme
3. White Board for Interactive Learning Programme for learning English language

The Training Cell is also being used for practical classes of the students of USI, and AIS course, and various other trainings/demonstrations of the Institute.

9. PUBLICATION AND INFORMATION 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 2005-2006 (ISSN: 0972-6136)
- IARI News (Quarterly) (ISSN: 0972-6144) - 4 issues
- IARI Current Events (Monthly) - 12 issues

Ad hoc Publications (English)

- Hybrid Rice Seed Production Technology under North Indian Conditions (ICN:40/2006)
- Marigold Cultivation for Higher Income (ICN:41/2006)
- Contribution of IARI Wheat Varieties to Increase in Wheat Production (ICN: 42/2006)
- Achievements of the Division of Seed Science & Technology (TB-ICN: 43/2006)
- Seed Production Agronomy of Paddy Pusa-44 (TB-ICN: 44/2006)
- A Practical Manual on Plant Tissue Culture in the Improvement of Horticultural Crops (ISBN: 81-88708-17-8)
- Crop Diversification for Sustainable Farming – A manual (ISBN: 81-88708-18-6)

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)

- *Krishi Mein Samuchit Jal Prabhandhan* (ISBN: 81-88708-15-1)
- *Jaivik Kheti Ke Pramukh Sootra* (ISBN: 81-88708-16-X)
- *Pusa Sansthan Kee Vyavasaye Yogay Prodyogikiyan* (ICN: H-35/2006)
- *Kisan Jigyasa Avam Samadhan* (ICN: H-36/2006)
- *Kapaas Kee Unnat Utpadan Takneek* (ICN: H-37/2007)
- *Vaigyanik Aadhar Per Dhaan Kee Kheti* (ICN: H-38/2006)
- *Beej Vigyan Avam Prodyogiki Sambhag Kee Uplabdhiyan* (ICN: H-39/2006)
- *Rajanigandha Kee Vaigyanik Kheti* (ICN: H-40/2006)
- *Gulab Ka Samvardhan* (ICN: H-41/2006)
- *Gladiolus Kee Kheti* (ICN: H-42/2006)
- *Kharif Kee Mukhya Phaslon Ka Beej Utpadan* (ICN: H-43/2006)
- *Beejon Kee Katayee Uprant Rakh-Rakhav Avam Prabandhan* (ICN: H-44/2006)
- *Uttar Bhartiya Paristhitiyon Main Sankar Dhaan Kee Beej Utpadan Prodiyogiki* (ICN: H-45/2006)
- *Adhik Aaye Ke Liye Gende Kee Kheti* (ICN: H-46/2006)
- *Gehoon Ka Utpadan Badane Main Bhartiya Krishi Anusandhan Sansthan Dwara Viksit Gehoon Kee Kismon Ka Yogdaan* (ICN: H-47/2006)

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

- A novel composition of biocontrol agent(s)
- Pusa process for experimental controlled atmosphere (CA) generation system
- Polymeric seed coats based on bioactive botanicals
- Pusa process for production and storage of frozen ginger slices
- Pusa process for ready-to-use dehydrated carrot shreds
- Synthetic gene encoding a chimeric ä-endotoxin of *Bacillus thuringiensis*
- Synthetic gene encoding Cry 1 Fal ä-endotoxin of *Bacillus thuringiensis*
- A novel bio-pesticidal formulation with improved shelf-life and the method for its preparation
- A process for the decontamination of vitavax residues from wheat seed

MoU/Agreement Signed

- A memorandum of understanding (MoU) between IARI and M/s West Bengal Hybrid Seeds & Bio Tech Pvt. Ltd., Kolkata signed on vegetable crop varieties released up to December, 2005 for large scale production of vegetable seed
- An agreement for consultancy service between IARI and IFFCO Foundation, New Delhi was signed for establishing a modern high tech. horticulture nursery in Aligarh district, U.P.

Technology Licensed

- Technology on super absorbent/high absorbent hydrogels licensed for commercialization to M/s Vishwagels Limited (a division of Earth International Pvt. Ltd.), New Delhi

Other Activities

- Organised a panel discussion on *"Krishi vyavsayeekaran main krishi udhmiyon ki Pusa sansthan se apekshayen"* as part of the Hindi Seminar on *"Pusa Sansthan Ki Vayavsay Yogya Takneeken"* with the professional from seed, fertilizer, pesticide and agricultural machinery industries as a follow up action on IARI-industry interactions in the past, at IARI on February 21, 2006.
- Organized an Intellectual Property Awareness Programme (IPAP) for IARI scientists on August 28, 2006 by the Patent Office, New Delhi at IARI to give an indepth view of patent related issues. The following three key-note lectures were given by the experts of the Patent Office:
  - (i) Patent – an insight
  - (ii) Patent writing and application filing procedure
  - (iii) Contents of patent specifications

11. LINKAGES AND COLLABORATION

Given the national leadership in almost all major agricultural research areas, the Institute has close linkages with almost all annual crop and horticultural crop research institutes, centres, project directorates, coordinated projects as well as a few selected institutes of the ICAR. Similar linkages exist for natural resources and socio-economic research institutions. Collaboration exists with almost all the state agricultural universities (SAUs), selected conventional universities, several of the institutes of the CSIR and the departments of Ministry of Science and Technology such as the Departments of Biotechnology, Space Research, Meteorology and Information and several other ministries/ departments/organisations of the Government of India.

At the international level, the Institute has close linkages with several of the CGIAR's international agricultural research centres (IARCs), more particularly with ICRISAT, CIMMYT, IRRI, IFPRI, INSAR, IIMI, ICARDA and IPGRI and CABI. Among other international organizations, FAO, IAEA, USAID, UNDP, WMO, UNIDO (through ICGEB) and UNEP have been the closest allies. Several bilateral research linkages involving developed and developing countries exist. These include linkages with USDA, selected universities in USA, Rockefeller Foundation, European Commission, ODA, DANIDA, IDRC, SIDA, JAICA, JIRC, CSIRO, ACIAR, MASHAV (Israel), IRRDB, AVRDC (Taiwan), etc. The details of externally funded projects in operation during 2006 are given in the following table.

Funding agencies and number of externally funded projects

Name of funding agency	No. of projects
Within India	
DBT, DST, ICAR, CICR, CSIR, NCPA, Ministry of Environment & Forest, DOAC, DRDE, NAAS, CPCB, etc.	67
AP Cess Fund, National Fellow Scheme of ICAR	43
Outside India	
PPIC, USAID, IDRC, CGIAR, CIMMYT	07

12. BUDGET ESTIMATES

Details of the budget estimates under plan and non-plan heads

Rs. In lakh

Subhead	Budget estimates 2005-2006		Revised estimates 2005-2006		Budget estimates 2006-2007	
	Plan	Non-Plan	Plan	Non-Plan	Plan	Non-Plan
Estt. charges including wages	-	5565.70	-	5995.00	-	5540.00
OTA	-	4.50	-	4.50	-	3.50
TA	35.00	8.60	25.00	21.00	20.00	17.00
Other charges	961.91	1117.00	1015.44	1892.86	1165.23	1125.50
Works	40.00	489.20	40.00	727.35	517.77	380.00
Other items/Fellowships	-	170.00	-	171.15	-	170.00
Total	1036.91	7355.00	1080.44	8811.86	1703.00	7236.00

13. STAFF POSITION
(As on 31.12.2006)

Category		No. of posts	
		Sanctioned	Filled
A.	**SCIENTIFIC STAFF***		
1)	Research Management Personnel	7	5
2)	Principal Scientist	69	177 (40)
3)	Senior Scientist/Scientist (S.G.)	184	188 (62)
4)	Scientist	355	63 (326)
B.	**TECHNICAL STAFF**		
1)	Category III	27	26
2)	Category II	384	321
3)	Category I	445	402
C.	**ADMINISTRATIVE STAFF**		
1)	Group A	20	14
2)	Group B	279	246
3)	Group C	249	240
D.	**SUPPORTING STAFF**		
1)	SS Grade IV	193	191
2)	SS Grade III	388	386
3)	SS Grade II	648	622
4)	SS Grade I	358	305

Note (i) The figures shown out of parentheses represent the number of scientists working in the particular grade (by as assessment/direct recruitment/induction)

(ii) The figures shown in the parentheses represent the number of scientists initially appointed by direct recruitment/ induction in the grade (i.e., excluding assessment)

