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भारतीय कृषि अनुसंधान संस्थान

INDIAN AGRICULTURAL RESEARCH INSTITUTE

(भारतीय कृषि अनुसंधान परिषद)

(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)

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Annual Report
2005 - 2006

भारतीय कृषि अनुसंधान संस्थान
Indian Agricultural Research Institute
(मानद विश्वविद्यालय)
(Deemed University)
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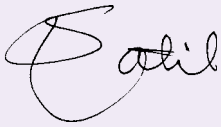
Preface

The year 2005 marked the centenary of the Indian Agricultural Research Institute. During the year, the Institute rededicated itself to the national goal of achieving food and nutritional security for its ever increasing population by contributing to higher agricultural production, productivity, and quality. Efforts were continued to be made towards protecting the environment and natural resource base. Transfer of appropriate technologies, multidisciplinary approaches to research, and creation of desired human resource continued to receive the Institute's attention.

This report summarises the various activities and achievements of the Institute during the year 2005-2006 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 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), under the technical guidance and immediate supervision of Dr. K.D. Srivastava, Incharge, Publication Unit and the overall supervision of Dr. A.K. Singh, Joint Director (Research) and former acting Director. Valuable guidance was also given by Dr. B.S. Parmar, former Joint Director (Research). Mr. Aman Kumar, Technical Assistant (T-4) assisted, particularly in proof reading. The Hindi version of the 'Executive Summary' included in the report was prepared by Mr. A.K. Dubey, Editor (Hindi). The computer typesetting of the manuscript was done by Shri Mukesh Kumar, Lower Division Clerk, and Ms. Sunita Joshi, Stenographer, Grade III.

My thanks are due to all.



(S.A. Patil)
Director

October 19, 2006
New Delhi

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IARI : AN INTRODUCTION

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

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

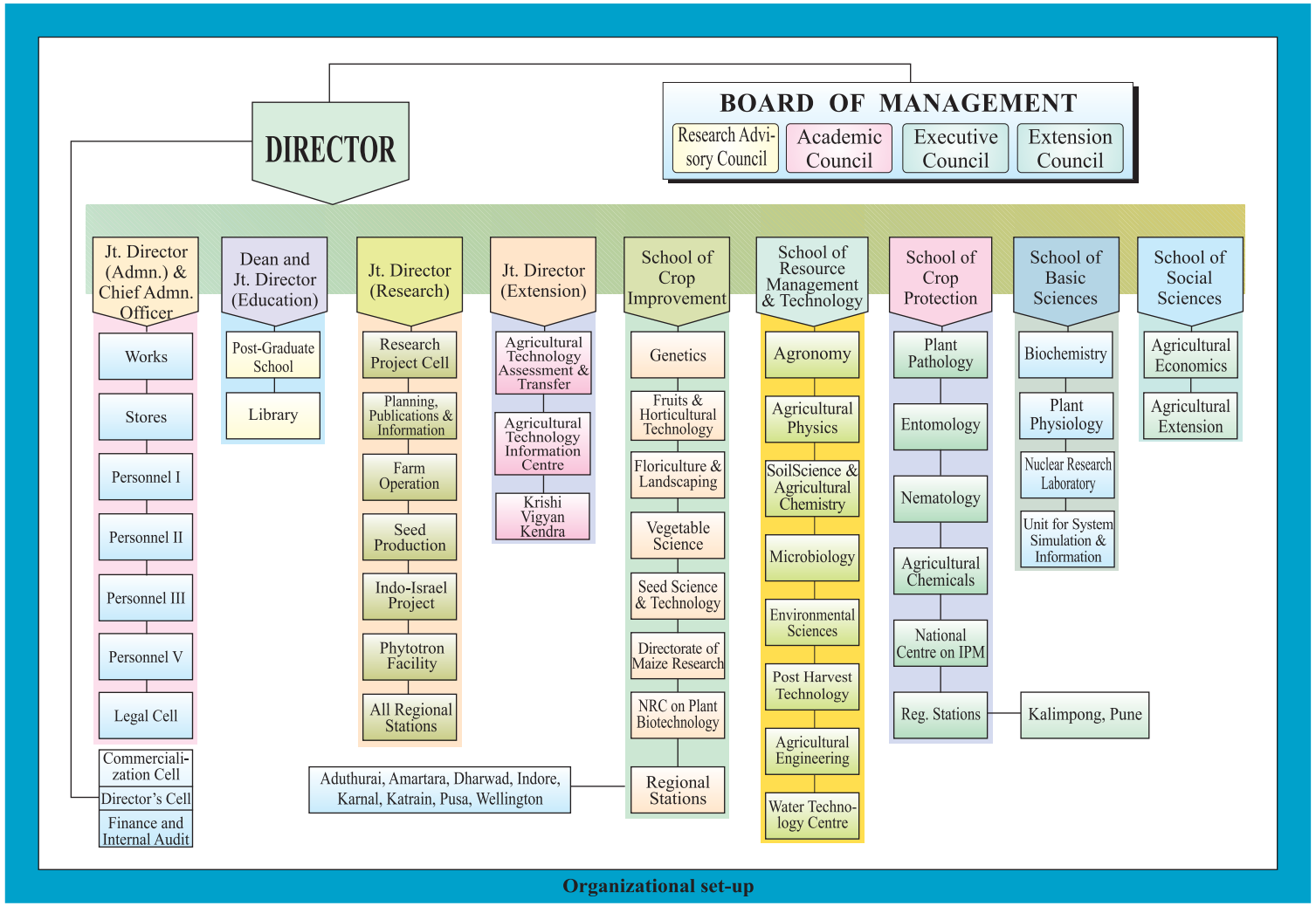
The growth of India's agriculture during the past 100 years is closely linked with the researches done and technologies generated by the Institute. The Green Revolution stemmed from the fields of IARI. Development of high yielding varieties of all major crops which occupy vast areas throughout the country, 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 3861comprising scientific, technical, administrative and supporting personnel. The revised budget of the Institute for the year 2004-2005 was Rs. 9312.71 lakh.



Organizational set-up

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वर्ष 2005–2006 के दौरान संस्थान द्वारा कृषि अनुसंधान, शिक्षा एवं प्रसार के अपने अधिदेशित क्षेत्रों में उल्लेखनीय कार्य किए गए।

बहुत सी फसलों में फसल सुधार कार्य प्रगति पर रहा तथा अनेक परीक्षणों को सफलतापूर्वक पूरा किया गया। गेहूं की चार किस्में नामतः एच डी 2888 (पूसा 107), एचडी 2833 (पूसा तृप्ति), एचआई 8627 (मालव कीर्ति) तथा एचडब्ल्यू 3094 (COW (W-1)) जारी की गईं। एचडी 2888 (पूसा 107) को बिहार, झारखण्ड, पश्चिम बंगाल, असम तथा उत्तर प्रदेश के कुछ भागों वाले उत्तरी पूर्वी मैदानी क्षेत्रों में समय से बुवाई वाली बारानी स्थितियों हेतु जारी किया गया। जबकि एचडी 2833 (पूसा तृप्ति) को प्रायद्वीपीय क्षेत्र की पछेती बुवाई वाली स्थितियों में व्यावसायिक खेती के लिए जारी किया गया। एचआई 8627(मालव कीर्ति) जो उच्च पैदावार वाला पहला जीनप्ररूप है तथा जिसका प्रदर्शन बारानी एवं प्रतिबंधित सिंचाई वाली परिस्थितियों में एक समान है, को मध्य क्षेत्र में खेती के लिए जारी किया गया। एचडब्ल्यू 3094 (COW (W-1)) किस्म को तमिल नाडु के सिंचित तथा मध्यम वर्षा वाले मैदानी क्षेत्रों और उससे सटे पर्वतीय क्षेत्रों में खेती के लिए जारी किया गया। इसके अलावा एचआई 1531 (हर्षिता) एवं एचडब्ल्यू 5001 (नीला मलार) किस्म की पहचान कर उन्हें क्रमशः मध्य क्षेत्र तथा दक्षिणी पर्वतीय क्षेत्रों में खेती के लिए जारी किया गया।

मक्का में दो कम्पोजिट किस्मों यथा पीसी 3 तथा पीसी 4 को बीज उत्पादन शृंखला की सुविधा हेतु अधिसूचित किया गया। भा.कृ.अ.सं. किस्म निर्मुक्ति समिति द्वारा संकर मक्का में अगेती परिपक्वता वाली श्रेणी में एएच 58 जिसे पहले जोन–IV के लिए पीईएचएम 3 के नाम से जारी किया गया था, को राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए जारी किया गया।

चारा–ज्वार की बहु–कटाई वाली किस्म पूसा चरी 615 को राष्ट्रीय राजधानी क्षेत्र, दिल्ली में जारी करने की सिफारिश की गई। चने में, बड़े दानों वाली दो काबुली किस्में बीजी 1108 तथा बीजीडी 128 एवं देसी चना उत्प्रजनक बीजीएम 547 की पहचान कर उन्हें विभिन्न उत्पादन परिस्थितियों के लिए जारी किया गया।

राष्ट्रीय राजधानी क्षेत्र, दिल्ली में व्यावसायिक खेती हेतु मसूर की एक किस्म, एल 4594 (पूसा मसूर 5) की पहचान कर उसे जारी किया गया। यह किस्म मध्यम बढ़वार, छोटे बीजों और नारंगी बीजपत्रों वाली है तथा रतुआ की भी प्रतिरोधी है। अरहर की पूसा 2001 किस्म की पहचान कर उसे राष्ट्रीय राजधानी क्षेत्र, दिल्ली में खेती के लिए जारी किया गया।

तिलहनी फसलों में दो *ब्रैसिका* किस्में नामतः एलईएस 39 (पूसा करिश्मा) जो पहली सिंगल जीरो (2 प्रतिशत से कम इरूसिक अम्ल वाली) किस्म है तथा जेडी 6 (महक) जो भारतीय सरसों की शीघ्र पकने वाली किस्म है, को अधिसूचित किया गया। शीघ्र पकने वाली तथा फलियां न चटकने वाली भारतीय सरसों की किस्म (पूसा तड़क) और एक *ब्रैसिका केरीनेटा* की किस्म एनपीसी 9 (पूसा आदित्य) की पहचान कर उन्हें राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए जारी किया गया।

सोयाबीन की एक किस्म, पूसा 9712 को राष्ट्रीय राजधानी क्षेत्र, दिल्ली के लिए अधिसूचित कर उसे उत्तरी पश्चिमी मैदानी क्षेत्र में जारी करने के लिए पहचाना गया। शाकीय फसलों में, सार्वजनिक क्षेत्र का पहला बन्दगोभी का संकर केजीएमआर 1 है। यह काला रतुआ बीमारी का प्रतिरोधी है तथा इसमें शीर्ष गठन के उपरांत खेत में टिके रहने की अच्छी क्षमता है व इसकी औसत पैदावार 35–45 टन/है. है। इसे जोन–I एवं जोन–IV

में जारी किए जाने की सिफारिश की गई। शिमला मिर्च का एक संकर केटीसीपीएच 3 फूले हुए खांचों के 3–4 आकर्षक हरे फल वाला व 25 टन/है. पैदावार देने वाला है। इसे जोन–I, VI तथा VII में जारी करने की सिफारिश की गई। अंगूर के दो आशाजनक संकर नामतः बीए X पर 75–32 तथा हूर X कार्डिनल 76–1 के श्रेष्ठ प्रदर्शन में निरंतरता पाई गई तथा इन्हें जारी करने के लिए पहचाना गया।

सजावटी फसलों में गुलाब की चार नई किस्मों जिनमें से तीन हाइब्रिड टी (पूसा अरूण, पूसा अजय तथा पूसा शताब्दी) तथा एक फ्लोरीबन्डा ग्रुप (पूसा कोमल) की है, को भा.कृ.अ.सं. किस्म पहचान समिति द्वारा जारी करने के लिए पहचाना गया। भा.कृ.अ.सं. किस्म पहचान समिति द्वारा गुलदाउदी के दो रेडियो उत्प्रजनक पूसा अनमोल और पूसा सेन्टेनरी की जारी किए जाने हेतु पहचान की गई।

आनुवांशिक संसाधनों के तहत विभिन्न किस्मों के बहुत से जीनप्ररूपों को बीमारी प्रतिरोधिता, क्वालिटी और अन्य आर्थिक गुणों की दृष्टि से उपयुक्त पाया गया। गेहूं जीनप्ररूप नामतः पूसा 2022ए, पूसा 2019ए/11, पूसा 2099ए तथा पूसा 2338ए/20 को राष्ट्रीय पादप आनुवंशिक संसाधन ब्यूरो, नई दिल्ली में पंजीकृत किया गया। कपास के दो आशाजनक वंशक्रमों बीएन–एआरबी 16 तथा बीएन–टीओएम 277 को भी राष्ट्रीय पादप आनुवंशिकी संसाधन ब्यूरो में पंजीकृत कराया गया। काबुली चने में शीघ्र परिपक्वता के नए स्रोत के रूप में बीजीडी 132 को भा.कृ.अ.सं. दलहन सुधार केन्द्र, धारवाड़ द्वारा विकसित किया गया। इसे आईसीसीवी 2 X आईसीसीवी 5 के संकर से प्राप्त किया गया। भा.कृ.अ.सं. केन्द्र, धारवाड़ में बुवाई के उपरांत इसमें 29–30 दिनों में फूल आए और यह 65–70 दिनों में पक कर तैयार हुई। यह एक अधिक पैदावार देने वाली किस्म है जिसमें आईसीसीवी 2, की तुलना में 5–7 दिन पूर्व फूल आ जाते हैं और यह 9–10 दिन पूर्व पककर तैयार हो जाती है। यह प्रायद्वीपीय एवं मध्य भारत में लोकप्रिय पहली अतिशीघ्र पककर तैयार होने वाली किस्म है। इसकी तुलना में स्थानीय रूप से अपनाई गई किस्म अन्निगेरी में फूल आने में 40–45 दिन का समय लगता है और यह 85–90 दिन में पकती है। वर्षा के बाद बची नमी में उगाए जाने पर इसके 100 बीजों का भार 28–30 ग्राम तथा दाना उपज क्षमता लगभग 1.4–1.5 टन/है. है। सूक्ष्मजैविक आनुवंशिक संसाधन पर किए गए अनुसंधान के तहत हैदराबाद तथा उससे सटे क्षेत्रों से संकलित मृदा नमूनों से नीलहरित शैवाल के 15 प्रभेद विलगित कर उनका जननद्रव्य के साथ संकलन किया गया। ये थे *नॉस्टॉक* (9), *एनाबीना* (4), *सिलिण्ड्रोस्पर्मम* (1) तथा *फॉरमिडियम* (1)।

वर्ष 2005 के दौरान 437 फफूंद नमूने जिनमें 38 टाइप नमूने भी शामिल थे, एचसीआईओ में क्रमबद्ध किए गए। दो नए वंशों; एक हाइफोमाइसीटीज, नामतः *मेनोहेराकेरियोमाइसेज लिग्निकोला* तथा अन्य एस्कोमाइसिटिज; नामतः *डायट्रीपॉइडियेला लिग्निकोला* का सृजन किया गया। चूर्णी फंफूद की पांच नई प्रजातियों; नामतः *ओडियम कैसिई लीशेनॉल्टिानी, ओ. कैसिई टोरी, ओ. क्रोटेलेरिये, ओ. हेलियोट्रॉपी स्ट्राइगोसम* तथा *ओ. रॉयले* को क्रमशः *कैसिई लीशेनॉल्टिनी एल; सी. टोरी एल; क्रोटेलेरिया जुन्शिया एल; हेलियोट्रापियम स्ट्रॉइगोसम वाइल्ड* तथा *रॉयले सिनेरिया* (डी.डॉन) बेइल पर संकलित कर उनका वर्णन किया गया। इसके अलावा डीमैटिएसी परिवार से जुड़ी डीमैटिसियस हाइफोमाइसीटीज; नामतः *मोलिसिया धन्कुटी* बेल्फोर ब्राउने की एक नई प्रजाति *एनेलोफोरा केटेनेटा* के रूप में पहली बार भारत में दर्ज की गई।

विभिन्न फफूंदों के 65 संवर्धनों को शामिल कर भारतीय किस्म संवर्धन संकलन (ITCC) को समृद्ध बनाया गया। विभिन्न फफूंद संवर्धनों में कुछ उल्लेखनीय पादप रोगजनक भी शामिल थे, जैसे : *सीरेटोसिस्टिस पेरॉडोक्सा* की *थीलेवियोप्सिस स्टेट; रॉइज़ोपस ओरायज़ी* जो कि सक्षम लेक्टिक एसिड उत्पादक है; गेहूं की बालियों से *ड्रेशलेरा हैलोडेस; फ्यूजेरियम पैलाडोरोसियम; जेटरोफा* से *मैक्रोफोमिना फेज़ियोलिना*; सफेद मूसली से *ग्लोमेरेला ट्यूकुमानेन्सिस; ऐम्पेलोमायसिज़ क्विनक्वेलिस; अल्टेरनेरिया अल्टरनेटा*; तेल–ताड़ में गुच्छा सड़न उत्पन्न करने वाला

कौलेटोट्रिकम ग्लीयोस्पोरिऑयडीज तथा *जेटरोफा* की आकस्मिक मृत्यु का कारण *बोट्रियोडिप्लोडिया थियोब्रोमी*।

प्रजाति स्तर पर कुल 145 संवर्धनों/नमूनों की पहचान की गई। रिपोर्टाधीन अवधि के दौरान कुछ महत्वपूर्ण फफूंद प्रजातियों की पहचान की गई; नामतः ग्वार पर *अल्टरनेरिया कुकुमेरिना* किस्म *साइमोप्सिडिस*, तेल–ताड़ पर *औकीनिटॉस डेन्कालेन्सिस*, तेल–ताड़ पर *सिंसिफेलेस्ट्रम रेसभाजम*, लौकी पर *कालेटोट्रिकम आर्बीकुलारे*, अंगूर के रस में *थाइलाविया टेरीकोला*, नारियल पर *फोमा मल्टीरोस्ट्रेटा*, बड़ी इलायची पर *पेस्टालोटिया ऑलिवेसिया*, चीन से आयातित लहसुन पर *इम्बेलिसिया एलाई*, अन्नानास *सेसेरैटोसिस्टिस पैराडॉक्सा*, सेब पर *एम्पेलोमाइसेस क्विनक्वैलिस* तथा चावल पर *स्प्लेरोटियम हाइड्रोफाइलम*। इसके अलावा, भिण्डी तथा सिल्क वर्म पर क्रमशः *ब्यूवेरिया बैसियाना* तथा *पीसिलोमाइसीज लिलेसिनस* की पहचान की गई।

दो नई प्रजातियों; नामतः *अपेण्डीकुलेला वेन्डलेन्डिया* प्रमिला एवं चौधरी तथा अन्य साथी और *मेलिओला युगोनिया* आब्लैटा चौधरी एवं प्रमिला तथा साथी का सृजन किया गया। इसके अलावा, *मोनीलिएल्स* समूह *बोट्रियोडिओरसम* की *हाइफोमाइसीटिज़* फफूंद का भारत से सृजन कर वर्णन किया गया तथा *बोट्रियोडिओरसम* इन्डीकम को टाइप प्रजाति के रूप में प्रस्तुत किया गया।

कीट पहचान सेवा के तहत कोलियाप्टेरा तथा हाइमेनोप्टेरा गणों (ऑर्डर) से संबंधित कुल 642 नमूनों की पहचान की गई।

भारतीय उपमहाद्वीप के उप कुल फार्मीसिनी से संबंधित सभी 16 वंशों एवं 148 प्रजातियों की सूची तैयार की गई। कैम्पोनोटस वंश की ग्यारह प्रजातियों यथा *सी. अंगुस्टिकोलिस, सी. ऐरोगन्स, सी. कैमेलिनस, सी. कम्प्रेसस, सी. डाइकोरस, सी. जाइगस, सी. मैकुलेटस, सी. निकोबैरिन्सिस, सी. पैरिया, सी. रूफोग्लेकस* तथा *सी. सेरीसियस* का पुनः वर्णन किया गया। अतिरिक्त लक्षणों, उपयुक्त चित्रों तथा आकृति–ज्यामिति का समामेलन कर वर्णन को विस्तृत रूप प्रदान किया गया।

फसल एवं संसाधन प्रबंध तथा पर्यावरण अनुसंधान के तहत बहुत से महत्वपूर्ण अध्ययन किए गए। इनमें प्रमुख थे :– सुगंधित चावल में जिंक समृद्ध यूरिया का मूल्यांकन; चावल–गेहूं फसल प्रणाली की उत्पादकता पर पादप पोषक तत्वों के कार्बनिक स्रोतों का प्रभाव; मक्का पर अकार्बनिक तथा कार्बनिक स्रोतों का प्रभाव और गेहूं पर उनका अवशिष्ट प्रभाव; छोलिया के लिए चने की अगेती किस्म पर फास्फोरस अनुप्रयोग की प्रतिक्रिया और अनुवर्ती बेबी कॉर्न की फसल पर उसका अवशिष्ट प्रभाव; अरहर–गेहूं फसल प्रणाली में सल्फर और उसके स्रोतों की प्रतिक्रिया; तना कटिंग और बीज के माध्यम से जेटरोफा की पौदों के प्रवर्धन हेतु कृषि तकनीकें; मूंग–सरसों फसल प्रणाली में सरसों की फसल में प्रयुक्त पोषक तत्वों का प्रत्यक्ष और अवशिष्ट प्रभाव; बारानी परिस्थितियों में मसूर की फसल में जलीय उर्वरकों के उपयोग के दौरान पोषक तत्व प्रबंधन; मक्का आधारित फसल प्रणाली में जुताई एवं अवशिष्ट प्रबंध संबंधी विधियां; विभिन्न खरीफ फसलों के उपरांत भिन्न जुताई एवं अवशिष्ट प्रबंध विधियों के तहत गेहूं का निष्पादन; चावल–गेहूं फसल प्रणाली में जैविक खेती पर अध्ययन; कार्बनिक स्रोतों के माध्यम से ब्रोकोली आधारित फसल प्रणाली में पोषक तत्व प्रबंध; सिंचित लवणीय परिस्थितियों में नए गेहूं जीनप्ररूप का निष्पादन; सिंचित परिस्थितियों में बुवाई की भिन्न तारीखों पर नए गेहूं जीनप्ररूपों का प्रदर्शन तथा पारंपरिक सिंचाई के साथ–साथ शून्य जुताई परिस्थितियों के तहत गेहूं की उपयुक्त किस्मों की छंटाई ।

बीज विज्ञान एवं प्रौद्योगिकी के अन्तर्गत सुगंधित चावल और संकर चावल व टमाटर तथा बैंगन की बीज उत्पादन प्रौद्योगिकी; पादप किस्म संरक्षण हेतु डीयूएस परीक्षण; बीज परीक्षण; बीज गुणवत्ता में सुधार एवं गिरावट; करेला तथा भिण्डी के बीजों में ठोस मैट्रिक्स प्राइमिंग तथा विकसित एवं विकासशील देशों के साथ भारत के शाकीय बीज अंकुरण मानकों के तुलनात्मक आकलन पर अध्ययन किए गए। विभिन्न फसलों के नाभिक, प्रजनक तथा भा.कृ.अ.सं. बीजों का उत्पादन भी बड़ी मात्रा में किया गया।

मृदा प्रबंध के तहत चावल–गेहूं तथा मक्का–गेहूं फसल प्रणालियों; मौसम परिवर्तन के तहत फसल जड़ क्षेत्र में पोषक तत्वों का संचरण; वायवीय चावल के तहत लौह (आयरन) अल्पता का निदान और सुधार; गेहूं तथा मक्का के राइज़ो–डिपोज़िटों द्वारा लेड और निकल की जटिलता; मिट्टी में भारी धातुओं से होने वाले संदूषण के प्रभाव और उसका उपचार; तथा रासायनिक और जैविक साधनों से चावल पुआल की कम्पोस्टिंग प्रक्रिया में तेजी लाना जैसे विषयों का अध्ययन किया गया।

जल प्रबंधन के तहत, टिकाऊ कृषि उत्पादन प्रणाली के लिए उन्नत जल प्रबंध और प्रौद्योगिकी विकास के माध्यम से जल संसाधन उपयोगिता; फसल उत्पादन बढ़ाने के लिए जल एवं पोषक तत्वों के उपयोग हेतु समुचित प्रौद्योगिकियों के विकास; सिंचित एवं बारानी खेती के लिए जल प्रबंध प्रौद्योगिकी के विकास; टिकाऊ कृषि के लिए जल संभर आधारित प्रबंध; राष्ट्रीय राजधानी क्षेत्रों के भू–जल में नाइट्रेट स्तर के साथ–साथ मिट्टी में रसायनों की मौजूदगी; और भू–जल के रासायनिक मूल्यांकन में मिट्टी, खनिजों और आइसोटोपिक प्रमाणों की भूमिका का अध्ययन किया गया।

समेकित पोषण प्रबंध पर महत्वपूर्ण अध्ययन किये गए। ये थे : सोयाबीन–गेहूं फसल प्रणाली के तहत मृदा की गुणवत्ता पर समेकित पोषक तत्व प्रबंध का प्रभाव; मूंग–आलू फसल अनुक्रम में फसल उत्पादकता तथा मिट्टी उर्वरता पर कार्बनिक–खनिज उर्वरकों की समृद्धता का मूल्यांकन; गेहूं के लिए मूल आंकड़ों का विकास और मृदा परीक्षण आधारित उर्वरकों की सिफारिशें; मृदा परीक्षण आधारित उर्वरकों की सिफारिशों का गेहूं की पैदावार और मृदा उर्वरता पर प्रभाव; मक्का–गेहूं फसल प्रणाली के तहत फसल उत्पादकता और मृदा की गुणवत्ता पर दीर्घावधि तक उर्वरकों और खाद के उपयोग का प्रभाव; समेकित पोषक आपूर्ति और प्रबंध के माध्यम से फसलों की उत्पादकता और गुणवत्ता बढ़ाने के लिए मृदा स्वास्थ्य को बनाए रखने; खरीफ की मूंग के लिए समेकित सल्फर प्रबंध; विभिन्न रोपण प्रणालियों के तहत गेहूं में समेकित पोषण प्रबंध; तथा फलीय फसलों में समेकित पोषक प्रबंध। इनके अतिरिक्त विभिन्न कृषि पारिस्थितिक क्षेत्रों में मृदा उर्वरता के स्तर; पारंपरिक तथा उठी हुई क्यारियों में रोपण के तहत चावल में नाइट्रोजन उपयोग की दक्षता; मानव पौष्टिकता के लिए खाद्य उत्पादों में जैव उपलब्धता/जैव सुरक्षा तथा फसल पौष्टिकता के लिए मिट्टी में आयरन तथा जिंक की गतिशीलता और उपलब्धता; तथा चावल में $^{137}C_s$ के ट्रांसफर फैक्टर पर पोटेशियम उर्वरक के अनुप्रयोग के प्रभाव पर भी अध्ययन किये गये।

अधिकतम फसल उत्पादन और कृषि कार्यों में लगने वाले श्रम को कम करने के उद्देश्य से संस्थान द्वारा खेती से संबंधित बहुत से उपकरण, मशीनरी और प्रौद्योगिकियां विकसित की गई हैं। क्षमता बढ़ाने और श्रम को कम करने के लिए प्याज की गांठों को पौधों से काटने के लिए एक यंत्र का विकास किया गया। मक्का फसल के रोपण हेतु हल्के वजन के कम हार्स पावर वाला तथा इंजन से चलने वाले मक्का रोपाई यंत्र का डिज़ाइन तैयार कर उसे विकसित किया गया। समान श्रेणी के चार नमूनों को छांटने के उद्देश्य से नींबू, बेर तथा आंवला जैसे फलों के लिए एक रोटेटिंग स्क्रीन ग्रेडर विकसित किया गया।

मशीनों के बड़े पैमाने पर उत्पादन में जिग्स तथा उसमें लगने वाले सामान (फिक्सचर) का विकास कर उत्पाद की गुणवत्ता बढ़ाने, फेब्रिकेशन की लागत घटाने, अदल–बदल कर लगाए जा सकने वाले पुर्जों के निर्माण को सुनिश्चित करने, उत्पादन समय में कमी लाने तथा उत्पादन की कुल विश्वसनीयता में सुधार लाने पर कार्य किया गया। तदनुसार हैंडल बैंडिग, शैंक बैंडिंग, तीलियों तथा फ्रेम बार के लिए वेल्डिंग फिक्सचरों और हाथ से चलने वाले व्हील के क्रास बार जैसे विभिन्न उपकरणों के पुर्जों का विकास किया गया। रबड़ रोल के शेलर, छिलका हटाने के लिए एक ब्लोअर तथा दाल पॉलिश करने वाली छोटी क्षमता की दाल मिल का भी विकास किया गया। अन्तराल समायोजन यांत्रिकी उपलब्ध कराकर पारंपरिक आटा चक्की में सुधार किया गया। मशीनीकरण के स्तर को इष्टतम बनाने के संदर्भ में संस्थान द्वारा करनाल और

गुड़गांव जिलों में फार्म मशीनरी उपयोग पैटर्न पर अध्ययन का आयोजन किया गया। अन्य अध्ययन भी किए गए जिनमें प्रमुख थे – भारतीय ट्रैक्टरों के लिए विभिन्न नियंत्रण खाकों की तुलना; कुछ फसल अवशेषों की संघनन संबंधी विशेषताएं; कृषि में पुनर्नव्य ऊर्जा स्रोतों का उपयोग; फूलगोभी का शुष्कन; परिशुद्ध खेती के लिए माइक्रो कन्ट्रोलर का विकास; ग्रीन हाउस की गणितीय मॉडलिंग; तथा जैव सामग्री का शुष्कन।

इंडो–इज़राइल परियोजना में शाकीय एवं पुष्पीय फसलों की उत्पादन प्रौद्योगिकी पर अध्ययन किए गए। शाकीय फसलों के लिए ड्रिप सिंचाई के द्वारा उर्वरकों के नियमित उपयोग को फसल चक्र के दौरान जड़ क्षेत्र में नमक के संचय और मृदा के संघनन के लिए जिम्मेदार माना गया। नमक को जमीन में नीचे रिसने देने के लिए ठोस पर्तों को तोड़ने हेतु प्रत्येक फसल चक्र के बाद गहरी जुताई की सिफारिश की जाती है। इन तथ्यों को ध्यान में रखते हुए दो टाइन्स वाले एक गहरे जुताई यंत्र की डिज़ाइन तैयार कर उसे बनाया गया।

पर्यावरण विज्ञान से संबंधित प्रमुख अध्ययन थे – भारत के विभिन्न प्राकृतिक क्षेत्रों में मृदा से कार्बन डॉइआक्साइड के तीव्र प्रवाह (फलक्स) का अनुक्रिया आधारित तापमान; पराग अंकुरण पर उच्च तापमान का प्रभाव; चावल–गेहूं फसल प्रणाली के तहत मृदा की विश्व ऊष्मन (ग्लोबल वार्मिंग) क्षमता पर जुताई प्रबंध का प्रभाव; चावल की फसल की बढ़वार एवं उपज पर उच्च तापमान का प्रभाव; पादप रोगजनक गतिकी पर उच्च तापमान का प्रभाव; जेटरोफा का कृषि प्रबंध; तांबे (कॉपर) के संदर्भ में जेटरोफा के बीज आवरण की शोषण और विशोषण क्षमता; *जे. कर्कस* के बीजांकुरण पर लवणता एवं परासरणी दबाव का प्रभाव; जैव–एथानॉल उत्पादन हेतु मक्का की उपयुक्त किस्मों की छंटाई; श्री गंगा नगर जिले की मिट्टी की सूक्ष्मजैविक समुदाय अवसंरचना एवं कार्यप्रणाली पर Bt कॉटन का प्रभाव; भार की कमी की विभिन्न खाद्य फसलों पर गुणात्मक एवं परिमाणात्मक प्रतिक्रिया; कृषि में कृषि–औद्योगिक निःस्रावों की उपयोगिता; राष्ट्रीय राजधानी क्षेत्र के लिए एक स्थानिक संसाधन चरित्रांकन प्रणाली; भूकम्प अध्ययन एवं आपदा प्रबंध के लिए भू–जल हीलियम का सर्वेक्षण; भू–जल विविधताओं से सम्बद्ध भौगोलीय अनिश्चितताओं के प्रमाण; तथा चावल की दाना पैदावार पर विभिन्न वातावरणीय प्रभाव। सूक्ष्मजीव विज्ञान के क्षेत्र में संस्थान द्वारा अनेक पहलुओं पर अध्ययन किये गए जिनमें प्रमुख हैं–सूक्ष्मजैविक कन्सोर्टियम का उपयोग करते हुए विभिन्न सबस्ट्रेट्स से तैयार कम्पोस्ट की पोषक क्वालिटी का मूल्यांकन; कम्पोस्ट की क्वालिटी पर नाइट्रोजन और जिंक समृद्धिकरण (फोर्टीफिकेशन) की भूमिका; निम्न जैविक कार्बन युक्त परिस्थितियों के लिए *एज़ोटोबैक्टर जैक्टीकों* (बायोइनोकुलेन्टस) का विकास; एज़ोटोबैक्टर पर कार्बन स्रोतों का प्रभाव तथा तरल जैव–टीकों का विकास; एज़ोटोबैक्टर प्रभेद–W5 के पुटीभूत होने में *n-ब्यूटानॉल* का प्रभाव; निम्न कार्बन परिस्थितियों हेतु *एज़ोटोबैक्टर* टीकों का विकास; फॉस्फेट को घुलनशील बनाने वाले तरल जैव–टीकों (पीएसबी) का फार्मुलेशन; बारानी परिस्थितियों के तहत सोयाबीन की पैदावार पर एएम फफूंद तथा पीएसबी का प्रभाव; बारानी सोयाबीन पर *ब्रैडीराइज़ोबियम जेपोनिकम* के साथ पीजीपीआर्स की पारस्परिक प्रतिक्रिया; *राइज़ोक्टोनिया बटाटीकोला* के प्रति फफूंदनाशी यौगिक का जैवरासायनिक लक्षण वर्णन; *पी. स्ट्रेटा* के क्लोन किए गए जीनों के साथ पराजीनी जैव–उर्वरक सायनोबैक्टीरिया (*नास्टॉक मस्कोरम*) का विकास; H_2 उत्पादन एवं N_2 स्थिरीकरण हेतु साइनोबैक्टीरिया का आनुवंशिक मूल्यांकन; साइनोबैक्टीरिया का आण्विक चरित्रांकन; कम निवेश में चावल उगाने वाले क्षेत्रों से नील हरित शैवाल का विलगन एवं उनकी पहचान; चावल तथा गेहूं की जैविक खेती; चावल–गेहूं फसल प्रणाली के समेकित पोषक तत्व प्रबंध में जैव–उर्वरक; साइनोबैक्टीरिया प्रभेदों से जैवसक्रिय यौगिक; सूक्ष्म शैवाल द्वारा भारी धातु क्रोमियम का जैवउपचार; *एज़ोला* का उपयोग करते हुए व्यर्थ जल का जैवउपचार तथा कानपुर के चमड़ा उद्योग से एकत्रित Cr संदूषित निःस्सारित तरल का उपचार।