* Excluding the cadre strengths of Directorate of Maize Research, and NRC on Plant Biotechnology

14. MISCELLANY

I. On-going Projects at IARI as on 31.12.2006

a)	School of Crop Improvement	39
b)	School of Resource Management	28
c)	School of Crop Protection	18
d)	School of Basic Sciences	14
e)	School of Social Sciences	13
f)	Mega & X Plan Projects	9
	Total	**121**

II. Scientific Meetings Organized

a)	Workshops	8
b)	Seminars	3
c)	Summer institutes	4
d)	Farmers' day (s)	18
e)	Others	22
	Total	**55**

III. Participation of Personnel in Scientific Meetings

India

a)	Seminars	183
b)	Scientific meetings	201
c)	Workshops	95
d)	Symposia	165
e)	Others	69
	Total	**713**

Abroad

a)	Seminars	5
b)	Scientific meetings	8
c)	Workshops	1
d)	Symposia	3
e)	Others	2
	Total	**19**

IV. Publications

a)	Research/symposia papers	990
b)	Books/chapters in books	191
c)	Popular articles	272
	Total	**1453**

V. Honours and Awards

1. Dr. B.S. Parmar, Joint Director (Research), received the Bharat Ratna Dr. C. Subramaniam Award of the Indian Council of Agricultural Research (ICAR) for Outstanding Teacher for the biennium, 2004-2005.
2. Dr. K.R. Koundal, Joint Director (Research), was elected General Secretary of the Society of Plant Biochemistry and Biotechnology.
3. Prof. H.S. Gaur, Dean and Joint Director (Education), was elected President of the Nematological Society of India for the period from April 1, 2006 to March 31, 2008.
4. Dr. Anil Kumar Singh, Project Director, Water Technology Centre, was elected Fellow of the National Academy of Agricultural Sciences and Secretary of the Indian Society of Water Management.
5. Dr. Anand Swarup, Head, Division of Soil Science and Agricultural Chemistry, received the TSI-FAI Award 2006 for outstanding contribution on "Plant Nutrient Sulphur". He was also elected Vice-President of the Indian Society of Soil Science for the biennium 2007-2008.
6. Dr. P.S. Deshmukh, Head, Division of Plant Physiology, was awarded the Dr. J.J. Chinoy Gold Medal of the Indian Society for Plant Physiology for the year 2006.
7. Dr. Gita Kulshrestha, Professor, Division of Agricultural Chemicals received the Punjab Rao Deshmukh Best Woman Scientist Award in the field of plant protection.
8. Dr. M.S. Sachdev, National Fellow, Nuclear Research Laboratory, was elected President of the Agriculture and Forestry Sciences Section of the Indian Science Congress Association.
9. Dr. J.D.S. Panwar, Principal Scientist, Division of Plant Physiology, was elected President of the Indian Society for Plant Physiology.
10. Dr. R.C. Gautam, Principal Scientist, Division of Agronomy, received the Bharat Ratna Dr. C. Subramaniam Award of the Indian Council of Agricultural Research (ICAR) for Outstanding Teacher for the biennium, 2004-05.
11. Dr. Rakesh Kumar Jain, Principal Scientist, Division of Plant Pathology, was elected Fellow of the National Academy of Agricultural Sciences.
12. Dr. R.K. Rattan, Principal Scientist, Division of Soil Science & Agricultural Chemistry, was elected Secretary of the Indian Society of Soil Science.
13. Dr. Subhash Chandra, Principal Scientist, Water Technology Centre, was elected Vice-President of the Indian Society of Water Management.
14. Dr. R.K. Sairam, Principal Scientist, Division of Plant Physiology, received the Hooker Award in the field of abiotic stress tolerance.
15. Dr. S. Ganguly, Principal Scientist, Division of Nematology, received the Aryabhatta Award from Vigyan Bharati.
16. Dr. Shiv Mangal Singh Tomar, Principal Scientist, Division of Genetics, was elected Fellow of the National Academy of Agricultural Sciences.
17. Dr. S.N. Sharma, Principal Scientist, Division of Agronomy, was elected fellow of the National Academy of Agricultural Sciences.
18. Dr. S.S. Tomar, Principal Scientist, Division of Agricultural Chemicals, was elected President of the Society of Pesticide Science, India.
19. Dr. V.P. Singh, Principal Scientist, Division of Genetics, was elected Fellow of the National Academy of Agricultural Sciences.
20. Dr. Jitendra Kumar, Senior Scientist, Division of Agricultural Chemicals, was elected General Secretary of the Society of Pesticide Science, India.
21. Dr. R.R. Sharma, Senior Scientist, Division of Post Harvest Technology, and Mr. A.K. Gupta, Technical Assistant (T-4), Agricultural Technology Information Centre (ATIC), jointly received the Dr. Rajendra Prasad Award 2003-2004 of the ICAR for the book entitled "*Strawberry: Adhunik Utpadan Ki Takeneekein*".
22. Dr. Abhijit Kar, Scientist, Division of Post Harvest Technology, received the NAAS Young Scientist Award for research contributions.
23. Dr. Neelam Patel, Scientist, Water Technology Centre, received the Young Professional Award of the International Commission on Irrigation and Drainage (ICID).
24. Dr. V.B. Patel, Scientist, Division of Fruits and Horticultural Technology, received the Young Scientist Award of NAAS for research on agricultural crops.

VI. Resource Generation

1) Consultancy services, etc.

Consultancy service	Rs. 22,40,795
Contract research	Rs. 23,42,017
Contract service	Rs. 2,34,382
Training	Rs. 12,74,392
Total (A)	**Rs. 60,91,586**

2) Revolving fund	Sale Proceeds Revenue Generated
(a) Seed	Rs. 102,44,182
(b) Commercialization	Rs. 10,78,427
(c) Prototype manufacturing	Rs. 11,43,215
Total (B)	**Rs. 124,65,824**

3) Post-Graduate school receipt

Training programme

(a) Foreigners & Indians	Rs. 2,51,200

M.Sc./Ph.D programme

(b) Institutional economic fee from foreign scholars under Work Plan	US$ 33425 + Rs. 7,37,640
(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. 33,56,543
(d) Cash transferred from Syndicate Bank to Director's Account No. C-49 (9029.305.17) from sale of information bulletin	Rs. 2,03,250
(e) Receipt deposited in Director's Account No. C-49 (9029.305.17) for theses evaluation, PDC & Misc. (it does not include refund of IARI scholarship by students)	Rs. 1,20,497
Total (C)	**US$ 34671 + Rs. 46,69,130**
Grand Total (A + B + C)	**US$ 34671 + Rs. 232,26,540**

VII. Significant Suggestions Given/Decisions Taken at Senior Management Personnel (SMP) Meetings during the Period January 1 to December 31, 2006

Board of Management

- Allotment of quarter in a type next below their eligible type in respect of the staff eligible for type II and type IV quarters.

Academic Council

- The question papers for entrance examination for Ph.D. degree programmes shall be prepared in bilingual form (English & Hindi) and the students will have the option to attempt the papers either in Hindi or English.
- The foreign students, as a special case will be permitted to repeat the course Bio.100, in the following trimester.
- The class schedules will be put up on IARI website.
- A short abstract, not exceeding 200 words, may be prepared for each lecture and put up on IARI website using HTML hyperlinks.

Executive Council

- Institution of Rao Bahadur Dr. Vishwanath Award

Extension Council

- A detailed exercise should be carried out taking into consideration all the options, technical as well as commercial aspects including public-private partnership, for linking IARI website with TAFE website.
- A detailed action plan along with specific suggestions and feasibility for introduction of animal-based production system in TOT programmes and collaborative arrangement with concerned institutes should be prepared and put up to Extension Council for consideration.
- In order to ensure adequate and timely availability of quality seeds to the farmers under TOT programmes, it was suggested to come out with a working paper on the subject with a consensus among the collaborating parties.
- The TOT programmes should be implemented with greater emphasis on complete package of practices, rather than just the varieties alone.
- Possibilities may be explored for evaluation of TOT programmes by an external/independent agency in order to ensure objectivity in assessment.
- Certificate courses on "Entrepreneurship Development in Agriculture" for farmers should be organized on the lines of certificate courses being offered by the PG School for agricultural graduates.
- Appropriate mechanism should be developed by the ATIC to document and utilize the feedback and expedite the responses to the farmers' queries.
- The feedback of the farmers and suggestions based on the impact analysis of the KVK programmes should be compiled.
- A detailed report of the outcomes and impact of IARI efforts in the Tsunami affected areas should be compiled. It was also suggested to standardize a set of recommendations for overcoming the ill-effects on agriculture due to Tsunami disturbances.