बागान प्रबंध के तहत निम्नलिखित अध्ययन किए गए

– आम अपरूपण; अमरूद, आम तथा नींबू वर्गीय फलों में मूलवृंत संबंधी अनुसंधान। कटाई उपरांत प्रौद्योगिकी और प्रबंध के तहत किए गए अध्ययन हैं – अमरूद के फलों के लिए नियंत्रित वातावरण प्रौद्योगिकी; पके हुए आम की बाजार क्षमता बढ़ाना; बेल फल की गुणवत्ता पर श्रेणीकरण का प्रभाव; आम में परिपक्वता अध्ययन; अमरूद (इलाहाबाद सफेदा) किस्म के वृक्ष की आयु और वितान ऊंचाई पर अध्ययन; प्रसंस्कृत आम (चौसा) की फांकों की पौष्टिक और सूक्ष्मजैविक गुणवत्ता; न्यूनतम प्रसंस्कृत करेले के छल्लों (पूसा दो मौसमी) का गुणवत्ता मूल्यांकन; प्रसंस्कृत आम की फांकों और न्यूनतम प्रसंस्कृत करेले के छल्लों का पैकेजिंग अध्ययन; आंवला के टुकड़ों का परासरणी–प्रसंस्करण, निर्जलीकरण के लिए गाजर की किस्मों का मूल्यांकन; मेथी की सूखी पत्तियों की पैकेजिंग और भण्डारण; करेले के सूखे छल्लों का भण्डारण; अमरूद की फांकों का परासरणी शुष्कन;, फ्रोजन गाजरों में बीटा–केरोटिन की मात्रा पर ब्लांचिंग विधियों का प्रभाव; प्रसंस्कृत विधियों से प्रभावित प्याज में पूर्ण फ्लैबोनॉइड्स को बनाए रखना; मक्का के जीनप्ररूपों का भौतिक लक्षण–वर्णन; कम्पोजिट मक्का की किस्मों के भौतिक गुण; अरहर की तीन किस्मों के कुकिंग समय पर रासायनिक उपचारों का प्रभाव; आम के गूदे का विकिरण उपचार; तथा अरहर की साबुत दाल को विकिरण द्वारा संक्रमण से बचाना।

फसल सुरक्षा के क्षेत्र में गेहूं, चावल, मक्का, चना, उड़द, मूंग, अरहर, सोयाबीन, तोरिया तथा सरसों, सब्जियों तथा बड़ी इलायची को प्रभावित करने वाले फंफूद रोगों पर महत्वपूर्ण अनुसंधान परिणाम प्राप्त किये गए। इसके अलावा, चावल के टुंगरो रोग; मूंग के पीली चित्ती विषाणु; टमाटर के पर्णकुंचन कारक नई दिल्ली विषाणु; मूंगफली के कली ऊतकक्षय विषाणु; और नींबू वर्गीय फलों के विषाणु और विषाणुक्त रोगों और उनके प्रबंध पर भी महत्वपूर्ण अध्ययन किये गए। साथ ही पपीते, नगरों के आस–पास उगाई जाने वाली सब्जियों और बड़ी इलायची को प्रभावित करने वाले विषाणु रोगों पर महत्वपूर्ण अनुसंधान परिणाम प्राप्त किए गए। चावल को प्रभावित करने वाले जीवाण्विक रोगों पर अध्ययन के साथ–साथ खुम्बी के जीवविज्ञान एवं प्रभेद सुधार पर भी अध्ययन किए गए।

कीट विज्ञान के क्षेत्र में अनाजों, तिलहनों, सब्जियों, सोयाबीन, दालों और कपास पर कीट व नाशीजीव प्रबंध संबंधी अध्ययन किये गए। भण्डारण कीटविज्ञान पर भी अध्ययन किए गए। इसके अलावा जैविक नियंत्रण; कीट शरीर–क्रियाविज्ञान और कीट आविषालुता पर भी अध्ययन किए गए।

सूत्रकृमि विज्ञान में जैव–विविधता; प्रतिरोधित यांत्रिकी; सूत्रकृमि प्रबंध; दीमक प्रबंध हेतु कीट–रोगजनक सूत्रकृमियों और जैविक नियन्त्रण एजेन्टों की आविषालुता पर महत्वपूर्ण अध्ययन किए गए।

कृषि रसायन के क्षेत्र में जिन विषयों के अनुसंधान पर विशेष बल दिया गया वे हैं – प्राकृतिक एवं कृत्रिम कृषि–रसायनों और उनके सहायकों का विकास; नाशीजीवनाशी जोखिमों का मूल्यांकन, पर्यावरण नियति एवं निदान; नाशीजीवनाशी फार्मुलेशनों की सुरक्षा तथा प्रभावशीलता में सुधार। खरपतवार प्रबंध अध्ययन के अन्तर्गत परम्परागत और शून्य जुताई वाली गेहूं की फसल में खरपतवार प्रबंध; अल्प मात्रा में शाकनाशी का उपयोग करते हुए सोयाबीन में खरपतवार प्रबंध; प्याज की बीज फसल में खरपतवार प्रबंध के साथ–साथ खरबूजे में समेकित खरपतवार प्रबंध जैसे विषय शामिल किए गए।

संस्थान द्वारा आधारभूत एवं नीतिगत अनुसंधान के क्षेत्रों में महत्वपूर्ण अध्ययन किये गये। पादप जैवप्रौद्योगिकी पर किए गए अध्ययन हैं – पराजीनों के विकास हेतु जीनों और प्रमोटरों का पृथक्करण; संकर ओज के दोहन द्वारा उत्पादकता वृद्धि; जैविक प्रतिबल प्रतिरोधिता हेतु पराजीनी फसलों का विकास; अजैविक प्रतिबल सहिष्णुता के लिए पराजीनी फसलों का विकास; प्रभावी सूक्ष्मजीव–पादप अंतरक्रिया के लिए आनुवंशिक अभियांत्रिकी द्वारा तैयार सूक्ष्मजीवों का विकास; फसलीय पौधों में गतिकी एवं आण्विक मार्कर; तथा फलीय फसलों में आण्विक चरित्रांकन और सूक्ष्मप्रवर्धन।

जैवरसायनविज्ञान संबंधी अध्ययन इस प्रकार हैं – *बोगेनविलिया ब्यूटियाना* के जीन संलेपित प्रतिविषाणु प्रोटीन का क्लोनीकरण एवं लक्षण वर्णन; *ब्रैसिका जुंशिया* से ली गई एक डाइएकाइलग्लिसरॉल के एकाइल ट्रांसफरेज जीन श्रृंखला का क्लोनीकरण; सोयाबीन से लिए गए *fad 2-1* जीन संलेपित ω–6–असंतृप्त का विलगन एवं लक्षण वर्णन; तथा *fad 2-1* एक्सप्रेशन हेतु एंटीसेंस निर्माण की डिज़ाइन; और चावल में नमी की कमी वाली स्थिति में विभिन्न निगमित जीनों का विलगन एवं लक्षण वर्णन।

पादप शरीरक्रियाविज्ञान से संबंधित महत्वपूर्ण अध्ययन थे – उत्पादकता को सीमित करने वाली शरीरक्रियाविज्ञानी बाधाएं; फसल पौधों में अजैविक प्रतिकूलता के प्रति सहिष्णुता में सुधार; फलों, सब्जियों व फूलों का कटाई उपरांत शरीरक्रियाविज्ञान; वैश्विक जलवायु परिवर्तन के प्रति फसलों की प्रतिक्रिया के संदर्भ में उनका लक्षण वर्णन; कृषि उत्पादों की पादप अनुक्रिया और कटाई उपरांत गुणवत्ता परिरक्षण का लक्षण वर्णन; फसल उत्पादकता और कटाई उपरांत भंडारण क्षमता बढ़ाने हेतु भौतिक विधियों का अनुप्रयोग; गेहूं में जस्ते की दक्षता के संदर्भ में आनुवंशिक एवं फाइटोसाइडेरफोर उत्पादन व उसका शरीरक्रियाविज्ञानी नियमन; फसल की पछेती अवस्था में उच्च तापमान की स्थितियों के अंतर्गत गेहूं के जैव–भौतिक प्राचलों के बीच संबंध; तथा प्रयोगशाला परिस्थितियों के तहत अंकुरण एवं पादप वृद्धि पर गामा विकिरण और नमी की मात्रा का प्रभाव।

संस्थान में गेहूं, चावल, मक्का, बाजरा, चना, मूंग और *ब्रैसिका* से संबंधित महत्वपूर्ण आनुवंशिक अध्ययन किए गए और *ड्रोसोफिला मिलेनोगेस्टर* के गुणसूत्र 2L के Wnt जीन गुच्छों पर अध्ययन करके महत्वपूर्ण निष्कर्ष निकाले गए।

कृषि भौतिकी के क्षेत्र में मृदा भौतिकी; कृषि मौसमविज्ञान; और सुदूर संवेदन एवं भौगोलिक सूचना प्रणाली (जीआईएस) पर अध्ययन किये गए। फसल मॉडलिंग पर भी महत्वपूर्ण कार्य किया गया।

कृषि अर्थशास्त्र के क्षेत्र में किए गए अध्ययनों में शामिल थे – कृषि में नाशीजीवनाशियों का उपयोग एवं टिकाऊपन; उभरते मुद्दे व नीतिगत विकल्प; भारत में मक्का के विशेष संदर्भ में कृषि के टिकाऊ विकास में सुधार लाने हेतु कारकों की पहचान; भारत के गंगा तटीय मैदानों में खेत की अर्थव्यवस्था पर संसाधन संरक्षित करने वाली प्रौद्योगिकियों को अपनाना एवं उनका प्रभाव; खाद्य सुरक्षा उपाय और भारतीय बागवानी निर्यात पर उनका प्रभाव; भारत में बागवानी बाजार का सह–एकीकरण; भारत में बागवानी जिंसों की विपणन सूचना प्रणाली, स्थिति, बाधाएं एवं संभावनाएं; भारतीय कृषि पर उदारीकरण का प्रभाव; तथा परिनगरीय कृषि और दिल्ली में इसका प्रबंध।

कृषि प्रसार में आयोजित अध्ययन में सम्मिलित थे – टिकाऊ विकास के लिए फार्मिंग प्रणाली अनुसंधान एवं प्रसार; प्रसार संगठनों की प्रभावोत्पादकता बढ़ाना; अन्तर–क्षेत्रीय सूक्ष्म–योजना हेतु सहभागिता प्रसार कार्यप्रणाली और नीति का विकास; कृषि प्रौद्योगिकियों के सामाजिक–आर्थिक एवं पर्यावरणीय प्रभाव का मूल्याकन; बाजारोन्मुख प्रसार को बढ़ावा देने के लिए सूचना एवं संचार प्रौद्योगिकियों का उपयोग; प्रशिक्षण कार्यक्रमों के प्रभाव का विश्लेषण; ग्रामीण संसाधन प्रबंध (कार्यक्रम मूल्याकन पर एक पायलट कार्य अनुसंधान) में क्षमता निर्माण का मूल्यांकन; दूर–दराज क्षेत्रों तक पहुंचना और आदिवासी क्षेत्रों से ग्रामीण पलायन को रोकना; *ड्यूरम* गेहूं की खेती एवं खपत को लोकप्रियता प्रदान करते हुए कुपोषण निवारण तथा गैर–पारम्परिक क्षेत्रों में गेहूं की खेती को सम्मिलित कर फसल विविधीकरण करना ।

राष्ट्रीय राजधानी क्षेत्र, दिल्ली के सिंचित कृषि पारिस्थितिक क्षेत्र में चावल–गेहूं उत्पादन प्रणाली के अन्तर्गत संस्थान–ग्राम सम्पर्क कार्यक्रम (आई वी एल पी) के माध्यम से प्रौद्योगिकी निर्धारण एवं परिष्करण पर चलाई जा रही संस्थान की परियोजना अपने अंतिम चरण में थी जिसे अप्रैल, 2005 में समाप्त कर दिया गया। हालांकि, फसल प्रणाली में सघनता और विविधता को सम्मिलित करते हुए परियोजना के तहत गांवों में कुछ

कार्यो को बनाए रखा गया । संस्थान द्वारा विभिन्न कृषि पारिस्थितिक क्षेत्रों में कृषि प्रौद्योगिकियों के उपयोग हेतु प्रगति के नवीन क्षेत्रों की संभावनाएं तलाशने के लिए अन्य प्रयास किये गये। विभिन्न फसलों के प्रदर्शन के अतिरिक्त संस्थान द्वारा रिपोर्टाधीन अवधि में अनेक अग्रणी प्रदर्शनों का आयोजन किया गया । संस्थान में 14–16 फरवरी, 2005 को शताब्दी वर्ष पूसा कृषि विज्ञान मेले का आयोजन किया गया जिसका मुख्य विषय 'बीज से समृद्धि' था। संस्थान द्वारा प्रसार संबंधी अनेक गतिविधियां चलाई गईं जिनमें कपास,चावल तथा कृषि प्रौद्योगिकियों पर किसानों को प्रशिक्षण देना भी शामिल था। संस्थान के कृषि प्रौद्योगिकी सूचना केन्द्र (एटिक) द्वारा 'सिगंल विंडो डिलीवरी सिस्टम' के माध्यम से विभिन्न पण– धारकों (स्टेक होल्डर्स) को उत्पाद, सेवाएं, प्रौद्योगिकी तथा सूचना उपलब्ध कराई जाती हैं। भारत के 21 राज्यों और एक केन्द्र शासित प्रदेश के कुल लगभग 10650 किसानों/उद्यमियों, विकास विभाग के अधिकारियों, छात्रों, गैर–सरकारी संगठनो के प्रतिनिधियों, आदि ने 'एटिक' का दौरा कर खेत परामर्श, नैदानिक सेवाओं, प्रौद्योगिकीय निवेशों/उत्पादों की खरीद और प्रशिक्षण और वहां उपलब्ध अन्य सूचनाओं से लाभ उठाया ।

संस्थान का शिकोहपुर, गुड़गांव स्थित कृषि विज्ञान केन्द्र, प्रौद्योगिकी हस्तांतरण संबंधी विभिन्न कार्यक्रमों के माध्यम से प्रौद्योगिकीय सहायता प्रदान करके ग्रामीण युवाओं को रोजगार प्रदान करने और खेत उत्पादकता बढ़ाने में महत्वपूर्ण भूमिका निभा रहा है । कृषि विज्ञान केन्द्र द्वारा वर्ष के दौरान अपने अधिदेशों के माध्यम से लक्ष्यों को प्राप्त करने के उद्देश्य से अनेक गतिविधियां चलाई गईं ।

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

भारतीय कृषि अनुसंधान संस्थान का 43वां दीक्षांत समारोह 11 फरवरी 2005 को आयोजित किया गया। इस समारोह में कुल 76 एम.एमसी. और 69 पीएच.डी. छात्रों को डिग्रियां प्रदान की गईं। रिपोर्टाधीन अवधि के दौरान संस्थान में अनेक नियमित व अल्पावधि प्रशिक्षण पाठ्यक्रम आयोजित किए गए। यहाँ कृषि जैव–सूचना और सॉफ्टवेयर विकास पर भी कार्य किए गए।

भारतीय कृषि अनुसंधान संस्थान का पुस्तकालय वैज्ञानिक समुदाय को निरन्तर अपनी सेवाएं प्रदान कर रहा है। अनुसंधान संबंधी सूचनाओं के प्रसार हेतु संस्थान से हिन्दी तथा अंग्रेजी, दोनों भाषाओं, में कई तदर्थ तथा नियमित प्रकाशन निकाले गए । संस्थान की व्यावसायिक और बौद्धिक सम्पदा अधिकार (आईपीआर) संबंधी गतिविधियों के परिणामस्वरूप 11 पेटेण्टों का आवेदन किया गया और पांच समझौता ज्ञापनों/करारों को अन्तिम रूप दिया गया। संस्थान का बहुत सी राष्ट्रीय और अन्तरराष्ट्रीय संस्थाओं के साथ संपर्क एवं सहयोग जारी है।

EXECUTIVE SUMMARY

Significant contributions were made by the Institute in its mandated areas of agricultural research, education and extension during the year 2005-2006.

The crop improvement work continued to play a vital role and many trials were conducted successfully in several crops. In wheat, four varieties, namely, HD 2888 (Pusa 107), HD 2833 (Pusa Tripti), HI 8627 (Malav Kirti) and HW 3094 (COW (W-1) were released. HD 2888 (Pusa 107) was released for timely sown rainfed conditions for North Eastern Plains Zone comprising the states of Bihar, Jharkhand, West Bengal, Assam and parts of Uttar Pradesh. HD 2833 (Pusa Tripti) was released for commercial cultivation under late sown irrigated conditions of Peninsular Zone. HI 8627 (Malav Kirti), the first high yielding genotype, which performed equally well under both rainfed and restricted irrigation conditions, was released for cultivation in Central Zone. HW 3094 (COW (W-1) was released for the state of Tamil Nadu under irrigated and medium rainfall areas of the plains and adjoining areas near to hills in Tamil Nadu state. Besides these two varieties, HI 1531 (Harshita) and HW 5001 (Neela Malar) were identified for release in Central Zone and Southern Hills Zone, respectively.