Research Advisory Council

- The RAC reiterated its earlier recommendation that IARI should put in place a planning and monitoring mechanism for strategic research. By the year 2010 the Institute's programmes should have a strong component of strategic research, and in another four or five years the Institute should be recognized as the country's foremost center for strategic research in the field of agriculture.
- The Institute should formulate a human resource development plan for scientific leadership. The Institute should send some of its highly talented scientists in the age group of 30 to 40 years for training abroad in selected fields where the Institute needs to be strengthen its scientific capabilities. The scientists so trained should be asked to train junior scientists on their return and provide leadership for the Institute's major research programmes.
- The Institute should play a pro-active role in analyzing emerging issues in Indian Agriculture and preparing authoritative documents for discussions and decision making at different levels.
- The Institute should review its post harvest technology research programme keeping in view the fact that ICAR has created a specific Institute for Post Harvest Technology, and should identify its comparative advantage in the field and develop the programme accordingly.
- The Institute should help to diversify the wheat varieties, specially in the north western region of the country, to avoid single variety domination in the main wheat belt to prevent the possibility of spread of disease epidemic.
- The Institute should seek to redress the problem of non-availability of hybrid varieties in crop like pigeonpea and mustard.
- The Institute should develop a new policy is to develop close linkages with the seed producers both in the public and the private sectors, so that the hybrid seed can be produced in large quantities and distributed to the farmers. The existing procedural problems, which do not motivate the private sector to take up these hybrids, should be solved through discussions with the ICAR.
- The Division of Floriculture & Landscaping should make a much greater impact in developing an export strategy and technology for cut flowers and other products.
- The Institute should collaborate with the National Soybean Research Center, Indore to develop a suitable technology for improving viability of soybean seeds following harvest. The technology should be farmer-friendly.
- There should be many more examples of partnerships with the private sector in the manner of some initiatives taken by the Institute earlier, and learning from the experience of developed countries like the Netherlands.
- Using radio isotope labeling techniques, the contributions of phosphorus solubilizing bacteria, both native and externally applied, should be quantified.
- Degradation of organic wastes with the help of microorganisms is a very old practice. The need now is to identify some of the more efficient micro-organisms for the purpose.
- IARI should take up leadership in the field of global warming and climatic change, which have become important issues in Indian Agriculture with major implications for country's food security and coordinate the work of other scientists in the country.
- The Institute should define its strategy and focus for research on bio-fuels.
- The Institute should help to estimate the nutritional requirements of different horticultural crops, if necessary, in collaboration with other research centers, as a first step since the horticultural production systems in the country by and large continue to be traditional with some notable exceptions.
- The Institute's work in the field of IPM should be totally devoted to strategic research.
- The Institute should train scientists from other research centers in undertaking wheat rusts studies on the pathogens responsible for diseases in other crops.
- The Institute should produce a document on mango malformation critically analysing the existing scientific information and make recommendations for future research, as mango malformation has continued to be a major problem in Indian horticulture.
- The Center for Protected Horticulture at the Institute should intensify its work and the green house technology should be extended to commercial growers by developing suitable linkages with them.
- IARI should come out with alternative models, which will stress the collaborative role of the research institutes, like departments of agriculture and the agri-business sector in the context of India's changing agriculture.
- The Institute should collaborate with the NCAP to identify reasons for the decline of total factor productivity (TFP). A more critical analysis is needed to define the problem and to seek solutions.
- The Institute should clearly define its role in organic farming research. It is no longer necessary to keep arguing the pros and cons of organic farming. IARI should organize a

major research programme in the field of organic farming, stressing the scientific and economic viability of organic farming systems.

Staff Research Council

Crop Improvement

- Economic gain with the new varieties/hybrids needs to be properly highlighted.
- More attention needs to be paid to researches on pulses, *Brassica*, and other oilseeds to enhance their production and check the imports. In pulses, plant type concept may be considered to express all qualities.
- The work on wheat hybrids needs to be translated into practice for the benefit of the farmers. The Division of Genetics should generate reliable data on the cultivation of IARI varieties, and their impact in different regions of the country during the last twenty years or more through involvement of private sector. The Division should identify only the national problems and account for the downfall in wheat production due to factors such as terminal heat tolerance, and plan research with regard to black rust, etc. The specific wheat material to be replaced by the new varieties should be borne out of the work on the development of varieties.
- Seed viability, moisture content, seed variety standard, etc., should be standardized on priority for seed storage. Effort should be made to reduce the cost of hybrid seed production technology.
- Emphasis should be laid on hybrid seed production of vegetables. Breeding effort in vegetables should concentrate on combining the anti-oxidants lycopene and carotene and refinements within F_1 hybrids in vegetables.
- The Division of Fruits & Horticultural Technology should distribute a schedule of practices for high density planting of Amarapali mango. A list of mango synonyms and homonyms for developing varieties, and a schedule on mango nutrition should be prepared for distribution.
- A suitable technology for protected horticulture in northern India may be developed as protected horticulture failed in northern India owing to high energy cost for efficient cooling. The economics of replacement of plastic sheet every year or two years needs to be worked out. Minimum area of protected cultivation should be one acre.
- Proper attention should be given to develop a low cost, locally available biodegradable packaging material. There is a need for integration of post-harvest technology with production areas.
- A strong monitoring system including performance evaluation is needed. There is a need to analyse the impact of the varieties released by the Institute.
- There is a need to modernize the whole system of research, administration and extension at IARI to make it a model centre. Research efforts need to be focused on genetics of nutrition and water use efficiency for rice and wheat plant ideotypes, zero till, conversion of C3 to C4 plant, crops for drought tolerance, promotion of pulses, maintenance breeding, rhizosphere engineering, safeguard for microorganisms, suitability of flowers for export purpose, development of an inbuilt mechanisms for prevention of lose of antioxidant during transportation and impact analysis of prime area of research.

Crop Protection

- Efforts should be made to create awareness among the farmers on the nematode problem. Impact of bio-control should be examined in farmers' fields. Cost benefit ratio of the doses in the laboratory and impact of such doses on environmental component need to be addressed.
- The Division of Agricultural chemicals should emphasize more on chemistry in relation to the bio-activity, and create a repository of old molecules for future use and develop MRL on those molecules.
- In integrated pests management (IPM) module, only registered bio-pesticides should be used. There should be emphasis on simulation studies to give more strength to pathological data, control of diseases, survey and surveillance based forecasting of diseases. Farmers' problems should be taken up in project mode.
- Impact, adoption and socio-economic aspect of IPM may be evaluated by an outside agency. Emphasis should be laid on basic research on IPM.

Resource Management

- Emphasis on clay mineralogy and differences in transformation under forest and cultivated soils be worked out. The qualitative and quantitative need parameters for soil health and soil quality index to be defined. Soil information system, water resources inventory, etc., for Delhi region need to be developed to manage the resources properly.
- The information on agricultural waste management and its role in crop production should be compiled in the form of a bulletin.
- The data on physico-chemical properties of soils and organic sources of inputs to be mentioned in the experiment on agronomy.
- A pamphlet on aqua-ferti-seed drill in rainfed area needs to

be brought out. Technology for increasing recharge of ground water, and extension of soil-less culture to red laterite soils of western India and soils of eastern India, which have tremendous capacity to absorb moisture, and the importance of agro-meteorology should be highlighted.

- Microbiological research may be extended to dry land agriculture, degraded soil and wasteland management. Development of technology for biofertilizer for cropping system needs to be stressed. Role of organic matter in the establishment of bio-fertilizer and its mode of action and quality control parameters need to be emphasized to popularize bio-fertilizers. Integration of micro-organisms with clay particles in rhizosphere and waste water treatment with azolla and the ultimate fate of azolla need to be studied holistically
- Global climate change studies in India and their importance need to be emphasized through appropriate compilation. Farmers' perception on climatic change should be ascertained and considered. Economics of growing *Jatropha* or other non-edible oil seeds in wasteland need to be quantified.
- Machinery for preparation/application of bio-fertilizer, waste management, municipality solid waste, etc., may be developed. Evaporative cooling be emphasized in developing low cost machines and structures. Attempt should be made to make diesel engine more efficient. There is a need to focus on a few selected areas like engineering component of *Jatropha*, green house engineering, implements, etc., and make a headway. The contribution of the output of the Division of Agricultural Engineering and its relevance to the society be compiled, and outlets for technology be earmarked for impact.
- The results of the experiment should be communicated in farmers' language. The observations in various experiments should be justified by supplementing information.