In maize, two composites, PC 3 and PC 4, were notified for facilitating their formal movement into seed production chain. In maize hybrid, AH 58 of early maturity, earlier released for Zone IV as PEHM 3, was released for NCR, Delhi by IARI Varietal Identification Committee.

A multi-cut forage sorghum variety, Pusa Chari 615, was recommended for release in NCR, Delhi. In chickpea, two *Kabuli* bold seeded varieties, BG 1108, BGD 128, and a *desi* chickpea mutant, BGM 547, were identified for release for various production conditions.

A lentil variety, L 4594 (Pusa Masoor 5), was identified for release for commercial cultivation in NCR, Delhi. This variety has medium growth habit, small seeds and orange cotyledon, and is resistant to rust. Pusa 2001, a pigeonpea variety, was identified for cultivation in NCR, Delhi.

In *Brassicas*, LES 39 (Pusa Karishma), the first single zero (< 2% erucic acid) variety, and JD 6 (Mahak), an early maturing variety of Indian mustard, were notified. An early maturing and non-shattering Indian mustard variety, EJ 13 (Pusa Tarak), and a *Brassica carinata* variety, NPC 9 (Pusa Aditya), were identified for release in NCR, Delhi.

A soybean variety, Pusa 9712, was notified for NCR, Delhi and identified for North Western Plains Zone. In vegetable, cabbage hybrid KGMR 1, the first public sector hybrid carrying field resistance to black rot disease with good staying ability in the field after head formation and an average yield of 35-45 t/ha, was recommended for release for Zones I and IV. A capsicum hybrid, KTCPH 3, having green attractive 3-4 lobed fruits with an average yield of 25 t/ha, was recommended for release for zones I, VI and VII. Two promising grape hybrids, viz., BA x Per 75-32 and Hur x Cardinal 76-1, were found to consistently perform well, and have been identified for their release.

Four new rose varieties–three belonging to Hybrid Tea (Pusa Arun, Pusa Ajay and Pusa Shatabdi, and one belonging to Floribunda group (Pusa Komal) – were identified by IARI Variety Identification Committee for release. The IARI Variety Identification Committee also identified for release two radio-mutants, Pusa Anmol and Pusa Centenary, of chrysanthemum.

Under the research on genetic resources, several genotypes of different crops were found to be suitable for disease resistance, quality and other economic traits. Wheat genotypes, viz., Pusa 2022A, Pusa 2019 A/11, Pusa 2099A and Pusa 2338A/20 were registered with NBPGR, New Delhi. Two promising cotton lines, BN-ARB 16 and BN-TOM 277, were also registered with the NBPGR. IARI Centre for Pulses Improvement, Dharwad, has developed BGD 132 as a new source of earliness in *Kabuli* chickpea. It was derived from the cross ICCV 2 x ICCV 5. It flowers in 29-30 days after sowing at IARI Centre, Dharwad, and reaches maturity in about 65–70 days. It is a higher yielding variety and is earlier by 5-7 days in flowering and 9-10 days in maturity compared to ICCV 2, the first extra-short duration chickpea variety popular in peninsular and central India. The locally adopted control cultivar Annigeri takes about 40–45 days to flowering and 85–90 days to maturity. Its 100-seed

weight is 28-30 g and has a grain yield potential of about 1.4-1.5 t/ha under residual moisture conditions. Under the research on microbial genetic resources, fifteen blue green algal isolates of *Nostoc* (9), *Anabaena* (4), *Cylindrospermum* (1) and *Phormidium* (1) from Hyderabad and adjoining areas were added in the germplasm collection.

During 2005, 437 fungal specimens, including 38 type specimens, were accessioned in HCIO. Two new genera, one belonging to Hyphomycetes, viz., *Manoharachariomyces lignicola* and another to Ascomycetes, namely, *Diatrypoidiella lignicola* were created. Five new species of powdery mildews, viz., *Oidium cassiae-leschenaultianae, O. cassiae-torae, O. crotalariae, O. heliotropii-strigosum and O. royle* collected on *Cassia leschanaultianae L., C. torae L., Crotalaria juncea L., Heliotropium strigosum* Willd., and *Roylea cinerea* (D. Don.) Baill, respectively, were described. Besides, *Annelophora catenata*, a new species of Dematiceous Hyphomycetes, i.e., *Mollisia dhankutae* Belfour-Browne belonging to the family Dermitiaceae is reported to be the first record from India.

The Indian Type Culture Collection (ITCC) was enriched by new addition of 65 different fungal cultures including some plant pathogens such as *Theilaviopsis* state of *Ceratocystis parodoxa; Rhizopus oryzae*, which is a potent lactic acid producer; *Drechslera halodes; Fusarium palladoroseum* from wheat head; *Macrophomina phaseolina* from *Jatropha*; *Glomerella tucumanensis; Ampelomyces quinqualis; Alternaria alternata* from *safed musli*; *Colletotrichum gloeosporoides* causing bunch rot of oil palm; and *Botryodiplodia theobromae* causing sudden death of *Jatropha*.

A total of 145 cultures/specimen were identified up to species level. Some of the important fungi identified during the period were *Alternaria cucumerina* var. *cymopsidis* on cluster bean, *Arachinitos dencalensis* on oil palm, *Syncephalastrum recemosum* on oil palm, *Colletotrichum orbiculare* on luffa, *Thielavia terricola* in grape juice, *Phoma multirostrata* on coconut, *Pestalotia olivacea* on large cardamom, *Embellisia alli* on garlic imported from China, *Ceratocystis paradoxa* from pineapple, *Ampelomyces quinqualis* on apple, and *Sclerotium hydrophyllum* on rice. In addition, *Beauveria bassiana* and *Paecilomyces lilacinus* on *bhindi* fruit fly and on silk worm were identified.

The two new species, viz., *Appendiculella wendlandia* Prameela and Chowdhry *sp. nov.* and *Meliola eugenia-oblata* Chowdhry and Prameela *sp. nov*. were created. Besides, a new Hyphomycetous fungus of Moniliales group, *Botryodeorsum*, gen.nov. was created and described from India, and *Botryodeorsum indicum* was proposed as the type species.

Under the insect identification service, 642 specimens belonging to the orders, Coleoptera and Hymenoptera, were identified.

A checklist of all 16 genera and 148 species belonging to subfamily Formicinae from the Indian subcontinent was prepared. Eleven species of genus *Camponotus*, *viz*., *C. angusticollis, C. arrogans, C. camelinus, C. compressus, C. dichorus, C. gigas, C. maculatus, C. nicobarensis, C. paria, C. rufoglacus* and *C. sericeus* were redescribed. The descriptions were strengthened by the incorporation of additional characters, suitable illustrations and morphometric ratios.

Under research on crop and resource management and environment, several important studies were conducted. These covered: evaluation of zinc enriched urea in aromatic rice; effect of organic sources of plant nutrition on productivity of rice-wheat cropping system; effect of inorganic and organic sources of nutrients on maize and their residual effect on wheat; response of early cultivars of chickpea for *Chhollia* to P application and residual effect on succeeding baby corn; response to sulphur and its sources in pigeonpea-wheat cropping system; agro-techniques for propagation of *Jatropha* saplings through stem cuttings and seed; direct and residual effect of applied nutrients on mustard in mungbean-mustard cropping system; nutrient management with aqua-fertilization in lentil under rainfed conditions; tillage and residue management practices in maize-based cropping systems; performance of wheat under varying tillage and residue management practices following different *kharif* crops; studies on organic farming of rice-wheat cropping system; nutrient management in broccoli-based cropping systems through organic sources; performance of new wheat genotype under irrigated saline conditions; performance of new wheat genotypes at different dates of sowing under irrigated condition; and screening of suitable wheat varieties under conventional as well as zero tillage conditions.

Under seed science and technology, studies were conducted on seed production technology of scented rice and rice hybrid, tomato and brinjal; DUS testing for plant variety protection; seed testing; seed quality enhancement and deterioration; solid matrix priming in bittergourd and okra seeds; and comparative appraisal of vegetable seed

germination standards of India with developed and developing region countries. Nucleus, breeder, and IARI seeds of different crops were also produced in large quantities.

Under soil management, studies were conducted on rice-wheat and maize-wheat cropping systems; nutrient transformation in crop rhizosphere under impending climate change; diagnosis and amelioration of iron deficiency under aerobic rice; complexation of lead and nickel by rhizo-deposits of wheat and maize; impact of heavy metal contamination on soil biota and its remediation; and hastening of composting process of rice straw by chemical and biological means.

Under water management, studies were conducted on water resources utilization through technology development and improved water management practices for sustained agricultural production system; development of appropriate technologies for water and nutrient use for enhancing crop production; development of water management technologies for irrigated and rainfed agriculture; watershed based management for sustainable agriculture; NCR groundwater nitrate levels vis-a vis chemicals load in soil; and role of clay minerals and isotopic evidences in chemical evolution of groundwater.

Important studies were conducted on integrated nutrient management. These were: effect of integrated nutrient management on soil quality under soybean-wheat cropping system; evaluation of enriched organo-mineral fertilizers on crop productivity and soil fertility in a mungbean-potato cropping sequence; development of basic data and soil-test-based fertilizer recommendations for wheat; effect of soil-test based fertilizer recommendations on wheat yield and soil fertility; influence of long-term application of fertilization and manure on crop productivity and soil quality under maize-wheat cropping system; sustaining soil health for increasing productivity and quality of crops through integrated nutrient supply and management; integrated sulphur management for *kharif* mungbean; integrated nutrient management in wheat under different planting systems; and integrated nutrient management in fruit crops. The studies under nutrient availability were on soil fertility status in different agro-ecological regions; nitrogen use efficiency in rice under conventional and raised bed-planting; studies on the availability and mobility of iron and zinc in soils for crop nutrition and bioavailability/biofortification in food products for human nutrition; and effect of potassium fertilizer application on transfer factor (TF) of $^{137}C_s$ in rice.

The Institute developed several farm related equipment, machinery and technology for optimizing crop production and reducing drudgery. A mechanical onion detopper was developed for enhanced capacity and low drudgery. A lightweight, low horsepower engine-operated maize planter was designed and developed for planting of maize crop. A rotating screen grader suitable for fruits like lemon, *ber* and *aonla* was developed to grade the samples in 4 homogenous grades.

In mass production of machines, the developemnt of jigs and fixtures adds to the quality of product, reduces the cost of fabrication, assures the production of interchangeable parts, reduces the production time and improves the overall reliability of the products. Accordingly, fixtures were developed for various components, namely, handle bending, shank bending, welding fixtures for spoke and frame bars and cross bars of a manually operated wheel hoe. A small capacity rice mill consisting of a rubber roll sheller, a blower for husk separation, and a polisher was also developed. A traditional *atta chakki* was modified by providing a gap adjusting mechanism. The Institute conducted a study on farm machinery use pattern in Karnal and Gurgaon districts in the context of optimizing the level of mechanization. Other studies were on comparison of control layout for Indian tractors; densification characteristics of some crop residues; use of renewable sources of energy in agriculture; drying studies on cauliflower; development of micro-controller for precision farming; mathematical modeling of a greenhouse; and drying of bio-materials.

In Indo-Israel project, studies were conducted on production technology of vegetables and flower crops. Consistent use of fertilizer through drip irrigation for vegetable crops has been found to cause accumulation of salts and consolidation of soil within the root zone during a crop cycle. Deep ploughing after each crop cycle is recommended to break the consolidation of layers to allow leaching of salts. Taking these facts into consideration, a deep tillage plough with two tynes was designed and fabricated.

The studies concerned with environmental sciences were on temperature dependent response of soil CO_2 efflux in different physiographic regions of India; effect of high temperature on pollen germination; impact of tillage management on global warming potential (GWP) of soils under rice-wheat cropping; impact of high temperature on growth and yield of rice; impact of high temperature on plant-pathogen dynamics; agri-management of *Jatropha*;

adsorption and desorption capacity of *Jatropha* seed coat for copper; effect of salinity and osmotic stress on seed germination of *J. curcas*; screening of maize varieties for bioethanol production; impact of Bt cotton on microbial community structural pattern in soil of Sri Ganganagar district, qualitative and quantitative response of different food crops to heavy metal stress; agro-industrial effluent utilization in agriculture; a spatial resource characterizing system (resourCeS) for national capital region; ground water helium survey for earthquake studies and disaster management; evidences of climatic uncertainties linked groundwater variability; and impact of different environments on grain yield components of rice. In microbiology, the Institute conducted several studies which covers evaluation of nutrient quality of mature compost prepared from various substrates using microbial consortium; role of nitrogen and zinc fortification on quality of compost; development of *Azotobacter* bio-inoculants for low organic carbon conditions; influence of C-sources on *Azotobacter* and development of liquid bio-inoculants; effect of n-Butanol to initiate encystment in *Azotobacter* Strain-W5; development of *Azotobacter* inoculants for low carbon conditions; formulation of liquid phosphate solubilizing bio-inoculants (PSB); influence of AM fungi and PSB on yield of soybean under rainfed conditions; co-inoculation response of PGPRs with *Bradyrhizobium japonicum* on rainfed soybean; biochemical characterization of antifungal compound against *Rhizoctonia bataticola*; development of transgenic biofertilizer cyanobacteria *(Nostoc muscorum)* with cloned mps genes from *P. striata;* genetic evaluation of cyanobacteria for H_2 production and N_2 fixation; molecular characterization of Cyanobacteria; isolation and identification of BGA from low input rice growing areas; organic cultivation of rice and wheat; biofertilizers in integrated nutrient management in rice-wheat cropping system; bioactive compounds from Cyanobacteria strains; bioremediation of heavy metal chromium by micro algae; bioremediation of waste waters using *Azolla*; and studies on treatment of Cr contaminated tannery effluents collected from Kanpur.

Under orchard management, studies were conducted on mango malformation; rootstock research in guava, mango and citrus. The studies under post-harvest technology and management covered controlled atmosphere (CA) technology for guava fruits; extending the marketability of ripe mango; effect of grading on quality of *bael* fruit; maturity studies in mango; studies on tree age and canopy height of guava (cv. Allahabad Safeda); nutritional and microbial quality of hurdle processed mango slices (cv. Chausa); quality evaluation of minimally processed bittergourd rings (cv. Pusa Do-Mousmi); packaging study of hurdle processed mango slices and minimally processed bittergourd rings; osmo-processing of *aonla* segments; evaluation of carrot cultivars for dehydration; packaging and storage study of dehydrated *methi* leaves; storage study of dehydrated bittergourd rings; osmotic dehydration of guava slices; effect of blanching methods on the beta-carotene content of frozen carrots; retention of total flavonoids in onions (cv. Pusa Red) as affected by processing methods; physical characteristics of maize genotypes; physical properties of composite maize varieties; effect of chemical treatments on cooking time of three pigeonpea varieties; irradiation study in mango pulp; and disinfestations of whole pigeonpea pulse by irradiation.

Under crop protection, important findings were made on fungal diseases affecting wheat, rice, maize, chickpea, urdbean, mungbean, pigeonpea, soybean, rapeseed and mustard, vegetables and large cardamom. Research was also conducted on viral diseases, i.e., rice tungro disease; mungbean yellow mosaic virus (MYMV); tomato leaf curl New Delhi virus (ToLCNDV); groundnut bud necrosis virus (GBNV); and virus and viroid diseases of citrus and their management. Important findings were also made on viral diseases affecting papaya, peri-urban vegetables and large cardamom. Significant studies were also made on bacterial diseases affecting rice. Studies were also conducted on biology and strain improvement in mushroom.

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

In nematology, important studies were conducted on biodiversity; mechanism of resistance; nematode management; entomopathogenic nematodes for termites management; and toxicity of biological control agents.

The emphasis of research on agricultural chemicals was on development of natural and synthetic agrochemicals and their adjuvants; pesticides-risk assessment, environmental fate and remedies; and improvement in safety and efficacy of pesticide formulations. Under weed management, studies were conducted on weed management in conventional as well as zero tilled wheat; weed management in soybean through use of low dose herbicides; integrated weed management in onion seed crop; and integrated weed management in muskmelon.

The Institute conducted important studies under basic and strategic research. In plant biotechnology, the studies covered isolation of genes and promoters for development of transgenics; enhancement of productivity through exploitation of heterosis; development of transgenic crops for biotic stress resistance; development of transgenic crops for abiotic stress tolerance; development of genetically engineered microbes for effective microbe-plant interaction; genomics and molecular markers in crop plants; and molecular characterization and micropropagation in fruit crops.

The studies in biochemistry covered cloning and characterization of gene encoding antiviral protein of *Bougainvillea xbuttiana*; cloning of diacylglycerol acyl transferase (*DGAT*) gene from *B. Juncea;* isolation and characterization of *fad 2-1* gene encoding ω–6-desaturase from soybean and designing of antisense construct for silencing *fad 2-1* expression; and isolation and characterization of differentially regulated genes under moisture stress in rice.

In plant physiology, the studies covered physiological constraints limiting productivity; improvements in abiotic stress tolerance in crop plants; post-harvest physiology of fruits, vegetables and flowers; characterization of crop responses to global climate change; biophysical characterization of plant responses and post harvest quality preservation of agro-products; application of physical approaches for enhancing crop productivity and post-harvest storability; genetic and physiological regulation of phytosiderophore (PS) production in relation to zinc efficiency in wheat; relationship between biophysical parameters and performance of wheat under late heat condition; and interactive effect of gamma radiation and moisture content on germination and plant growth under laboratory condition.