Basic Sciences

- Plant breeders should collaborate closely with the scientists of biochemistry and plant physiology. Biochemical basis of temperature tolerant varieties needs to be worked out. Plant physiology needs to lead the plant breeder to address the challenges of future. The variety that will be relevant to the future scenario should be used.
- Attempt should be made to study the changes at structure level after subjecting to magnetic radiations in NRL as molecular and atomic level work will yield better information compared to that in empirical studies.

Social Sciences

- The Division of Agricultural Extension should include the livelihood of small farmers, policy implications of participatory approach, training of private and public sector personnel, critical analysis of achievements of mission (e.g., horticulture mission), role of ICT village level centers, etc.
- Special attention needs to be given by the Division of Agricultural Economics to analyze issues such as increasing poverty, transgenics, credit continuance, wheat import, etc. Impact of IARI technologies should be brought out as a bulletin and circulated to all national departments. The work of the Division of Agricultural Economics, Division of Agricultural Extension and CATAT needs to be integrated on common research agenda.

VIII. All India Coordinated Research Projects in Operation during the year 2006

Project headquarters

1. All India Coordinated Research Project on Nematodes
2. All India Coordinated Research Project on Pesticide Residues
3. All India Coordinated Research Project on Floriculture Improvement

National centres functioning under all India coordinated research projects

1. All India Network project on Biofertilizers (Erstwhile All India Coordinated Research Project on Biological Nitrogen Fixation)
2. All India Coordinated Project on Long Term Fertilizer Experiments
3. All India Coordinated Research Project on Soil Test Crop Response
4. All India Coordinated Research Project on Tillage Requirements of Major Indian Soils for Different Cropping Systems
5. All India Coordinated Research Project on Floriculture Improvement
6. All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries
7. All India Coordinated Research Project on Honey Bees
8. All India Coordinated Research Project on Biological Control of Crop Pests
9. All India Coordinated Research Project on Soybean
10. All India Coordinated Research Project on Sub-tropical Fruits

IX. Foreign Visitors during 2006

Sl. No.	Visitor (s)	Month
1.	Prof. Khalid Mahmood Khan, Secretary-General, Pakistan Academy of Science, Pakistan	January
2.	A South African Delegation	January
3.	A 20-member Bhutanese delegation	February
4.	A 32-member French delegation	February
5.	A 12-member delegation from Bhutan	March
6.	His Excellency Mundia F. Sikatana, Ministry of Agriculture, Zambia	March
7.	A 3-member delegation from Agriculture and Agri-Food Canada (AAFC) led by Dr. Johanne Boisvert, Director, Bilateral Relations, International Scientific Cooperation Bureau, Alberta, Canada	March
8.	A 2-member delegation from Niger	April
9.	His Excellency Daivew Katsonga, Minister of Foreign Affairs of Malawi	May
10.	A 12-member delegation from Tajikistan	May
11.	An 8-member delegation led by Mr. Pang Damou, Vice-Chairman, Standing Committee on Human Provincial People's Congress, China	May
12.	His Excellency Mohammad Alameen Kabbashi Eisa, Minister of Agriculture and Forestry, Sudan	June
13.	Mr. Andereag Reng, Licensing Manager from Basf Plant Science, Germany	June
14.	His Excellency Arefaine Gehbremedhin, Minister of Agriculture, Eritrea	June
15.	Dr. Vijay Pandey, Professor, European Commission	July
16.	Dr. Christian Roth, South Asia Regional Coordinator, Australian Centre for International Agricultural Research, Australia	July
17.	A 7-member delegation from China	July
18.	Senior level Officers of the Ministry of Agriculture, Animal Husbandry and Food, Govt. of Afghanistan	July
19.	A 5-member delegation from Kenya	July
20.	His Excellency Prof. Venancia Massingue, Minister of Science & Technology, Republic of Mozambique	July
21.	An 11-member delegation from Japan	August
22.	A 4-member delegation from Bhutan	August
23.	A 2-member delegation from Eritrea led by Dr. Ghebsehiwet Teame, Director of Technical Services, Eritrea	August
24.	A 4-member delegation from China led by Mr. Zhang Wei, Professor, Agriculture Information Technology, China Agriculture University, China	August
25.	Mr. Alvaro Garcia Chavez, Secretary of Rural Development for the State of Jalisco, Mexico	September
26.	A 2-member delegation from Mozambique	September
27.	An 8-member delegation led by His Excellency Abera Deressa, State Minister of Agriculture and Rural Development, Ethiopia	October

Sl. No.	Visitor (s)	Month
28.	A 5-member delegation from Mexico led by Dr. Gustao Chopela, Director General, National Council of Science and Technology (CONACYT), Mexico	October
29.	A group of 40 participants attending APPARI-GFAR Day organized by ICAR/DARE	October
30.	Dr. C. Peterman, Director of Research on Biotechnology, Agriculture and Alimentation, DG for Research, European Commission	November
31.	A 5-member delegation led by Mr. Shinguru Metai, Chairman, Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan	November
32.	Mr. Michael Johanns, Secretary, US Departmental of Agriculture, United States	November
33.	A 27-member delegation from Germany	November
34.	A 3-member delegation from Nigeria	November
35.	A group of 13-scientist from Uzbekistan	November
36.	A 6-member delegation led by His Excellency Tomas Frederico Mandlate, Minister of Agriculture, Mozambique	November
37.	A 2-member delegation from Dar-e-salam University, Tanzania	December
38.	A 9-member delegation led by His Excellency Theo-Ben Gurriab, Speaker of the National Assembly of the Republic of Namibia	December

H.E. Alvaro Garcia Chavez, Secretary of Rural Development for the State of Jalisco, Mexico (right) during a visit to IARI. Seated with him is Dr. S.A. Patil, Director, IARI

H. E. Tomas Frederico Mandlate, Minister of Agriculture, Mozambique (right) during a visit to IARI. Seated with him is Dr. K.R. Koundal, Joint Director (Research), IARI

Appendix 1

Members of Board of Management of IARI

(As on 31.12.2006)

Chairman

1. Dr. S.A.Patil,
   Director, IARI

Members

2. Dr. H.S. Gaur
   Dean & Joint Director (Education), IARI

3. Two Members of GB, ICAR
   (Nomination awaited)

4. Eight members from JDs/PD/HODs
   (Nomination awaited)

5. A Vice-Chancellor of an Agricultural University
   (Nomination awaited)

6. One representative from ICAR
   (Nomination awaited)

7. Director, NDRI/IVRI on rotation for 2 years
   (Nomination awaited)

8. Dr. N.B. Singh
   Agricultural Commissioner, Deptt. of Agril and Cooperation, Min. of Agril., Krishi Bhawan, New Delhi-110001

9. One eminent scientist
   (Nomination awaited)

10. One eminent educationist
    (Nomination awaited)

11. Dr. A.G. Sawant
    Former Chairman
    Agricultural Scientists Recruitment Board
    Plot No 13, Gagan Giri, Sehwas Cooperative Housing Society, Karve Nagar, Pune

12. Dr. Jagdish Chander Bakshi
    Former Vice-Chancellor, RAU, Pusa Bihar
    132D, Kitchlu Nagar, Ludhiana-1410001

13. Dr. (Mrs.) Rita Sharma
    Additional Secretary and Financial Advisor
    (DARE/ICAR), Room No. 114A,
    Krishi Bhawan, New Delhi-110001

14. Smt. Naini Jayaseelan
    Development Commissioner
    Govt. of NCT of Delhi, 5/9 Under Hill Road
    Delhi-110054

15 Dr. K.R. Koundal
   Jt. Director (Research), IARI

Member-Secretary

16. Shri P.C. Jacob
    Joint Director (Administration), IARI

Appendix 2

Members of Research Advisory Council of IARI

(As on 31.12.2006)

Chairman

1. Dr. H.K.Jain,
   Ex-Director, IARI,
   40, Surya Niketan,
   Vikas Marg Extension,
   Delhi-110092

Members

2. Dr. G.L.Kaul,
   Ex-Vice Chancellor,
   Assam Agriculture University,
   K.A.-59 (F.F.), Kaushambi,
   Ghaziabad-201012 U.P.

3. Dr. V.P.Gupta,
   Ex-Vice Chancellor,
   GH-10 / 69A, Sunder Apartments,
   Paschim Vihar, New Delhi-110 087

4. Dr. Asis Datta,
   Director,
   National Centre for Plant Genome Research,
   JNU Campus, New Delhi

5. Dr. S.S. Magar,
   Ex-Vice Chancellor,
   B.S.Konkan Krishi Vidyapeeth,
   Dopoli, Distt. Ratnagiri,
   Maharastra

6. Prof. S. Kannaiyan,
   Ex-Vice Chancellor,
   Tamil Nadu Agricultural University,
   Chairman, National Biodiversity Authority, 475,
   9th South Cross Street,
   Kapaleeswarar Nagar, Neelankarai,
   Chennai- 600041 (T.N.)

7. Dr. S.N. Shukla,
   Assistant Director-General (F &FC)
   ICAR, New Delhi-110001

8. Dr. S.A. Patil,
   Director, IARI

Member-Secretary

9. Dr. K.R. Koundal,
   Joint Director (Research)
   IARI, New Delhi

Appendix 3

Members of Academic Council of IARI
(As on 31.12.2006)

Chairman

1. Dr. S. A. Patil
   Director, IARI

Vice-Chairman

2. H.S. Gaur
   Dean & Joint Director (Edn.), IARI

Members

3. Dr. S.P.Tiwari
   Dy. Director General (Edn), ICAR

4. Dr. S. Edison
   Director, CTCRI

5. Dr. (Ms.) Manju Sharma
   Former Secretary, DBT

6. Dr. B.L. Jalali
   Former Director (Research), CCSHAU

7. Dr. J.P. Tiwari
   Dean, GBPUA & T

8. Dr. S.D. Sharma
   Director, IASRI

9. Dr. K. R. Koundal
   Joint Director (Research), IARI

10. Dr. J.S. Panwar
    Professor of Agril. Engineering

11. Dr. P.S. Datta
    Project Director, NRL

12. Dr. R.K. Katiyar
    Director, NRCPB

13. Dr. D.B. Saxena
    Professor of Agril. Chemicals

14. Dr. R.P. Singh
    Professor of Agril. Economics

15. Dr. A.K. Singh
    Project Director,
    Water Technology Centre

16. Dr. (Ms.) Rekha Bhagat
    Professor of Agril. Extension

17. Dr. K.S. Sundra Sarma
    Professor of Agril. Physics

18. Dr. V.K. Sharma
    Professor of Agril Statistics

19. Dr. B.N. Mishra
    Professor of Agronomy

20. Dr. Prikhshayat Singh
    Head, Biochemistry

21. Dr. P.K. Malhotra
    Professor of Computer Application

22. Dr. R.D. Gautam
    Professor of Entomology

23. Dr. H. C. Joshi
    Professor of Environmental Sciences

24. Dr. R.D. Singh
    Professor of Genetics

25. Dr. R.R. Sharma
    Professor of Horticulture

26. Dr. A. P. Singh
    Head, Floriculture & Landscapping

27. Dr. D.V.K. Samuel
    Head & Professor, Post Harvest Technology

28. Dr. A.N. Srivastava
Professor of Nematology

29. Dr. K. D. Srivastava
Professor of Plant Pathology

30. Dr. G.C. Srivastava
Professor of Plant Physiology

31. Dr. B.B. Mondal
Professor of Plant Genetic Resources

32. Dr. R.K. Chowdhury
Professor of Seed Science & Technology

33. Dr. B.K. Nad
Professor of Soil Science & Agril. Chemistry

34. Dr. B.R. Yadav
Professor of Water Science & Technology

35. Dr. R.K. Rai
Master of Halls of Residences

36. Shri N.S. Pakhale
Head, IARI Library

37. Dr. Subedar Singh
Academic Council Representative

38. Dr. S.K. Mishra
Faculty Representative to the Academic Council

39. Shri Lokesh Babar
President, PGSSU

40. Shri M.K. Pachauri
Dy. Registrar

Member-Secretary

41. Shri P.C. Jacob
Joint Director (Administration)/Registrar (Academic)

Appendix 4

Members of Extension Council of IARI

(As on 31.12.2006)

Chairman

1. Dr. S.A. Patil,
   Director, IARI, New Delhi

Members

2. Dr. I.P.S. Ahlawat, Head,
   Division of Agronomy, IARI, New Delhi
3. Dr. B.B. Singh, Head,
   Division of Genetics, IARI, New Delhi
4. Dr. G. Narayanasamy, Head,
   Division of Soil Science & Agricultural Chemistry,
   IARI, New Delhi
5. Dr. M. Saha, Head,
   Division of Nematology, IARI, New Delhi
6. Dr. (Ms.) M. Dadlani, Principal Scientist,
   Division of Seed Science & Technology, IARI,
   New Delhi
7. Dr. Aparna Chattopadhyaya,
   Prof., Division of Agricultural Extension, IARI,
   New Delhi
8. Dr. A.P. Srivastava, Principal Scientist,
   Division of Agricultural Engineering, IARI,
   New Delhi
9. Dr. (Ms.) Pratibha Sharma, Principal Scientist,
   Division of Plant Pathology, IARI, New Delhi
10. Dr. Anjani Kumar, Incharge
    KVK, Shikohpur, Gurgaon, Haryana
11. Dr. R.K. Chowdhary, Principal Scientist,
    Seed Science & Technology, IARI, New Delhi
12. Dr. H.N. Pandey, Head,
    IARI Regional Station, Indore, M.P.
13. Dr. Joginder Singh, Additional Commissioner (Crops),
    Department of Agriculture, Ministry of Agriculture,
    Krishi Bhawan, New Delhi
14. Dr. K.L. Khurana, Director (A.H.),
    Govt. of NCT of Delhi
    MSO Building, 11th floor, IP Estate, New Delhi
15. Dr. D.K. Thakur, Joint Director (Agri.),
    Govt. of NCT of Delhi
    MSO Building, 11th floor, IP Estate, New Delhi
16. Dr. Ram Kumar, Principal Scientist, (Dairy Extension),
    NDRI, Karnal
17. Dr. Y.R. Meena, Director,
    Farm Information, Directorate of Extension,
    Ministry of Agriculture, IASRI Campus,
    Pusa, New Delhi.
18. Dr. P. Das, DDG (Extension), ICAR,
    KAB, Pusa, New Delhi
19. Shri P.C. Jacob, Jt. Director (Administration),
    IARI, New Delhi
20. Dr. K.R. Koundal, Actg. Jt. Director (Extension),
    IARI, New Delhi
21. Dr. K.R. Koundal, Jt. Director (Research),
    IARI, New Delhi

Member-Secretary

22. Dr. Baldeo Singh, Head
    Division of Agricultural Extension, IARI, New Delhi

Special Invitees

1. Dr. R.S. Chillar, Head, CATAT, IARI, New Delhi
2. Dr. J.P. Sharma, Incharge, ATIC, New Delhi
3. Dr. Premlata Singh, Senior Scientist,
   Division of Agricultural Extension, IARI, New Delhi
4. Dr. R.N. Padaria, Senior Scientist,
   Division of Agricultural Extension, IARI, New Delhi
5. Ms. Nishi Sharma, Technical Officer, CATAT,
   IARI, New Delhi

Appendix 5

Members of Staff Research Council of IARI

(As on 31.12.2006)

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 31.12.2006)

Chairman

1. Dr. S.A. Patil
   Director, IARI

Members

2. DDG (CS), ICAR

3. Dr. K.R. Koundal
   Joint Director (Research)
   IARI

4. Dr. R. L. Mishra
   Project Coordinator
   Division of Floriculture and Landscaping, IARI

5. Joint Director (Extension)

6. Dr. H.S. Gaur
   Dean & Joint Director (Education), IARI

7. Dr. Baldeo Singh
   Head
   Division of Agril. Extension, IARI

8. Dr. B.D. Kaushik
   Head
   Division of Microbiology, IARI

9. Dr. D.V. Singh
   Head
   Division of Plant Pathology, IARI

10. Dr. A.P. Singh
    Head
    Division of Floriculture and Landscaping
    IARI

11. Dr. (Ms.) M. Dadlani
    Head
    Division of Seed Science and Technology

12. Dr. A.K. Chakraborty
    Head
    Division of Vegetable Science, IARI

13. Head
    Division of Fruits and Horticultural Technology, IARI

14. Dr. S.R. Sharma
    Head
    Regional Station, Katrain

Member-Secretary

15. Shri P.C. Jacob
    Joint Director (Administration), IARI

Appendix 7

Members of Institute Joint Staff Council (IJSC)