The Institute also conducted important genetics studies involving wheat, rice, maize, pearl millet, chickpea, mungbean and *Brassicas*. Important findings were made by the Institute in the study of a Wnt gene cluster on chromosome 2L of *Drosophila melanogaster*.

In agricultural physics, the studies conducted cover soil physics; agro-meteorology; and remote sensing and GIS. Important studies were also made on crop modeling.

In agricultural economics, the Institute conducted studies on pesticide use and sustainability of agriculture: emerging issues and policy options; identification of pulling factors for enhancing sustainable development of agriculture with special reference to maize in India; adoption and impact of resource conserving technologies on farm economy in Indo-Gangetic plains; food safety measures and their implications on India's horticultural exports; co-integration of horticultural markets in India; marketing information systems for horticultural commodities in India: status, constraints and prospects; impact of trade liberalization on Indian agriculture; and study on peri-urban agriculture and its management in Delhi.

Studies conducted in agricultural extension were on farming systems research and extension for sustainable development; enhancing the efficiency of extension organizations; development of participatory extension methodology and strategy for inter-sectoral micro-planning; assessing the socio-economic and environmental impact of agricultural technologies; harnessing information and communication technologies for promoting market-led extension; impact analysis of training programmes; evaluation of capacity building in rural resource management (a pilot action research on programme evaluation); reaching un-reached areas and checking rural migration from tribal areas; alleviating malnutrition through popularization of cultivation and consumption of *durum* wheat; and crop diversification through introduction of wheat in non-traditional areas.

The Institute's project on technology assessment and refinement through IVLP under rice-wheat production system in irrigated agro-eco region of NCR, Delhi was in its final phase and terminated in April 2005. However, a few interventions were carried out in the operational villages with the objective of intensification and diversification of the cropping system. Other interventions also were made by the Institute for exploring the prospects of new growth areas for application of agricultural technologies in different agro-eco regions. Several front line demonstrations were conducted by the Institute during the reported period, besides other demonstrations involving different crops. The Centenary Year *Pusa Krishi Vigyan Mela* of the Institute on the theme "Prosperity through Seeds" was organized from February 14 to 16, 2005. The Institute also conducted several extension related activities, including training of farmers on cotton, rice and agricultural technologies. The Agricultural Technology Information Centre (ATIC) of the Institute is providing products, services, technologies and information to different stakeholders through a 'Single Window Delivery System'. About 10650 farmers/entrepreneurs, development officials, students, NGO representatives, etc., from 21 states

and one union territory of India visited ATIC during the year for farm advisory, diagnostic services, purchase of technological inputs/products and trainings.

The Institute's Krishi Vigyan Kendra (KVK) at Shikohpur, Gurgaon is playing a vital role in combating unemployment of rural youth through technological empowerment, and in improving the farmers' awareness and farm productivity through various transfer of technology programmes. The KVK organized several activities during the year to achieve the goals covered by its mandate.

The Institute also undertook many activities for empowerment of women and mainstreaming of gender issues.

The 43rd convocation of the Institute was held on February 11, 2005. At this convocation, 76 M.Sc. and 69 Ph.D. students were awarded degrees. The Institute also conducted several regular/short-term training courses during the reported period. Work was also done at the Institute in agri-bioinformatics and software development.

The IARI library continues to provide services to the scientific community. The Institute brought out several *ad-hoc* and regular publications both in English and Hindi to disseminate information on research. The Institute's commercialization and IPR activities have resulted in filing of five patents and signing of five MoUs/agreement. Linkages and collaboration existed with several national and international institutions.

1. CROP IMPROVEMENT

1.1 CEREALS

1.1.1 Wheat

1.1.1.1 Varieties released

HD 2888 (Pusa 107). A wheat variety, HD 2888 was released by the Central Sub-committee on Crop Standards, Notification and Release of Varieties for timely sown rainfed conditions for North Eastern Plains Zone comprising the states of Bihar, Jharkhand, West Bengal, Assam and parts of Uttar Pradesh. The average yield of HD 2888 is 2.25 t/ha with a yield potential of 2.83 t/ha. This variety exhibits a high degree of resistance to leaf and stem rusts and moderate resistance to stripe rust. The high hectoliter weight of HD 2888 indicates the high extraction (flour recovery) without disturbing the quality of wheat and micro nutrient contents. The GLU 1 score of this variety matches with that of C 306, which is the best variety for *chapati* making.

Wheat variety HD 2888 released for timely sown, rainfed conditions of North Eastern Plains Zone

HD 2833 (Pusa Tripti). A double dwarf wheat variety, HD 2833 developed from the cross, PBW226/ HW1042(TR380-14^{7}/3Ag#14)//HD2285 was released by the Central Sub-committee on Crop Standards, Notification and Release of Varieties for commercial cultivation under late sown irrigated conditions of Peninsular Zone. The average yield of HD 2833 is 3.89 t/ha with a yield potential of 5.0 t/ha. The variety HD 2833 exhibits a high degree of adult plant resistance to leaf and stem rusts and, therefore, the cultivation of this variety will help in the management of stem rust in a sensitive epidemiological zone. HD 2833 produces lustrous grain and has high hectoliter weight. This variety has been identified as product specific variety possessing >8/10 score for *chapati* making.

HI 8627 (Malav Kirti). HI 8627 (Malav Kirti), the 1st high yielding genotype which performed equally well under both rainfed and restricted irrigation conditions, was released for cultivation in Central Zone by the Central Sub-committee on Crop Standards, Notification and Release of Varieties during 2005. High yields of HI 8627 under all sowing conditions from October to November-end proved its thermo-tolerance which will help in sustaining wheat production under challenges of "global warming". Being semi-dwarf, it will make productive use of additional irrigation or winter rains while conventional tall varieties lodge. Its "dual quality" (for *chapati* as well as *macaroni* preparations), and rich combination of protein, â-carotene, iron, zinc and copper will ensure "nutritional security" at household level, providing "health food" to rural India.

HI 8627 (*Malav Kirti*), the first limited irrigation, dual quality *durum* wheat variety released for Central Zone

Comparison of important quality traits of HI 8627 and Lok 1

Variety	Hecto-litre Weight(kg)	Protein content %	ß-carotene (ppm)	Iron content (ppm)	Zinc content (ppm)	Copper content (ppm)	Manganese content (ppm)
Lok 1 (*aestivum*)	80.6	10.6	2.3	35.5	27.2	4.5	33.5
HI 8627 (*durum*)	82.3	11.0	5.7	49.6	42.1	6.0	27.4

HW 3094 (COW (W-1). A high yielding, early duration, tropical bread wheat variety, HW 3094 (COW (W-1) was released for the state of Tamil Nadu under irrigated and medium rainfall areas of the plains and adjoining areas near

to hills in Tamil Nadu state. The variety gave a grain yield of 2.36 t/ha and an increase of 5.4% over another culture HW 3070 in a total of 120 trials for the past four years. This is the first wheat variety for Tamil Nadu with joint collaborative efforts made by IARI, Regional Station Wellington, the Tamil Nadu Agricultural University and the State Department of Agriculture, Government of Tamil Nadu. The protein content is 11.6% with a hectoliter weight of 78.0, and sedimentation value of 51.0. It possesses amber grain colour with 8.14 *chapati* score. It also possesses rust resistant genes.

1.1.1.2 Varieties identified/proposed for identification

HI 1531 (Harshita). HI 1531 (Harshita) is the first early maturing, high yielding, semi-dwarf bread wheat genotype ever evolved in the history of drought tolerance breeding in central India. It was identified at the Wheat Workshop for rainfed as well as limited irrigation cultivation in Central Zone held during August 2005. Late maturity of Sujata and HW 2004 hindered their spread to Gujarat, southern Rajasthan and Malwa tract of Madhya Pradesh, as these areas are prone to frosting and terminal drought at the time of crop maturity. HI 1531, being nearly one week early in heading and maturity compared to HW 2004, will escape frosting and terminal drought, ensuring stability in wheat production in Central Zone. Being semi-dwarf, HI 1531 resists lodging; while HW 2004 and HI 1500 are prone to lodging under one or two irrigation conditions.

HI 1531 (Harshita), the first semi-dwarf bread wheat variety identified for rainfed as well as restricted irrigated conditions of Central Zone.

HW 5001 (Neela Malar): The variety HW 5001 was identified by the 43rd All India Wheat Workers' Workshop held at IARI, New Delhi for Southern Hills Zone. The variety carried *Agropyron elongatum* desired linked genes *Sr* 24, *Lr* 24 and Secale cereale genes, viz., *Lr* 26, *Sr* 31, *Yr* 9 and *Pms* 8. It has recorded the highest grain yield over the checks even under late sown situation and varied nutrient status and the overall gain in grain yield was 28.6% and 21.1% over that of the best checks. The seeds are bold (43.0 g/1000–grain weight) with 12 per cent protein content.

HD 4713. A variety of *Triticum durum* wheat, HD 4713 is showing consistent performance for three consecutive years in coordinated trials and being proposed for identification for release in NCR, Delhi. The average yield of the variety HD 4713 is 4.71 t/ha with a yield 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 ã-Gliadin, which is a desirable trait.

HD 2894. The high yielding variety HD 2894 performed consistently superior to checks over the years scoring first rank in five out of seven trials. Its yield superiority ranged from 8.6% to 17.1%. This is proposed for identification for release for cultivation in Delhi state under timely sown irrigated condition. This 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 entries are being tested in various varietal trials:

Trials	Entry name/ numbers
Advance Varietal Trials (AVTs)	HD 2894, HD 2922, HD 2940, HD 2894, HD 2906, HD 2891, HD 2933, JKW 20, HD 2913, HD 4713
National Initial Varietal Trials (NIVTs)	HD 2947, HD 2949, HD 2951, HD 2954, HD 2956, HD 2961, HD 2962, HD 2963, HD 2964, HD 2966, HD 2920, HD 2921, HD 2926, HD 2930, HD 2932, HD 2937, HD 2938, HD 2939, HD 2952, HD 2959, HD 4718
Common Varietal Trials (CVTs)	110 entries in different agroclimatic zones of the country at 32 locations
Station Trials	About 1000 improved wheat strains tested in Station trials

A promising culture, HP 1883 was promoted to AVT (TS) irrigated condition in NEP Zone. It showed a fair degree of resistance against black, brown and yellow rusts.

Outstanding cultures having dwarf stature and very good tillering efficiency and showing synchrony in maturity and resistance to brown rust and Helminthosporium leaf blight are: 2643/4723(-Chirya-3/W76//HP1761), 2561/4744 (=HD2687/HP1761), 2648/4876 (=HD2733/HW2044), 2557/4729, 560/4729(=HD 2733/ GW273), 2322/4681(=HP 1744/HW 2043).

Presence of strong necrotic gene Ne_2^s was detected in

the new genotypes such as K 409, HW 5030, HD 2906, PBW 569, PHR 1004, PHR 1007, PHR 1008, PHR 1009, PHR 1010, PHR 1017 and RW 3703 which produced lethal hybrids with the cultivar HD 2733 (Ne_1^s) and C 306 (Ne_1^s).

Five hundred and one fresh crosses including simple and three way combinations were attempted. PHR lines are known lines for higher biomass. For converting higher biomass into yield, promising PHR lines were utilized in crossing programme. Known sources for Terminal Heat Tolerance (THT) such as HD 2808, PBW 510, WH 730, PBW 493, Raj 4026 and Raj 4037 were also exploited in crossing programme.

Three thousand five hundred and ten breeding lines were evaluated for their promise in segregating and advance generation lines.

Two genotypes – HS 473 under timely sown condition of high altitude (*rabi* season) and HS 424 under timely sown condition of very high altitude (summer season)–were promoted to final year of testing in coordinated trials of Northern Hills Zone.

Two other genotypes – HS 461 (timely sown, rainfed, very high altitude under summer season) and HS 485 (late sown, restricted irrigation) – were promoted to the second year of testing in coordinated trials of Northern Hills Zone. In addition to this, 10 genotypes, viz., HS 471, HS 481, HS 486, HS 487, HS 488, HS 489, HS 490, HS 491, HS 492 and HS 493 were included in All India Coordinated Trials for further evaluation under different production conditions of Northern Hills Zone on the basis of high yield potential and high degree of rusts resistance. HS 493 was also promoted from CVT-1 to NIVT 1B of Coordinated trial. Two new genotypes, HS 424 and HS 431, have been identified 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.

Genetics of resistance against the most virulent pathotype 46S119 of stripe rust was studied on resistant wheat variety PBW 343 and new resistant sources, WBM 1587 and WBM 1591, developed by Regional Station, Tutikandi, Shimla. Resistance in PBW 343 is governed by a single recessive gene while newly identified resistant sources, WBM 1587 and WBM 1591, control this most virulent pathotype through two dominant complimentary genes. Inheritance of resistance against newly evolved pathotype 78S84 of stripe rust, virulent on PBW 343, was also studied and it was reported to be controlled by a single dominant gene.

Varieties developed at IARI Regional Station, Wellington are in various all India co-ordinated wheat trials.

AVT trial–Southern Hiils Zone 2005-2006

Name of the variety	Pedigree	Genes(s) carried	Year of testing in AVT
HW 2065@	HD 2402*3//CS 2 A M 4/2	*Lr*28	3
HW 5021	MACS 2496*1//MC 10	*Sr*31, *Lr*26, *Yr*9, *Pm*8	2
HW 5044	LOK-1//WH 542	*Sr*31, *Lr*26, *Yr*9, *Pm*8	2
HW 5102	PBW 343/PH 137//HW 3005	*Sr*31, *Lr*26, *Yr*9, *Pm*8+*Lr*24, *Sr*24	1
HW 5202	HD 2669/HW 3003	*Sr*31, *Lr*26, *Yr*9, *Pm*8+*Lr*24, *Sr*24	1
HW 5203	HW 3018//HW 2045	*Sr*31, *Lr*26, *Yr*9, *Pm*8+ *Lr*19, *Sr*25	1
HW 5204	HW 3018// HW 2046	*Sr*31, *Lr*26, *Yr*9, *Pm*8+ *Lr*19, *Sr*25	1
HW 5205	HW 3020 // HD 2669	*Sr*31, *Lr*26, *Yr*9, *Pm*8+*Lr*24, *Sr*24	1
HW 2044#	PBW 226*6 // SUNSTAR *6 / C 80-1	*Lr*19, *Sr*25	Check
HW 5001#	HD 2646 // HW 2002 A/ CPAN 3057	*Sr*31, *Lr*26, *Yr*9, *Pm*8 + *Lr*24, *Sr*24	Check

@ In final year of testing
# - checks

IVT trial- Southern Hills Zone 2005-2006

Name of the variety	Pedigree	Genes carried
HW 5206	HW 2017 // HW 4008	*Lr*32+*Lr*24, *Sr*24
HW 5207	HW 3029 // Yr15	*Sr*31, *Lr*26, *Yr*9, *Pm*8+ *Lr*24, *Sr*24, *Yr*15
HW 5208	ATTILLA // OLIGO	*Sr*31, *Lr*26, *Yr*9, *Pm*8+
HW 5209	HW 2017 //HW 4008	*Lr*32 +*Lr*24, *Sr*24
HW 5103	PBW 343/ PH137//HW3039	-
HW 5104	PBW 343/PH 137 // VW 9897	-
HW 5105	PBW 343/ PH 137// HW 2016	-
HW 4067	HD 2687*3//COOK*6/ C80-1	*Sr*31, *Lr*26, *Yr*9, *Pm*8 + *Lr*19, *Sr*25, *Sr*36, *Pm*6
HW 4049	HW 4002*2//WH 542	*Sr*31, *Lr*26, *Yr*9, *Pm*8 +*Lr*32
HW 4053	HW 4006*2//WH 542	*Sr*31, *Lr*26, *Yr*9, *Pm*8 +*Lr*32

Several wheat genotypes developed at IARI Regional Station, Indore are being tested in various Advanced Varietal Trials. Among these, *durum* genotype HI 8663 has wide adaptability as it has performed well across three agroclimatic zones. Bread wheat genotype HI 1544 performed well in two zones.

Genotypes in advanced varietal trials

Genotype	Species	Zone	Cultivation condition
HI 1535	*Aestivum*	PZ	Irrigated late sown
HI 1539	*Aestivum*	NEPZ	Irrigated timely sown
HI 1540	*Aestivum*	PZ	Irrigated timely sown
HI 1544	*Aestivum*	CZ and PZ	Irrigated timely sown
HI 1547	*Aestivum*	PZ	Rainfed timely sown
HI 8663	*Durum*	CZ, PZ and NWPZ	Irrigated timely sown
HI 8664	*Durum*	NWPZ	Irrigated timely sown

Seven newly evolved wheat genotypes including five durums, V 21-13, V 21-23, V 21-27, V 21-28 and V 21-31; and two bread wheat lines, S 2-1 and S 2-7 were evaluated for tolerance to early and late heat under three dates of sowing – early (11-10-2004), normal (10-11-2004) and late (7-12-2004) – along with HD 4672, HI 8498, HI 8627 and HI 8638 as *durum* checks, and Lok 1, HI 1500, HI 1531 and HW 2004 as bread wheat checks. Post sowing irrigation + 2 additional irrigations were given to October and November sown crops, whereas 4 additional irrigations were given to the late sown crop. *Durum* wheat variety HI 8627 showed consistently good yield performance in the 3 dates of sowing indicating that it possessed tolerance to both early and late heat. Under October sown conditions, maximum grain yield of 3.82 t/ha was obtained in HI 8627 followed by 3.69, 3.65, 3.58, 3.44, 3.42 t/ha in V21-13, V 21-23, V 21-27, V 21-28 and V 21-31, respectively. The highest 1000 – grain weight of 67.04 g in HI 8498 was followed by 65.00 g in V 21-28, 63.36 g in V 21-13, 61.40 g in V 21-31, 59.72 g in V21-23, 57.72 g in Lok 1, 53.60 g in S2-7, 52.32 g in S2-1, 51.48 g in HI 1500 and only 44.0 g in HI 1531. Thus, the above mentioned five 'V 21' *durum* lines of medium late duration showed good levels of early heat tolerance, and hence are suitable for early sowings, making the best use of stored moisture. Their stable yields in different environments proved that they had a good measure of late heat tolerance as well. Among bread wheat lines, the highest grain yield of 3.8 t/ha was obtained in S 2-1, followed by 3.65, 3.50, 3.31, 3.05 and 2.07 t/ha in HI 1531, S 2-7, HI 1500, HW 2004 and Lok 1, respectively. Hence, the newly developed bread wheat lines S 2-1 and S 2-7 possess good levels of late heat tolerance as well. It may be noted that Lok 1, currently the most widely cultivated wheat variety in central India, suffered heavy yield losses under early as well as late sown conditions, compared to other varieties under normal sowing. Its grain yields (t/ha) recorded in the above experiment were: 2.38, 3.41 and 2.07 t/ha under October, November and December sowings, respectively.

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

1.1.1.4 Development of diverse restorers for hybrid wheat

Eight new restorer lines, namely, PWR 3 (from winter wheat), PWR 4, PWR 5, PWR 6, PWR 7, PWR 8, PWR 9, and PWR 10 were developed. Four lines showed equal performance with check varieties, PBW 343 and HD 2329.

1.1.1.5 Evaluation of wheat germplasm for quality traits

Germplasm comprising of 511 genotypes from diverse origins besides advanced material of breeders was procured, purified and multiplied in the field for various quality tests. These and the available germplasm in the programme were tested for quality traits such as grain protein, SDS-sedimentation value, micronutrient content, high molecular weight glutenin subunit composition, etc., in order to identify genotypes possessing superior quality as well as novel variability. Thirty genotypes with grain protein > 13.5%, 10 genotypes with strong gluten, and seven genotypes with high Zn (> 50ppm) were identified. As many as five novel variants of high molecular weight glutenin subunits were identified in the seeds of farmers' collections. These were named as $17^{1}+18^{1}$ (at Glu B1 locus), $5+12_{2}$, $5_{1}+12_{2}$,$5_{2}+12_{3}$ and $5_{3}+12_{3}$ (at Glu D1 locus). Besides these, the development of genotypes combining high grain protein in high yielding background was continued. Four genotypes (PQW 13, PQW 42, PQW 45 and PQW 47) performed consistently superior in multilocation tests conducted by DWR, Karnal. Four more entries PQW 40, PQW 57, PQW 59 and PQW 75 were identified for multilocation testing based on their superior performance at a single location in DWR, Karnal.

1.1.1.6 Breeding for stable quality traits in *durum* wheat

Most of the *durum* wheat lines showed stable performance for sedimentation value (SDS value) under both rainfed and limited irrigation conditions, while â-carotene and protein contents showed a slight increase under limited irrigation. This may be due to the better intake of nutrients under supportive irrigation, leading to improved expression of quality traits. Under low input conditions, protein and â-carotene contents showed significant positive relationship with grain yield, while 1000-grain weight and SDS value behaved independently of the grain yield. Protein showed significant positive relationship with 1000-grain weight, whereas SDS value and â-carotene behaved independently of the protein content. Under high input conditions, both protein content and 1000-grain weight showed significant positive relationship with grain yield. Grain weight showed significant positive relationship with protein content also, while SDS value had positive association with â-carotene.

These findings advocate the possibility of evolving good quality high yielding *durum* varieties having rich combination of grain weight, protein and â-carotene content through present breeding approaches. Grain weight can be adopted as one of the selection parameters to evolve *durum* wheat varieties with high yield coupled with high quality. Hence, selecting genotypes with stable quality traits over locations/ environments is essential to ensure "rich nutritional value" of the *durum* cultivars.

1.1.2 Rice

1.1.2.1 Development and evaluation of restorer lines

In a *basmati* restorer evaluation station trial, out of 15 entries evaluated, four entries out yielded the best check Pusa Sugandh 5.

Name of entry	Yield (t/ha)
ET 2-1	6.4
ET 2-2	6.8
ET 2-3	6.2
ET 2-5	6.9
Pusa Sugandh 5	6.1

In a non-*basmati* station trial, out of 22 entries evaluated, 10 entries out yielded the best check IR 64.

Name of entry	Yield (t/ha)
ET 1-1	8.0
ET 1-2	10.0
ET 1-3	8.7
ET 1-4	9.5
ET 1-5	8.3
ET 1-7	8.5
ET 1-10	8.1
ET 1-16	7.8
ET 1-17	7.6
ET 1-24	8.8
IR 64 (check)	6.5

1.1.2.2 Development and evaluation of hybrids

In a hybrid station trial, out of eight hybrids evaluated, three hybrid combinations out yielded the best check Pusa RH 10.

Name of Hybrid	Yield (t/ha)
Pusa 6A/SPS-89	14.0
Pusa 5A/TCP-74	13.2
Pusa 6A/SPS 2-51	12.6
Pusa RH 10	9.6

1.1.2.3 Development and evaluation of CMS lines

Four new CMS lines of *basmati* quality, namely, Pusa 7A (BC_9), Pusa 8A (BC_8), Pusa 9A (BC_8), and Pusa 10 A (BC_8), and three non-*basmati* quality CMS lines, Pusa 11A (BC_4), Pusa 12A (BC_4) and Pusa 13A(BC_4) are at different stages of back crossing for conversion. The source of cytoplasm in *basmati* types is PMS 2A and in the case of non *basmati* types it is Pusa 5 A and the cytoplasm is of WA type. The nucleus seed production of already developed *basmati* (Pusa 3A, Pusa 4A, Pusa 6A) and non-*basmati* CMS line (Pusa 5A) was undertaken by paired crossing. In addition to this, the general multiplication of CMS lines was also taken.

1.1.3 Barley

Two genotypes, BHS 365 and BHS 366, were promoted to second year of testing under dual purpose coordinated trial while three genotypes, BHS 368, BHS 369 and BHS 371, were promoted to AVT of Northern Hills Zone for grain purpose. Five genotypes, viz., BHS 372, BHS 373, BHS 374, BHS 375 and BHS 376, were included in All India Coordinated Barley Trials for further evaluation under both grain as well as dual purpose quality.

1.1.4 Maize

1.1.4.1 Composites PC 3 and PC 4

Two maize composites PC 3 and PC 4 earlier released by the State Variety Release Committee were notified by the Central Sub-committee on Crop Standards, Notification and Release of Varieties facilitating their formal movement into seed production chain.

1.1.4.2 Hybrid released for NCR

The Hybrid AH 58, belonging to early maturity was released by the Central Sub-committee on Crop Standards, Notification and Release of Varieties in the year 2000 for Zone IV as PEHM 3. This hybrid showing consistent superior performance in the NCR, Delhi also in the on-farm demonstrations was released for NCR, Delhi by IARI Varietal Identification Committee.

1.1.4.3 Hybrids in pipeline

On the basis of evaluations during the year 2004, eleven entries including four AH entries (AH 23039, AH 23035, AH 017045 and AH 017051) were advanced to the final year testing (AET-II). In addition, two entries AH 24008 and AH 24003 in *rabi* trials also reached the AET-II year. The experimental hybrid AH 23039 performed 41.13% better than the check HIM 129 and 45% better than Surya of the same maturity group (Extra Early) in zone-V, which includes

Gujarat, Madhya Pradesh, Rajasthan and western Haryana. Like wise, another single cross hybrid in extra early maturity group AH 23025 was found to be a better performer in Zone-II which includes Delhi, Punjab, Haryana, U.P. and Uttaranchal. This hybrid gave 3.86 tonnes grain yield/ha, which was 22.38% higher than that of HIM 129 and 24.63% higher than that of Surya of the same maturity group. In the medium maturing group also, two single cross hybrids, namely, AH 017045 and 017051 were found superior to the comparable check Navjot.

1.2 MILLET

1.2.1 Pearlmillet

1.2.1.1 Hybrids and composites in coordinated trials

One hybrid, namely, Pusa 746 (MS 379 A x PPMI 85M) was promoted from AHPT-I to AHPT- II for the 3rd year of testing. Another hybrid, namely, Pusa 751(MS 576 A x PPMI 23) was promoted from AHPT I to AHPT II, for the 2nd year of testing. Five new entries of hybrids, namely, Pusa 758 (MS 576 A x PPMI 295), Pusa 759 (MS 431 A x D 23), Pusa 760 (MS 431 A x PPMI 85), Pusa 761(MS 549 A x PPMI 295) and Pusa 762 (MS576 A x PPMI 301) were included in the Initial Hybrid Trial (*Kharif* 2005). One composite population, namely, MP 443 was promoted from APT second year to APT third year of testing during *kharif* 2005. Another composite population, namely, MP 453 was promoted from IPT to APT and a new population, viz., Pusa Comp. 596 was included in the Initial Population Trials-(*Kharif* 2005).

1.2.1.2 Evaluation of new hybrids in station trials

In an advanced station trial conducted during *kharif* 2005, twenty hybrids along with three checks, Pusa 322, Pusa 23 and Pusa 605 were tested. The data were recorded on plant height, days to 50% flowering, number of effective tillers per plant, ear length, ear girth and grain yield. Four hybrids, namely, MS 411 A x PPMI 69, MS 411 A x PPMI 301, MS 576 A x D-23 and MS 576 A x PPMI 295 out yielded the best check by 18-25%.

1.2.1.3 Development of high yielding, disease resistant open pollinated composites suitable for moisture stress conditions

Six newly developed dual-purpose downy mildew resistant composite populations, namely, PPMP 609, PPMP 611, PPMP 612, PPMP 614, PPMP 615 and PPMP 616, along with three checks Pusa 266, Pusa 334 and Pusa 383 were tested in a population station trial. The composite PPMP 612 out yielded the best check Pusa Composite 383 by 11.8%.

1.3 FORAGE CROP

1.3.1 Forage Sorghum

1.3.1.1 Variety identified

Pusa Chari 615. A multi-cut forage sorghum variety, Pusa Chari 615 was recommended for release in NCR, Delhi. It was developed from a cross Pusa Chari 40 x Pusa Chari 67. It has tall plants (3.0 -3.2m), 10-12 dark green leaves/plant, medium thick cane and stay green character. In addition to high green (70 t/ha) and dry (20 t/ha) fodder yields, it also showed better seed production ability (1.2-1.5 t/ha).

1.3.1.2 Promising genotypes

Based on better performance, one single–cut genotype, PC 1001, is being evaluated in the final year of testing in AVT in coordinated trials. In addition, two multi-cut genotypes, viz., PC 801 and PC 802 were under initial stage of coordinated testing.

1.4 GRAIN LEGUMES

1.4.1 Chickpea

1.4.1.1 Varieties identified

BG 1108. A *Kabuli* bold seeded variety, BG 1108 was tested in coordinated trials in central India and also in Delhi and adjoining states during 2000-2004. Over the years, it has significantly out yielded all the checks and recently released varieties. This variety has shown resistance against soil borne diseases. The seeds are bold, uniform, creamy in colour and attractive. Cooking quality is excellent. The traders, on the basis of its seed superiority, offer high market prices. This variety was identified for release in Delhi and adjoining states.

BGD 128. A *Kabuli* bold seeded variety, BGD 128 was identified for release in central India comprising the states of MP, Maharastra, Gujarat, Bundelkhand parts of UP and

BGD 128, a bold seeded *Kabuli* chickpea variety identified for release in central India

adjoining parts of Rajasthan. The variety BGD 128 possesses a yield potential of more than 2.0 t/ha, resistance against soil borne diseases and wide adaptation. Seeds of this variety are uniform, attractive and excellent for culinary proposes. The growth habit of BGD 128 is semi-erect and suitable for mechanical harvesting. This variety is well adapted to rainfed environments because of its resistance against drought.

BGM 547. A *desi* chickpea mutant, BGM 547 was identified for North Western Plains Zone for late sown conditions. The mean yield superiority is 15.84 % over all ruling checks. The average grain yield is 1.8 t/ha with a potential yield of 3.1 t/ha. It has bold, attractive golden brown colour of seed with 100 seed weight > 25.1 g. It has thin testa, preferred by the consumers, and seeds with good taste and cooking quality. It is of medium maturity (135 Days), tolerant to wilt, root rot, stunt diseases and pod borer.

1.4.2 Mungbean and Urdbean

1.4.2.1 Entries in pipeline

Pusa 0531 (K851 x ET 52186) was promoted to AVT-I in NEPZ and CZ. Pusa 0532 (K851 x PLM-21) was promoted in AVT-I in NEPZ.

1.4.3 Pea, Lentil and Cowpea

1.4.3.1 Variety identified

L 4594 (Pusa Masoor 5). A lentil variety, L 4594 was identified for release for commercial cultivation in NCR, Delhi. This variety has medium growth habit, small seeds and orange cotyledon, and is resistant to rust.

1.4.3.2 Promising material

The following material of pea, lentil, cowpea and vegetable pea are in various stages of trials:

Crop	Trials		
	AVT 2	AVT l	IVT
Pea	DMR 47, DMR 48, DDR 6l	DMR 49, DMR 52, DDR 69	DMR 53, DMR 54, DDR 73, DDR 74
Lentil	L 4595, L 4661	L 4671, L 4672, L 4674, L 4676	L 4678, L 4679, L 4680, L 4682, L 4684, L 4685
Cowpea	DCP 2	DCP 6, DCP 7, DCP 10	DCP 12, DCP 13
Vegetable pea	—	DVP 1, DVP 2	

1.4.4 Pigeonpea

1.4.4.1 Variety identified

Pusa 2001. Identified for NCR, Delhi on the basis of three years' consecutive testing in coordinated trials, the pigeonpea variety Pusa 2001 showed superiority for yield, grain size and early maturity. In large-scale demonstrations in farmers' fields it showed 10% yield superiority over the best check variety Pusa 991.

1.4.4.2 Variety proposed for identification

A pigeonpea variety, Pusa 2002-2 has shown 9% superiority in yield (coupled with extra-early maturity) over that of the best check on the basis of weighted average in coordinated trials for NWPZ over three years' testing. Large-scale demonstrations were laid out in Punjab, Haryana and Delhi.

1.4.4.3 Varieties in pipeline

The variety Pusa 2004-2 is under extensive testing of AVT -1 in the coordinated trial for South Zone. Pusa 2006-1 (H88-23 x D_0) and Pusa 2006-2 (Pusa 33 x 89-44-33) gave the highest yield (2.23 t/ha) in multi-location and Institute trials.

1.4.4.4 Breeding material

Different filial generations of breeding material from F_1 to F_7 were raised. Top ten progenies in the fixed material showed a yield performance of more than 2.2 t/ha as compared to that of the control variety, Pusa 992 (2.02 t/ha). Besides, these material were earlier in maturity compared to the check variety. The highest yielding progeny showed 5 days' earliness compared to the latest released variety Pusa 992. Medium bold seed character was also observed for these progenies.

1.5 OILSEED CROPS

1.5.1 *Brassicas*

1.5.1.1 Varieties notified

LES 39 (Pusa Karishma), the first single zero (<2% erucic acid) variety and JD 6 (Mahak), an early maturing variety of Indian mustard, were notified.

1.5.1.2 Varieties identified for release in NCR, Delhi

EJ 13 (Pusa Tarak). An early maturing and non-shattering Indian mustard variety with initial quick growth and synchronous maturity, EJ 13 has wider adaptability and is comparatively free from diseases and insect pests. It responds well under intensive cropping system. It 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.

NPC 9 (Pusa Aditya). A *Brassica carinata* variety, NPC 9 produced 38.07 and 16.96 per cent higher seed yield over checks Kiran and JTC 1, respectively. The average seed yield of NPC 9 is 1.4 t/ ha under rainfed conditions in trials and 1.33 t/ ha in farmers' fields in NCR, Delhi. It has shown

39.76 and 31.52 per cent superiority over checks Kiran and JTC 1, respectively, for oil yield also. 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, Sclerotinea stem rot and powdery mildew. It is tolerant to aphid under field conditions.

1.5.1.3 Varieties proposed for identification in NCR, Delhi

LES 1-27. A single zero (low erucic acid <2%) strain, LES 1-27 performed better than the conventional checks (high erucic acid) for three consecutive years in zones II and III of India as well as in the NCR, Delhi. The mean seed yield of LES 1-27 is 2.14 t/ ha, whereas, the potential seed yield is 2.73 t/ha in coordinated trials conducted in North Western Plains Zone. On the basis of yield superiority and better quality, it will be proposed for identification.

NPJ 93. A mustard variety, NPJ 93 performed consistently better for seed and oil yields in the coordinated trials in zone II and in common trials and demonstrations in farmers' fields. At Delhi, NPJ 93 exhibited superiority over all the existing popular varieties, viz. Varuna (46.94%), Kranti (29.23%), Pusa Bold (19.63%), Pusa Jai Kisan (23.50%) and Pusa Jagannath (27.05%) over the years. It will be proposed for identification in the NCR, Delhi.