(As on 31.12.2006)

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. B.D. Kaushik, Head
   Division of Microbiology

5. Dr. S.N. Sinha, Head
   Regional Station, Karnal

6. Shri Devender Kumar
   Chief Finance and Account Officer

Secretary (Official Side)

7. Shri. P.C. Jacob, Joint Director (Administration)

Members Staff Side (Elected)

1. Shri Ganesh Rai
2. Shri Ishwar Chand
3. Shri Bhagat Singh
4. Shri Subed Chandra Dikshit
5. Shri R.K. Duggal
6. Shri V.K. Sharma
7. Shri S. K. Jain
8. Shri Yogesh Kumar
9. Shri Umesh Thakur
10. Shri Shashi Kant Kamath
11. Shri Ram Gopal
12. Shri Bijender Singh

Secretary (Staff Side)

13. Shri Vijay Kumar Sharma

Appendix 8

Members of Grievance Committee of IARI

(As on 31.12.2006)

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, Directorate

4. Shri B.K. Bansal
   Finance & Accounts Officer, Directorate

Members (Staff Side)

1. Dr. G.P. Singh

2. Shri Ishwari Singh

3. Shri R.N. Jain

4. Shri Davinder Rai

Member-Secretary

5. Shri Umesh Chandra Sharma

Appendix 9
Personnel
(As on 31.12.2006)

Directorate

Director
Dr. Patil, S.A.

Jt. Director (Research)
Dr. Koundal, K.R.

Dean & Jt. Director (Education)
Dr. Gaur, H.S.

Acting Jt. Director (Extension)
Dr. K.R. Koundal

Jt. Director (Administration)
Mr. P.C. Jacob

Incharge (Publication Unit)
Dr. Srivastava, K.D.

Principal Scientist (PPI Unit)
Dr. Ganguly, A.K.

Principal Scientist (ITMU)
Mr. Saxena, J.P.

Chief Administrative Officer
Mr. Deshbandhu, G.R.

Chief Finance and Accounts Officer
Mr. Devendra Kumar

Editor (Hindi)/T-9
Mr. Dubey, A.K.

Editor (English)/T-9
Mr. Thomas, C.

Sr. Administrative Officers
Mr. Gajmoti, S.K.
Mr. Jain, M.K.
Mr. Malik, J.P.
Mr. Pachauri, M.K.
Mr. Raja, N.
Mr. Ravi Kumar

Registrar (Academic)
Mr. P.C. Jacob

IARI Library

Head (Library Services)
Mr. Pakhale, N.S.

Agricultural Chemicals

Head
Dr. (Ms.) Dureja, Prem

Professor
Dr. Saxena, D.B.

National Fellow
Dr. Gopal, Madhuban

Principal Scientists
Dr. Devakumar, C.
Dr. Dikshit, A.K.
Dr. Gajbhiye, V.T.
Dr. Gupta, R.L.
Dr. Rangaswamy, S.
Dr. Tomar, S.S.
Dr. Walia, Suresh

Sr. Scientists/Scientists (S.G.)
Dr. (Ms.) Gupta, Suman
Dr. Jitender Kumar
Dr. (Ms.) Mukherjee, Irani
Mr. Shakil, N.A.
Dr. (Ms.) Singh, Neera
Dr. (Ms.) Singh, S.B.

Scientists
Dr. (Ms.) Anupama Mann
Dr. Rajesh Kumar

Agricultural Economics

Head
Dr. Singh, R.P.

Professor
Dr. Mathur, V.C.

Principal Scientists
Dr. Atteri, B.R.
Dr. Puran Chand
Dr. (Ms.) Singh, Alka
Dr. Tyagi, V.P.
Dr. Vasisth, A.K.

Sr. Scientists/Scientists (S.G.)
Ms. Bisaria, Geeta
Dr. Jha, G.K.
Dr. Kar, Amit

Scientists
Mr. Badal, P.S.
Dr. Parmod Kumar
Dr. Ranjeet Kumar
Mr. Sekar, I.
Dr. Shiv Kumar
Dr. Singh, N.P.

Agricultural Engineering

Head
Dr. Adlakha, S.K.

Professor
Dr. Panwar, J.S.

Principal Scientists
Dr. Kalra, M.S.
Mr. Saxena, J.P.
Dr. Sharma, H.S.
Dr. Shrivastava, Ranjan
Mr. Singh, Amar
Dr. Singh, J.K.
Dr. Singh, O.P.
Dr. Srivastava, A.P.
Dr. Tomar, S.S.

Sr. Scientists/Scientists (S.G.)
Mr. Adarsh Kumar
Dr. Indra Mani
Dr. Sharma, P.K.

Scientists
Mr. Arvind Kumar
Dr. (Ms.) Gupta, M.J.

Agricultural Extension

Head
Dr. Singh, Baldeo

Professor
Dr. (Ms.) Bhagat, Rekha

Principal Scientists
Dr. Bahal, Ram
Dr. Vashishtha, S.B.
Dr. Vijayaraghavan, K.

Sr. Scientists/Scientists (S.G.)
Dr. Dommeti, U.M.R.
Dr. Padaria, R.N.
Dr. (Ms.) Singh, Prem Lata
Ms. Singh, Rashami
Dr. (Ms.) Wason, Monika

Agricultural Physics

Head
Dr. Kalra, Naveen

Principal Scientists
Dr. Chakravarthy, N.V.K.
Dr. (Ms.) Chopra, Usha Kiran
Dr. Sarma, K.S.S.
Dr. Subba Rao, Y.V.

Sr. Scientists/Scientists (S.G.)
Dr. (Ms.), Agarwal, Pramila
Mr. Garg, R.N.
Mr. Saxena, C.M.
Dr. Sehgal, V.K.
Dr. Tomar, R.K.

Scientists
Dr. Chakraborty, D.
Dr. Sahoo, R.N.
Ms. Vashisth, Ananta

Agronomy

Head
Dr. Ahlawat, I.P.S.

Professor
Dr. Mishra, B.N.

Principal Scientists
Dr.Chillar, R. K.
Dr. Giri, Gajendra
Dr. Rai, R.K.
Dr. Sharma, A.R.
Dr. Sharma, S.N.
Dr. Singh, Ranbir

Sr. Scientists/Scientists (S.G.)
Dr. Ashok Kumar
Dr. Behra, U. K.
Dr. Das, T.K.
Dr. Dhar, Shiva
Dr. Dinesh Kumar

Dr. Gangaiah, B.
Dr. Idnani, L.K.
Dr. Rana, D.S.
Dr. Rana, K.S.
Dr. Sharma, Rajvir
Dr. Shivay, Y.S.
Mr. Shivakumar, B.G.

Biochemistry

Head
Dr. Singh, Prikhshayat

Professor
Dr. Singh, Prikhshayat

National Fellow
Dr. (Ms.) Santha, I.M.

Principal Scientist
Dr. Kapoor, H.C.

Sr. Scientists/Scientists (S.G.)
Dr. (Ms.) Dubey, Nirupama
Dr. (Ms.) Rai, Mamta
Dr. (Ms.) Sachdev, Archana
Dr. (Ms.) Tyagi, Aruna

Scientist
Dr. Dahuja, Anil

Entomology

Head
Dr. Gujar, G.T.

Professor
Dr. Gautam, R.D.

National Fellow
Dr. Paul, A.V.N.

Principal Scientists
Dr. (Ms.) Dhingra, S.
Dr. Khanna, S.C.
Dr. (Ms.) Khokhar, Sucheta
Dr. Ramamurthy, V.V.
Dr. Subrahmanyam, B.
Dr. Vishwanath

Sr. Scientists/Scientists (S.G.)
Dr. Chandra, Subhash
Dr. (Ms.) Dey, Debjani
Dr. (Ms.) Kalia, Vinay K
Dr. Paul, B.
Dr. (Ms.) Sharma, Kirti
Dr. Sharma,R.K.
Dr. (Ms.) Srivastava, Chitra

Environmental Sciences

Head
Dr. Aggarwal, P.K.