1.5.1.4 Entries in pipeline

The following entries are in various stages of testing:

Name of the trials	Entries
AVT-I (Toria)	EJ 15
AVT-I (Timely sown irr.)	JS 19
AVT-I (Late sown)	NPJ 99
AVT-I (Quality)	LET 3, LET 18
AVT-II (Quality)	LET 14, LET 17, LET 1-27 (Repeat)
IVTs	EJ 16, NPJ 107, JS 21, PBG 1188, NPJ 108, HYT 14, LET 10, LET 20, NPC 16, NPC 17
CVT	12 entries were tested at IARI and KVK Sikohpur

1.5.1.5 Development of early maturing material

Early sown and short duration breeding material with less than 100 days maturity was identified and advanced and eighteen bulks were made for early sown (September) testing. The higher yielding entries were NPJ 90 (2589 kg/ha, maturity 101 days) followed by NPJ 107 (2560 kg/ ha, maturity 96 days). Other early maturing promising cultures were NPJ 95 and NPJ 108.

1.5.2 Soybean

1.5.2.1 Variety released

Pusa 9712. The variety, Pusa 9712 was notified for NCR, Delhi and identified for North Western Plains Zone also. It has significantly higher and stable yields over the checks, PK416 and PK1042 (14.97% and 21.49%). It is resistant to yellow mosaic virus, soybean mosaic virus, bacterial pustule, charcoal rot, Myrothecium leaf spot and stem fly. It is earlier in maturity than checks (PK416 and PK1042) and the qualifying variety (SL 518). DS 9712 is a bold seeded variety having 100-seed weight of more than 10 g.

1.5.2.2 Variety for identification

Pusa 9814. The variety Pusa 9814 showed significantly higher and stable yields over the checks PK 416 and PK 1042 (20.95% and 25.89%) and the qualifying genotype SL 518 (11.89%). It has resistance against yellow mosaic virus, soybean mosaic virus, pod blight, and charcoal rot and moderate resistance to stem fly. It is a bold seeded variety with a seed weight of more than 10 g/100 seeds.

1.6 FIBRE CROP

1.6.1 Cotton

1.6.1.1 Variety for warmer and non-traditional areas

P 17-52-10, an early maturing strain was found promising for cultivation during spring/summer season in Delhi, Uttar Pradesh and Punjab. It matures in 130-136 days. It can be planted in the 3rd to 4th week of February and harvested by 30th June. It showed an average yield of about 0.85 t/ha against 0.55 t/ha of check during spring/summer season. Its performance was also found promising in Sunderbans (West Bengal) against the check LRA 5166. It showed good fibre quality with 27-28 mm fibre length and 20 g/tex fibre strength.

1.6.1.2 Entry in pipeline

Pusa 734 is under evaluation in multilocation coordinated trial Br. 03(a). It is an early maturing genotype and is tolerant to jassid and cotton leaf curl virus disease. During 2004-2005, it showed a seed cotton yield of 2.19 t/ha in AICCIP trial Br. 02(a) under irrigated conditions in comparison to 2.06 t/ha of the check.

1.6.1.3 Entries with improved fibre quality

During 2003 and 2004, Pusa 56-4 showed 28.6 mm mean 2.5% span length, 52.3% uniformity, 3.75 micronaire and 28.05 g/tex fibre strength. Likewise Pusa 56-6 showed 27.3 mm mean 2.5% span length, 53.1% uniformity, 4.3 micronaire and 27.2 g/tex fibre strength during the same

period. A number of genotypes were found promising for superior fibre quality, especially fibre strength.

1.7 VEGETABLE CROPS

1.7.1 Cole Crops

1.7.1.1 Cauliflower

In early maturity group (I), cauliflower selection DC 23000 was found to be the most promising selection with a yield potential of 14.70 t/ha. CMS based hybrid combinations, namely, 98 x PD, 98 x PM and 98 x 41-5, gave a yield of 16.1, 15.6 and 15.2 t/ha, respectively. The promising self incompatibility based hybrid combination 14 x PD gave a yield of 14.5 t/ha. The best check Pusa Meghna of this group gave a yield of 14.3 t/ha.

In mid-maturity group (II), the most promising CMS based hybrid combinations, namely, 8409 x 312, 8410 x 395, 8409 x IJ, 8410 x 301 and 8410 x IJ gave a yield of 34.0, 31.5, 30.9, 30.8 and 30.7 t/ha, respectively. The best check Pusa Sharad of this group gave a yield of 25.0 t/ha. In mid-late group (III), the most promising hybrid combinations, namely, 9 x HR 6-5-1 and 9 x 401 gave a yield of 34.5 and 33.9 t/ha, respectively. DC 5 and DC 435 were the most promising lines which gave a yield of 30.5 and 32.1 t/ha, respectively, as against the best check Pusa Synthetic (27.2 t/ha).

The promising moderately resistant/tolerant families, namely, SR 12 and SR 13 (Lawyana x 41-5 F_6) for Sclerotinia rot gave a yield of 34.0 and 29.6 t/ha, respectively; AL 15 (Lawyana x 41-5 F_6) and AL 23 (Kn 81 x 41-5 F_6) for Alternaria leaf spot gave a yield of 34.5 and 34.0 t/ha, respectively; BR 1, BR 48 and BR 23 (Lawyana x 41-5 F_6) for black rot gave a yield of 29.6, 28.4 and 27.4 t/ha, respectively, and DM 18 (Kn 81 x 98-4 F_5) for downy mildew gave a yield of 30.2 t/ha. The best check Pusa Sharad gave a yield of 25.0 t/ha.

In late (snowball) group of cauliflower, the highest yielding CMS based hybrid KTH 1 (30.1 t/ha) and SI based hybrid KTH 2 (29.4 t/ha) gave 33.7 and 30.6 per cent superiority over the check Pusa Snowball K 25, respectively. These were entered for multi-location testing under AICRP on vegetable crops. The reported self-incompatible lines are being improved for self-incompatibility level and CMS lines for better seed setting ability. Transfer of CMS system into desirable genotypes is in progress.

Multi-location testing under AICRP on vegetable crops of the two enteries, viz., KT 8 (24.5 t/ha) and Kt 22 (27.8 t/ha) gave consistant superiority for yield over the best check Pusa Snowball K 25 (22.5) this year also at the Station. The selections developed through hybridization and showing promise for yield and quality parameters were Kt 2 (28.7 t/ha), Kt 9 (28.2 t/ha) and Kt 18 (28.1 t/ha).

Nine F_4 progenies were identified for black rot resistance. Two each of Kt 25 x EC 162587 and No. 1 x EC 162587; four of RSK 1301 x (HxL) and one of Kt 25 x Lawyana combinations were improved for horticultural traits and advanced to next generation.

1.7.1.2 Cabbage

Cabbage hybrid KGMR 1, the first public sector hybrid carrying field resistance to black rot disease with good staying ability in the field after head formation and an average yield of 35-45 t/ha, was recommended for release for Zones I and IV in the XXIII group meeting of the AICRP on vegetable crops. Cabbage hybrid KCH 5 was entered in the co-ordinated trial for multi-location testing. It has given the highest yield of 51.36 t/ha in the IET.

Cabbage hybrid KGMR 1

Twenty seven F_1 hybrids of cabbage were evaluated for yield and horticultural traits. Hybrid 83-1 (Pl-1) x C-2 was the earliest to head formation (56.2 days)) followed by 83-5 x C-6 (57.5 days). The highest yield of 64.8 t/ha was recorded in SI based hybrid 83-2 (Pl-2) x 490174 and in CMS based hybrid GA x 490174 (51.1 t/ha).

Screening of 21 germplasm and 8 F_1 hybrids against black rot disease and diamondback moth was carried out during summer season. Purple coloured varieties, RRM and Red Cabbage exhibited minimum damage due to diamondback moth (15 % each). However, these 2 varieties were found highly susceptible to black rot disease with an incidence of 42.6 and 35 per cent, respectively. AC 204, KCH 5, KGMR 1, KGMR 2, KCH 2, H 113, AC 208 and Pride of Asia showed minimum damage due to black rot disease

(0-6.6 %). Among the different genotypes evaluated, minimum DBM infestation was recorded in varieties, KIRC 2 and KIRC 9, and hybrids, KIRCH 10, KIRCH 8 and KIRCH 5. High yielding superior hybrids/varieties are being selected. Selection GMR 2 is showing great promise for yield and resistance to black rot, downy mildew and tolerance to Sclerotinia disease.

1.7.2 Cucurbitaceous Crops

1.7.2.1 Ash gourd

Sixteen new germplasm were collected and evaluated. Among these lines, nine were purified and maintained. Two promising selections DAG 4 and DAG 6 were developed for growing in both summer and *kharif* seasons. They gave 42.0 tonnes and 43.5 tonnes yield per hectare, respectively, during *kharif* season. Both were earlier in maturity than Pusa Ujwal (Check). The fruits of these selections are oblong in shape and medium in size. The average fruit weight is 8.5 and 9.0 kg. They are suitable for long distance transportation, storage and processing purpose (candy preparations).

Ten promising genotypes and 45 F_1 hybrids selected/ developed earlier were utilized to study heterosis, combining ability and gene action for yield and quality characters.

1.7.2.2 Bitter gourd

Twenty-three lines were collected and will be evaluated and maintained. The gynoecious line DBTG-202 gave earliest (46.0 days after sowing) fruit harvest which was followed by a small fruited line DBTG-101 (54 days after sowing), whereas the genotype CO-1 took the longest period of 94 days to first harvest. These two lines were utilized for making different cross combinations. The highest ascorbic acid content (122 mg/100g edible portion) and carotenoids (2829 ìg/100g edible portion) were recorded in DBTG 3 and DBTG 101, respectively. High heritability coupled with high genetic advance for characters like total number of female flowers per plant, average fruit weight, average fruit thickness and average fruit length may be attributed to additive gene effects and could be improved through simple mass selection.

Among 116 random decamer primers screened, 29 were polymorphic and informative enough to analyse 38 genotypes of bitter gourd. Of 208 markers generated, 76 (36.50%) were polymorphic and the number of bands per primer was 7.17, of which 2.62 were polymorphic. Pair-wise genetic distance (GD) based on molecular analysis ranged from 0.07 to 0.50 suggesting a wide genetic base for the genotypes. The clustering pattern based on yield related traits and molecular variation was different.

Screening of 20 genotypes in a pot experiment against 4 different salt concentrations (1, 2, 4 and 8 EC) showed that Pusa Do Mousami, Sel. 1 and Green Long were tolerant to soil salinity up to 4EC, and Arka Harit was the most susceptible one even at 1EC. None of these genotypes were found to be tolerant to 8EC soil salinity level.

1.7.2.3 Cucumber

Three promising selections, DC 1, DC 3 and DC 6, yielded 18.9 t/ha, 18.2 t/ha and 17.4 t/ha showing an increase of 18%, 14% and 9% over check Pusa Uday, respectively. Twenty germplasm of *C. sativus* var. *hardwickii* were evaluated and maintained. DH 3, DH 14 and DH 24 were promising for yield adaptability and CMV resistance. These were utilized in crossing programme to study the genetics of yield and CMV resistance. Monoecious F_1 hybrid DCH 3 and gynoecious F_1 hybrid DCHG 2 gave yields of 19.3 t/ha and 18.6 t/ha which were 21% and 17%, respectively, higher than that of the check Pusa Uday,. Twenty-five genotypes of cucumber including 5 *Cucumis sativus* var. *hardwickii* were screened artificially for salinity stress under 5 salt concentrations (0, 1, 2, 4 and 8 dSm^{-1}) of salts NaCl, Na_2CO_3 and K_2SO_4 (1:1:1). The genotypes, CRC 8, DC 1, WBC 28, and Poinsette were found moderately tolerant to salinity stress on the basis of different morphological traits.

1.7.2.4 Luffa

Fifty-seven new germplasm of sponge gourd and 28 new germplasm of ridge gourd including some *Satputia* types were evaluated and promising lines maintained. Sponge gourd Sel. DSG 5 and DSG 7 gave a yield of 14.5 t/ha and 13.5 t/ha which were 21% and 12.5%, respectively, higher than that of the check Pusa Sneha. These two selections were also highly tolerant to Gemini mosaic virus. Promising ridge gourd selection DRG 2 gave a yield of 13.5 t/ha, which was 59% higher than that of the check Pusa Nasdar (8.5 t/ha).

1.7.3 Solanaceous Crops

1.7.3.1 Brinjal

One hundred and forty-two entries were tested under 13 different trials comprising of Institute's, AICRP (VC) and NATP trials. In long fruited hybrid trials (NATP), DBHL 14 (47.05 t/ha) and DBHL 150 (45.93 t/ha) were found promising with an increase of 11.4% and 8.7%, respectively, over that of the best check Pusa Hybrid 5 (42.23 t/ha). In round-fruited hybrid trial (Institute's), DBHR 159 (47.26 t/ha) and DBHR 101 (46.68 t/ha) were found best with an increase of 13.74% and 12.34%, respectively, over that of the best check Pusa Hybrid 6 (41.55 t/ha). In small round fruited hybrids, DBHSR 160 (34.42 t/ha) was found best with 12.93% increase over the check MHB 39 (32.00 t/ha). Thirty segregating generations were studied, and selected ones were

advanced for further study.

In resistance breeding programme, screening was done against Phomopsis blight. Two lines, namely, Pusa Bhairav and 11a-12-2-1 were found resistant. Twenty-five lines were screened against shoot and fruit borer. On fruit number basis, comparative tolerance was observed in HE 12, Nurki, PPC and Pant Samrat.

1.7.3.2 Tomato

Among the determinate types of hybrids, DT 1 and DT 2 gave 46% and 40.6%, respectively, higher yields over that of the best check CO 3. In determinate varietal trial, DT 11 was superior (8.5%) to check DT 10. Among thirty F_1 hybrids evaluated, hybrid combinations, DT 39 x Chikoo, Sel. 3900 x Pusa Sheetal and Sel. 3900 x DT 10, gave quality fruits under biotic stress conditions. Under TLCV resistant varietal trial, H 24, H 86, H 88 and Nun 5005 showed tolerant reaction under natural epiphytotic conditions among the eleven promising lines evaluated. FEB 2, Megha and Super Market were found resistant against early blight among thirty genotypes evaluated. NF 31, CB 28 and Pusa 120 were observed to be resistant against root-knot nematode among 25 genotypes tested.

Under abiotic conditions, genotypes WIR 362, Booster, Pusa Sheetal, New Wonder and EC 78180 were found to be promising for fruit setting under both higher temperature regime and low temperature regime. Hybrids, Pusa Sheetal x Sel. 263, Sel. 1234 x Booster and Chikoo x 262, were found promising for fruit setting under low temperature regime (8°C and below night temp.) during December-January. Sel. 7 x Sel. 3 showed fruit setting under high temperature regime (28°C and above night temp.) during May-June.

1.7.3.3 Capsicum

Capsicum hybrid KTCPH 3 having green attractive 3-4 lobed fruits with an average yield of 25 t/ha was recommended for release for Zones I, VI and VII in the XXIII group meeting of the AICRP on vegetable crops.

Capsicum hybrid KTCPH 3

Six lines of paprika were evaluated against the standard check variety Kt Pl-19. None of the line could out yield the check which gave a maximum yield of 27.7 t/ha.

1.7.4 Root and Bulbous Crops

1.7.4.1 Carrot

From July sowing, based on extrinsic and intrinsic characteristics, two breeding lines, IPC Ht_1 and IPC Ht_2, were most promising heat tolerant red root lines, which gave 24.4 and 26.7 t/ha root yield. The roots were harvested during first week of October. From August sowing, the addition of red breeding lines, namely, IPC 116, IPC 25, IPC 29, IPC 28 and IPC 53, and orange line IPC 13 showed great potential for early season sowing. For the normal season, the breeding lines, IPC 13, IPC 16, IPC 25, IPC 29, IPC 34, IPC 39, IPC 63, IPC 65, IPC 72, IPC 75, IPC 96, IPC 100, IPC 109 and IPC 131, were found promising with respect to plant ideotype, external and internal root colour. These lines are being advanced for further evaluation and utilization.

In temperate carrot, sixty six F_1 hybrids were developed using nine CMS (A) and eight pollinator (c) lines. In respect of marketable yield, 67 per cent hybrids were found superior to the best check Pusa Yamdagni. The two highest yielding hybrids, namely, N-7 x 1061 (37 t/ha) and PY-8x1061 (35 t/ha), gave 84.8 and 80 per cent economic heterosis, respectively. In addition to existing seven CMS lines, additional two new lines having nearly isogenic maintainer were developed.

From eight new breeding lines evaluated in replicated randomized block design at two sites along with checks, three lines, viz., IPC 122 (red), IPC 133 (orange) and IPC 126 (black) were found to be the best from external and internal root colour point of view, and gave root yield of 24.5, 23.5 and 21.1 t/ha, respectively as against the checks, Pusa Kesar (19.6 t/ha) and Pusa Meghali (18.0 t/ha). These are also under evaluation at multilocations, viz., Karnal, Gurgaon and New Delhi.

Cytoplasmic male sterility has been transferred into â-carotene rich lines, namely, IPC 14, IPC 11 and IPC 13 and also other horticulturally superior new breeding lines. This is being stabilized for utilization in F_1 hybrid breeding.

1.7.4.2 Onion

Two selections, viz., Sel 383 and Sel 402 yielded 40.13 and 36.13 t/ha bulbs, which are under testing at AICRP trials.

Inbred lines were advanced for further selection. Twenty male sterile lines were maintained and 26 F_1 hybrids were evaluated. Hybrid 42, Hybrid 52 and Hybrid 44 yielded 55.99, 50.66 and 46.66 t/ha, respectively.