Professor
Dr. Joshi, H.C.

National Fellow
Dr. (Ms.) Kaur, R.

Principal Scientist
Dr. Choudhary, R.

Sr. Scientists/Scientists (S.G.)
Dr. (Ms.) Choudhary, Anita
Dr. Gupta, Navindu
Dr. Singh, Shiv Dhar

Scientists
Dr. (Ms.) Banerjee, Bidisha
Dr. (Ms.) Bhatia, Arti
Dr. Jain, Niveta
Mr. Sanjeev Kumar
Dr. Shakeel A. Khan
Dr. Sharma, Dinesh Kumar
Mr. Shiv Prasad
Dr. Singh, Omvir
Dr. (Ms.) Singh,Renu
Dr. (Ms.) Usha Mina

Farm Operation Service Unit

Incharge
Dr. Kamble, H.G.

Floriculture and Landscaping

Head
Dr. Singh, A.P.

Principal Scientists
Dr. Choudhary, M.L.
Dr. Misra, R.L.

Sr. Scientists/Scientists (S.G.)
Dr. Kishan Swaroop
Dr. Prasad, K.V.
Dr. Sindhu, S.S.
Mr. Singh, Kanwar Pal
Dr. Singh, K.P.

Scientists
Mr. Kumar, P. Naveen
Dr. Raju, D.V.S.

Fruits and Horticultural Technology

Head
Dr. Sharma, Y. K.

Principal Scientist
Dr. Singh, Room

Sr. Scientists/Scientists (S.G.)
Dr. Bhagat, S.K.
Dr. Dubey, A.K.
Dr. Grover, R.P.
Dr. Singh, A.K.
Mr. Singh, Kashmir
Dr. Singh, Sanjay Kumar
Dr. (Ms.) Usha, K.

Scientists
Mr. Patel, Vishwa Bandhu
Dr. Pramanick, P.K.
Dr. Srivastava, Manish

Genetics

Head
Dr. K.V. Prabhu

Professor
Dr. Singh, R.D.

National Fellows
Dr. (Ms.) Chandrashekaran, S.
Dr. Prasanna, B.M.

Principal Scientists
Dr. Chaudhary, H.B.
Dr. Farooqui, O.R.
Dr. Govil, J.N.
Dr. Jitender Kumar
Dr. Kharakwal, M.C.
Dr. Malik, B.S.
Dr. Malik, R.S.
Dr. Naresh Chandra
Dr. Rajendra Kumar
Dr. Sapra, R.L
Dr. Singh, B.B.
Dr. Singh, Jagmail
Dr. Singh, R.D.
Dr. Singh, S.S.
Dr. Singh, Vijay Pal
Dr. Tomar, S.M.S.
Dr. Unnikrishnan, K.V.

Sr. Scientists/Scientists (S.G.)
Dr. Dikshit, H.K
Dr. Gadag, R.N.
Dr. Jain, Jaagrati
Dr. Jorhat, Akshay
Dr. Lal, S.K.
Dr. (Ms.) Mahendru Singh, Anju
Dr. Raje, R.S.
Dr. Rajendra Kumar
Dr. Satyavathi, Tara
Dr. Sharma, J.B.
Dr. Sharma, R.K.
Dr. Sharma, Rajiv Kumar
Dr. Singh, A.K.
Mr. Singh, Bhanwar
Mr. Singh, Braham
Dr. Singh, G.P.
Dr. Singh, Rishi Pal
Dr. Singh, R.V.P.
Dr. (Ms.) Vasudev, Sujata
Dr. Vinod Kumar
Dr. Yadav, D.K.
Dr. Yadav, Rajbir

Scientists
Dr. Hari Prasad, A.S.
Dr. Hossain, Firoz
Dr. Jain, Neelu
Dr. Singh, Vijendra

Microbiology

Head
Dr. Kaushik, B.D.

Professor
Dr. Johari, K.S.

Principal Scientist
Dr. Verma, O.P.

Sr. Scientists/Scientists (S.G.)
Dr. Abraham, G.
Dr. (Ms.) Annapurna, K.
Dr. (Ms.) Lata, Rani
Dr. (Ms.) Paul, Sangeeta
Dr. (Ms.) Singh, Geeta
Dr. (Ms.) Shukla, Livleen

Nematology

Head
Dr. Saha, M.R.

Professor
Dr. Srivastava, A.N.

Principal Scientists
Dr. Dhawan, S.C.
Dr. Ganguly, A.K.
Dr. (Ms.) Ganguly, S.
Dr. Jain, R.K.
Dr. Kaushal, K.K.
Dr. (Ms.) Majumdar, K.V. Laxmi
Dr. Meher, H.C.
Dr. (Ms.) Mittal, A.
Dr. Prasad, D.
Dr. Singh, Rambir

Sr. Scientists/Scientists (S.G.)
Dr. Chawla, Gautam
Dr. (Ms.) Kamra, Anju
Mr. Mathur, K.N.
Dr. Pankaj
Dr. (Ms.) Rao, Uma
Dr. Sharad Mohan
Dr. Sharma, H.K.
Dr. Sirohi, Anil

Plant Pathology

Head
Dr. Srivastava, K.D.

Professor
Dr. Srivastava, K.D.

National Fellow
Dr. (Ms.) Aggarwal, Rashmi, P.

Principal Scientists
Dr. Aggarwal, D.K.
Dr. Chatterjee, S.C.
Dr. Jain, R.K.
Dr. (Ms.) Kandhari, Janaki
Dr. (Ms.) Malathi, V.G.
Dr. Niazi, M. F.R.
Dr. (Ms.) Ramachandran, Padma
Dr. (Ms.) Sharma, Pratibha
Dr. Sharma, R.C.
Dr. Singh, U.D.

Sr. Scientists/Scientists (S.G.)
Dr. Baranwal, V.K.
Dr. Dubey, S.C.
Dr. Gogoi, Robin
Dr. (Ms.) Gopalkrishsan, Jayashree
Dr. Khan, Q.Z.
Dr. Mandal, Bikash
Dr. (Ms.) Prameela Devi, T.
Dr. Mondal, K.K.
Dr. Sharma, R.K.
Dr. (Ms.) Shelly, Praveen
Dr. Singh, Dinesh
Mr. Sinha, Parimal

Scientist
Dr. Biswas, K.K.

Plant Physiology

Head
Dr. Deshmukh, P.S.

Professor
Dr. Srivastava, G.C.

National Fellow
Dr. Uprety, D.C.

Principal Scientists
Dr. Ghildiyal, M.C.
Dr. Nath, V.
Dr. Panwar, J.D.S.
Dr. Sairam, R.K.

Sr. Scientists/Scientists (S.G.)
Dr. Arora, Ajay
Dr. (Ms.) Jain, Vanita
Dr. Madan Pal
Dr. (Ms.) Natu, Poonam
Dr. Promod Kumar
Dr. (Ms.) Santosh Kumari
Dr. Singh, V.P.
Dr. Vijay Paul

Scientists
Dr. Pandey, Rakesh
Dr. Pandey, Renu

Post Harvest Technology

Head
Dr. Samuel, D.V.K.

Sr. Scientists/Scientists (S.G.)

Dr. (Ms.) Kaur, C.
Dr. Pal, R.K.
Dr. Ram Ashrey
Dr. Ram Sagar, Vidya
Dr. Sharma, R.R.

Scientists

Dr.Abhijit Kar
Dr. Jha, S.K.
Dr. (Ms.) Sethi, Shruti

Seed Science and Technology

Head

Dr. (Ms.) Dadlani, M.

Professor

Dr. Choudhary, R.K.

Principal Scientists

Dr. Gaur, Ashok
Dr. Mathur, D.S.
Dr. Parihar, S.S.
Dr. Singh, Jai
Dr. Singh, J.N.
Dr. Surendra Prakash
Dr. Tomar, S.R.S.
Dr. (Ms.) Vari, A.K.
Dr. Varshney, J.L.

Sr. Scientists/Scientists (S.G.)

Dr. Chakraborty, S.K.
Dr. Jain, S.K.
Dr. Tomar, B.S.
Dr. Yadav, S.K.

Scientists

Mr. Arun Kumar, M.B.
Dr. (Ms.) Basu, Sudipta
Dr. Lal, S.K.
Dr. Pandey, Sushil
Dr. Singh, K.K.

Soil Science and Agricultural Chemistry

Head

Dr. Swaroop, Anand

Professor

Dr. Nad, B.K.

Principal Scientists

Dr. Datta, S.C.
Dr. Deopal
Dr. Rattan, R.K.
Dr. Sharma, B.M.
Dr. Shukla, L.M.
Dr. Singh, Dhyan
Dr. Singh, R.D.
Dr. Singh, Sarjeet

Sr. Scientists/Scientists (S.G.)

Dr. Biswas, D.R.
Dr. Dwivedi, B.S.
Dr. Nayan, Ahmed
Dr. Pandey, R.N.
Dr. Patra, A.K.
Mr. Purakayastha, T.J.
Dr. Sharma, J.P.
Dr. Singhal, S.K.

Scientists

Dr. Bhadraray, S.
Dr. Datta, S.P.

Vegetable Science

Head

Dr. Sidhu, A.S.

Principal Scientists

Dr. Joshi, Subodh
Dr. Kalia, Pritam
Dr. Mishra, J.P.
Dr. Sharma, R.R.

Sr. Scientists/Scientists (S.G.)

Dr. Dhar, Shri
Dr. Raj Kumar
Dr. Ravinder Kumar

Scientist

Dr. Behera, T.K

Nuclear Research Laboratory

Project Director

Dr. Datta, P.S.

National Fellow

Dr. Sachdev, M.S.

Principal Scientists

Dr. Chopra, S.K.
Dr. Kaim, M.R.S.

Dr. (Mrs.) Nagarajan, Shanta
Dr. (Ms.) Sachdev, P.
Dr. Sud, Y.K.

Sr. Scientists/Scientists (S.G.)

Dr. (Ms.) Anand, Anjali
Dr. Manjaiah, K.M.
Dr. Mookerjee, P.
Dr. Singh, Bhupinder

Water Technology Centre

Project Director

Dr. Singh, A.K.

Professor

Dr. Yadav, B.R.

National Fellow

Dr. (Ms.) Chopra, Renu Khanna

Principal Scientists

Dr. Chandra, Subhash
Dr. Nathan, K.K.
Dr. Parihar, S.S.
Dr. Rajput, T.B.S.
Dr. Sharma, R.K.
Dr. Singh, Subedar

Sr. Scientists/Scientists (S.G.)

Dr. Babu Ram
Dr. Dubey, S.K.
Dr. Kalra, B.S.
Dr. Khanna, Manoj
Dr. Misra, A.K.
Dr. Rao, M.S.
Dr. Sarangi, A.
Dr. Singh, D.K.
Dr. Singh, Man
Dr. (Ms.) Sudhishri, Susama

Scientists

Dr. (Ms.) Patel, Neelam
Dr. Vishwanathan, C.

Unit for Simulation and Informatics (USI)

Incharge

Dr. Chandrasekhran, H.

Sr. Scientists/Scientists (S.G.)

Dr. Bandhopadhyay, S.K
Dr. Chandra, Shubhash
Mr. Mathur, K.N.
Dr. Pathak, H.

Scientists

Dr. Kumar S., Sujith
Mr. Mishra, A.K.

Centre for Agricultural Technology Assessment and Transfer (CATAT)

Incharge

Dr. Chiller, R.S.

Sr. Scientists

Dr. Dabaas, J.P.S.
Dr. Sharma, J.P.
Dr. Singh, B.K.

Centre for Conservation and Utilization of Blue-Green Algae

Incharge

Dr. Singh, P.K.

Principal scientist

Dr. (Ms.) Dhar, D.W.

Sr. Scientists/Scientist (S.G.)

Dr. Pabbi, Sunil
Dr. Singh, Yudhvir
Ms. Arora, Anju

Scientist

Dr. (Ms.) Prasanna, Radha

Centre for Protected Cultivation Technology

Incharge

Dr. Sirohi, N.P.S.

Sr. Scientists/Scientists (S.G.)

Dr. Munshi, A.D.
Dr. Singh, Balraj

Scientists

Mr. Hasan, Murtaza
Mr. Singh, M.C.

IARI Regional Station, Amartara Cottage

Head

Dr. Kishore, D.K.

Sr. Scientists/Scientists (S.G.)

Dr. Dharam Pal
Dr. Pramanik, K.K.
Dr. Sanjay Kumar
Dr. Sharma, S.K.

IARI Regional Station, Indore

Head

Dr. Pandey, H.N.

Principal Scientists

Dr. Mishra, A.N.

Dr. Verma, P.K.

Sr. Scientists/Scientists (S.G.)

Dr. Sai Prasad, S.V.

Dr. Samdur, M.Y.

Scientists

Dr. Kantwa, S.R.

Dr. Singh, A.K.

IARI Regional Station, Kalimpong

Scientist-in-charge

Dr. Pun, K.B.

IARI Regional Station, Karnal

Head

Dr. Sinha, S.N.

Principal Scientists

Dr. Modi, B.S.

Dr. Pandita, V.K.

Sr. Scientists/Scientists (S.G.)

Dr. Atwal, S.S.

Mr. Chopra, N.K.

Dr. (Ms.) Chopra, N.K.

Dr. Gupta, Anuja

Dr. Rakesh Seth

Dr. Singh, P.B.

Dr. Yadav, R.N.

Scientists

Dr. Raj Kumar

Dr.Rana, S.C.

Mr. Sinha, J.P.

IARI Regional Station, Katrain

Head

Dr. Sharma, S.R.

Principal Scientists

Dr. Barwal, R.N.

Dr. Kapoor, K.S.

Scientists

Dr. Chander Parkash

Mr. Dhiman, Mast Ram

Dr. Ranjan Kumar, P.

Dr. Suman, R.S.

IARI Regional Station, Pune

Head

Mr. Chavan, V.M.

Sr. Scientists/Scientists (S.G.)

Dr. Sharma, S.K.

Dr. (Ms.) Verma, Raj

IARI Regional Station, Pusa

Head

Dr. Choudhary, S.

Principal Scientist

Dr. Anil Kumar

Sr. Scientists/Scientists (S.G.)

Dr. Dilip Kumar

Dr. Singh, Kanhaiya

Scientist

Mr. Narayan Kumbhare

IARI Regional Station, Wellington (The Nilgiris)

Head

Dr. Nayeem, K.A.

Principal Scientist

Dr. R.N. Brahma

Sr. Scientists/Scientists (S.G.)

Dr. Prabhakaran, A.J.

Dr. Sivasamy, M.

IARI Rice Breeding & Genetics Research Centre, Aduthurai

Scientist-in-Charge

Dr. Nagarajan, M.

IARI Centre for Improvement of Pulses in South, Dharwad

Scientist-in-Charge

Dr. Hegde, V.

IARI Krishi Vigyan Kendra, Shikohpur, Gurgaon

Scientist-in-charge

Dr. Anjani Kumar

Emeritus Scientists

Dr. Ahlawat, Y.S.(Division of Plant Pathology) (17/08/2006 to 16/08/2008)

Dr. Bhattacharya, A.K. (WTC)
(22/05/2006 to 21/05/2008)

Dr. Chhonkar, P.K. (Division of Soil Science and Agricultural Chemistry)
(17/05/2006 to 16/05/2008)

Dr. Dalmir Singh (Division of Genetics) (06/04/2004 to 31/08/2007)

Dr. Gupta, G.P. (Division of Entomology) (01/08/2006 to 31/07/2008)

Dr. Mishra, S.M. (Division of Nematology) (01/07/2006 to 30/06/2008)

Dr. Parmar, B.S. (Division of Agricultural Chemicals) (30/08/2006 to 29/08/2008)

Dr. Sharma, P. Usha (Division of Plant Pathology (12/08/2004 to 11/08/2006

Dr. Sirohi, P.S. (Division of Vegetable Science) (01/05/2006 to 30/04/2008)

INSA Senior Scientists

Dr. Rajendra Prasad (Division of Agronomy) (01/01/2004 to 31/12/2007)

Dr. Sharma, R.P. (National Research Centre on Plant Biotechnology) (01/03/2005 to 29/02/2008)

Dr. Varma, Anupam (Division of Plant Pathology) (05/07/2005 to 04/07/2008)