1.7.5 Leguminous Crop

1.7.5.1 Garden Pea

Studies on morpho-physiogenetical analysis of dry matter production and yield were conducted on 10 genotypes of garden pea which were sub-grouped into five early and five mid-season genotypes. The highest crop growth rate, relative plant growth rate and mean relative pod growth rate were recorded by GP 4 and Bonneville in their respective groups. The highest shelling percentage and harvest index values were recorded indicating their better partitioning coefficient at pod and plant levels, respectively.

A total of 147 genotypes were evaluated for off-season cultivation. These were purified and maintained. Forty F_3, 20 F_4, 5 F_5, 4 F_6 and 4 F_7 populations of different crosses were evaluated. Single plant selections were made on the basis of maturity. GP 4, GP 6, GP 17, GP 207, GP 447, GP 468 and GP 471 were found promising in different maturity groups. In F_4 generation, F4-3A-16-16, F4-3A-23-20A, F4-3A-24-21 and F4-3A-9-10 gave an early green pod yield.

Promising selections, GP 1, GP 447, GP 468 and GP 471, were found to possess resistance to Fusarium wilt, whereas, GP 4, GP 17, GP 207 and VL 3 were observed to be tolerant to this disease. Promising selections GP 7, GP 11, GP 12, GP 20, GP 40, GP 43, GP 45, GP 116, GP 139, GP 162, GP 165, GP 192, GP 193, GP 211, GP 326, GP 360 and GP 427, were found to possess resistance to powdery mildew disease at field screening.

GP 4, GP 17, GP 207, GP 447, GP 468 and GP 471 gave the earliest green pod harvest as compared to commercial varieties like Arkel, Pusa Pragati and VL 7. Promising lines GP 4, GP 17 and GP 207 are being tested under All India Coordinated trials.

A powdery mildew resistant variety of pea KTP 8 having well-filled green pods with 8 grains/pod with an average yield of 10-12 t/ha was recommended for release for Zones I, IV and V in the XXIII group meeting of the AICRP on vegetable crops.

KTP 8, a powdery mildew resistant variety of pea

1.7.6 Malvaceous Crop

1.7.6.1 Okra

A total of 230 breeding lines, 33 elite material and 14 new collections were evaluated for reaction against YVMV and productivity. Sel. DOV 1 and Sel. DOV 2 have shown promise under multilocation trials of AICRP (VC). Major wild species of okra are being grown to utilize them in transfer of YVMV resistance. Selections having 5 ridge with dark green colour and short fruits (8 cm) viz., C 289, C 302, A 9 and C 10 have shown stability for horticultural and export traits.

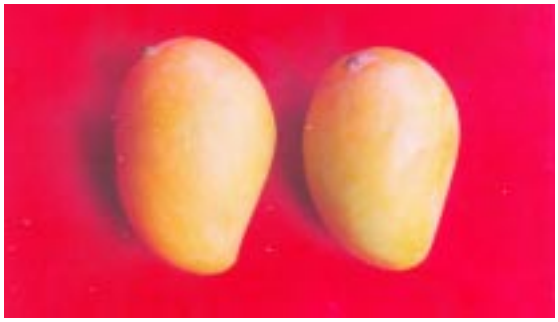
1.8 FRUIT CROPS

1.8.1 Mango

After the release of two new mango varieties, namely, Pusa Arunima and Pusa Surya, five new hybrids, namely, H 1-1, H 1-6, H 2-6, H 4-12 and H 8-11 were identified for consistently good performance. They are in advance stage of their release. All these hybrids are regular in bearing with red peel colour, optimum fruit size (≈ 250 g), good pulp (>70%), good TSS (18.5 to 20%), moderate acidity and good

Mango hybrid H 1-1

Mango hybrid H 1-6



Mango hybrid H 2-6

â-carotene contents. In hybridization, crosses were made in eight parental combinations utilizing 5006 flowers on 815 panicles with Amrapali and Mallika as female parents and Tommy Atkins, Sensation, Lal Sundari, Janardan Pasand and Pusa Surya as male parents.

Performance of some new mango hybrids

Hybrid	Fruit weight (g)	Pulp: stone ratio	TSS (%)	Acidity (%)	Reducing sugars (%)	Total carotenoids µg/100 g
H 1-1	162.00	2.62	19.3	0.13	2.07	11,232
H 1-5	363.11	5.78	21.7	0.18	3.14	3,637
H 1-6	191.24	2.98	21.3	0.15	1.06	9,510
H 1-7	121.25	2.02	21.7	0.19	2.29	14,493
H 1-9	224.72	3.57	16.4	0.14	1.29	11,358
H 1-11	350.55	3.13	18.2	0.13	3.73	8,262
H 2-6	201.85	4.55	18.2	0.26	1.04	11,358
H 8-11	212.45	3.75	18.4	0.22	2.08	11,250

Twenty-one indigenous genotypes were evaluated for different physico-chemical characteristics. Among the indigenous cultivars, Mallika produced the largest fruit (385 g) followed by Zardalu (320 g) and Pusa Surya (275 g). The smallest fruits were produced by Neelum (98.8 g). The maximum TSS was recorded in Amrapali (23.8 %) followed by Mallika (21.8%) and Dashehari (21.6%). The minimum TSS was estimated in Bhadauran (12.8%). The minimum acidity was estimated in Amrapali and Neelum (0.19%), while the maximum was in Bombay Green (0.35%) followed by Mallika (0.34%). â-carotene content was the maximum in Amrapali (15,546 µg/100 g pulp), followed by Pusa Arunima (14,220µg/100 g pulp). The maximum vitamin C content was estimated in Mallika (49.30 mg/100g) followed by Bombay Green (43.56). Both Pusa Surya and Pusa Arunima exhibited long shelf-life (12 days) at room temperature after ripening.

Among the exotic cultivars, Tommy Atkins bore the largest (492.5 g) fruit followed by Edward (373.5g). Ametista produced the smallest (112.2g) fruit. In both Tommy Atkins and Edward, fruits were highly fibrous and severely infested by fruit fly. All the fruit biochemical parameters were in the intermediate range compared to those in indigenous genotypes.

Over 40 new genotypes suitable for different purposes, i.e., sucking and pickling types were added to the existing germplasm, which would be evaluated in future. The characteristic features of some of the collected genotypes are listed below:

Collection and evaluation of sucking type mango genotypes

Genotype	Fruit wt.(g)	Pulp: stone ratio	TSS (%)	Acidity (%)	Reducing sugars (%)
Madhukuppi	144.9	3.13	16.5	0.48	3.90
Cepia	176.7	2.37	15.0	0.63	2.63
Mithuwa Gazipur	190.6	2.41	20.5	0.20	4.73
Mithuwa	184.7	2.57	19.5	0.22	4.34
Gaurjeet	182.4	2.24	22.5	0.18	5.42

Collection and evaluation of pickling type mango genotypes

Genotype	Fruit weight (g)	Pulp : stone ratio	T.S.S. (%)	Acidity (%)
Ramkela	141.0	2.63	9.50	3.88
Sukul	232.6	3.55	11.50	3.41
Challenger	157.6	2.02	11.50	3.11
Bathui	147.3	2.81	11.75	3.15
Ketki	190.4	2.94	13.75	2.75
Plant No.2	148.0	2.64	10.25	1.77
Chiratkutti	96.1	1.00	14.00	2.06

1.8.2 Grape

Thirty-three grape varieties were assessed for their desirable traits. Out of these, Tas-A-Ganesh and Centennial Seedless were observed to have uniform ripening and good fruit quality.

In total, 17,581 F_1, F_2 and open-pollinated hybrid seeds were produced by attempting 15 different crosses, selfing (2) and open-pollination (4). The seeds produced during the preceding year were stratified and sown.

One hundred and thirty-two hybrids were assessed for their desirable traits and primary selection, out of which two were observed to perform well on different training systems. The two promising grape hybrids, viz., BA x Per 75-32 and Hur x Cardinal 76-1 were found to consistently perform well, and have been identified for their release. Twenty-five varieties and 15 promising grape hybrids were multiplied for gap planting.

Performance of two promissing grape hybrids

Hybrid	Ripening time	Av. no. of bunches/vine		Av. bunch wt. (g)	Av. berry wt. (g)	TSS (%)	Remarks
		Head system	Bower system				
BA x Per-75-32	2nd week of June	24.0	40.0	600	2.0	18.0	Yellowish seedless berry can be used as table grape
Hur x Card-76-1	1st week of June	30.0	-	650	6.5	22.0	Yellowish bold berry , seeded can be used as table grape and *Munnakka* making

1.8.3 Citrus

1.8.3.1 Sweet orange (*C. sinensis*)

Twenty-five malta and five mosambi accessions were evaluated for their growth parameters. MS 7 was found vigorous while MS 3 was slow growing. Similarly, in mosambi, MOS 3 was vigorous while MOS 5 was slow growing.

1.8.3.2 Mandarin (*C. reticulata*)

Out of the 12 Narangi (mandarin) accessions, Accession No. 13 was found most vigorous with respect to plant height, trunk diameter and canopy volume whereas Narangi Accession No.1 gave cent per cent increase in canopy volume after one year of planting.

1.8.3.3 Lemon (*C. limon*)

Among six hill lemon accessions, Accession No. 6 gave the maximum height (2.09 m). The smallest plants were present in Accession Nos. 4 and 5 (1.67 m). However, the maximum canopy volume increase was noted in HLS 2.

1.8.3.4 *Galgal* (*C. pseudolimon*)

Accesion No.2 gave the maximum (2.07 m) height; the lowest height was recorded in Accession No.1 (1.23 m). One new accession was added.

1.8.3.5 Lime (*C. aurantifolia*)

Out of the two acid lime collections, acid lime No. 1 grew faster than acid lime No. 2. Three new accessions were added to the existing germplasm.

1.8.3.6 Pummelo (*Citrus grandis*)

Six collections of pummelo are performing very well after their introduction during 2003-2004.

1.8.4 Apple and Apricot

An apple accession collected from Shillong (Meghalaya), i.e., *Malus baccata* (Shillong), was found completely resistant to woolly aphid *(Eriosoma lanigerum)*, and the development of root rot (c.o. *Dematophora necatrix*) and powdery mildew (*Podosphora leuchotricha*) was significantly delayed as compared to well known source of resistance, *Malus zumi*. It has shown field resistance to apple scab (c.o. *Venturia inaequalis*) also. It has a very good propagation potential. The chilling requirement of this species is less than that of M 9 and MM106. In vigour, it is equivalent to MM106 and has proved adaptable for use in high-density plantings. Though leaf stomata counts indicated that as a rootstock it might be as dwarfing as M9 yet the actual growth of grafts on this rootstock was similar to those on MM106. The test scion cultivars were Spur-Type-Red Delicious and Golden Delicious. A high density apple plantation experiment is in progress with planting densities of 4561, 2500, 1736, 1111 and 625 trees per hectare. The test cultivar is Spur-Type-Red-Delicious. An attempt was made to ascertain the quantum of sunlight penetration through the tree canopy. Maximum sunlight interception in the middle and at the bottom of the tree was observed in the case of planting density of 4651 trees per hectare. There were very little differences with respect to the tree densities of 2500 and 1736. In the case of planting density of 1111, the difference between the sunlight interception in the middle and at the bottom of the tree was negligible. Minimum sunlight interception was recorded in the planting density of 625 trees per hectare. The germplasm holds promise for use as rootstock for semi-dwarfing and semi-vigourousness. It can also be useful in breeding programme for disease and pest resistance. Apple cultivar Starking Delicious exhibited perfect graft compatibility with the various types of *Malus baccata* used as rootstocks. Amongst various *Pyrus* species *Pyrus pashia* var. *Kumaonii* was found to be resistant to white root rot (c.o. *Dematophora necatrix*). Experiments are in progress to develop techniques for multiplication of apple planting material. Among these, grafted cuttings of apple were successfully rooted in a preliminary trial. Once standardized, this technique will effect a saving of two years of nursery space and investment.

Work on the molecular characterization of *Malus* species has been initiated in collaboration with the scientists of the Central Potato Research Institute.

The germplasm being maintained at the Station was screened for the prevalent diseases. In apricot, the cultivar Royal was least susceptible. Soil solarization has reduced

the population of *Dematophora necatrix* and other soil fungi, bacteria and actinomycetes and controlled white root rot disease in nursery. Studies on the effect of different planting densities on microflora in apple rhizosphere revealed that bacteria dominated the rhizosphere followed by actinomycetes, fungi and *Azotobacter* and it decreased with decreasing plant densities and increasing soil depths. *Trichoderma* spp. and their cultural filtrate inhibited *Dematophora necatrix* and *Sclerotium rolfsii in vitro.*

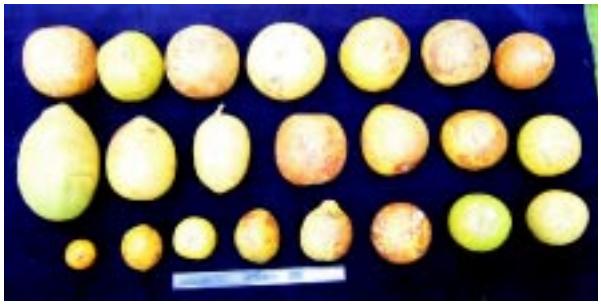
1.8.5 Minor Fruits

1.8.5.1 *Aonla*

Four genotypes, namely, Krishna, Chakaiya, Kanchan and NA 7 were evaluated. The highest estimated yield (50 kg/plant) was recorded in NA 7 followed by Chakkaiya. Furthermore, the maximum TSS (11.6%), acidity (1.5%), total sugars (11.12 %), ascorbic acids (491.6 mg/ 100 g pulp) and tannins (1.18 mg/ 100 g pulp) were also recorded in NA 7.

1.8.5.2 *Bael*

Twenty-two genotypes were collected from Varanasi and Mirzapur districts of Uttar Pradesh. Three accessions, namely, BV 8, BV 12 and BM 20 were identified to be superior based on the physico-chemical characters. Four *bael* genotypes, namely, NB 4, NB 5, NB 7 and NB 9 were evaluated. Fruit cracking was seen in all the cultivars. The highest number of fruits was observed in NB 9 (55 fruits/tree) followed by NB 5 (51 fruits/tree). The highest average fruit weight (1,260 g) was recorded in NB 7, whereas the minimum skull weight was recorded in NB 4 (113.5 g). The maximum TSS, acidity, reducing sugars and ascorbic acid were recorded in NB 9 followed by NB 5.



Diverse *bael* genotypes collected and evaluated for various physico-chemical characters

1.8.5.3 *Ber*

In *ber,* 54 different characters comprising plant canopy, thorn, leaf, flowering, fruiting and seed morphology were studied on 40 accessions for preparing the dendrogram based on numerical taxonomy. Three accessions – one each from early (11/3-4), medium (3/9-10) and late (4/3-4) group–were found suitable for fruit quality and yield potential.

1.8.5.4 *Jamun*

A survey was made in Goa and adjoining areas of Karnataka and Maharashtra. Twenty-nine genotypes were collected and evaluated for their physico-chemical characters. Seven promising types were identified based on superior physico-chemical characters (fruit wt. 13-14 g, TSS 16-18%, acidity 0.55-0.61%).

1.8.5.5 Pomegranate

In pomegranate, the performance of five commercial cultivars was evaluated. The cultivars Jyoti and Ganesh outperformed the others.

Performance of pomegranate cultivars

Genotype	Cracking	Fruit colour	Aril colour	Fruit wt. (g)	Juice	TSS (%)	Acidity (%)	TSS: acid ratio
Jyoti	S	Yellow with pink blush	Pink	252	67.2	16.2	0.21	77.1
Ganesh	S	Red with yellow patches	Pinkish white	232	56.7	15.3	0.22	69.5
Dholka	M	Red with yellow patches	Light pink	243	57.8	13.4	0.28	47.8
Alandi	T	Pink	Light pink	236	52.3	14.4	0.24	60.0
Bedana	T	Yellow	Pinkish white	204	54.3	13.2	0.28	47.1
Jalore Seedless	T	Pink	Pinkish white	248	53.4	14.2	0.32	44.3
Achick Dana	T	Brownish yellow	white	186	54.9	12.8	0.31	41.2

S= susceptible; M= moderately tolerant; T= tolerant

1.9 ORNAMENTAL CROPS

1.9.1 Rose

Four new varieties, three belonging to Hybrid Tea (Pusa Arun, Pusa Ajay and Pusa Shatabdi) and one belonging to Floribunda group, (Pusa Komal) were identified by IARI Variety Identification Committee for release.

The variety Pusa Arun was developed through hybridization between an exotic variety Queen Elizabeth and an indigenous variety Jantar Mantar. This variety has bright red colour and is suitable for cut flowers. It takes 45-50 days to bloom after pruning in second fortnight of October. It

produces 20-30 flowers during winter and 35-40 flowers during spring season per plant.

The variety Pusa Ajay is a cross between Pink Parfait and Queen Elizabeth. It produces 20-30 flowers during winter and 35-40 flowers during spring season per plant. The blooms are pink and remain fresh for 8-10 days in field conditions as well as in vase when harvested at the bud stage. The plants have very vigorous growth and recurrent blooming habit.

Promising rose varieties

The variety Pusa Shatabdi is a hybrid seedling between two exotic varieties, Jadis and Century Two. This variety has very long flower buds of attractive pink colour. It takes 45-50 days to bloom after pruning in the second fortnight of October. It produces 20-30 flowers during winter and 35-40 flowers during spring season per plant. The blooms remain fresh for 8-10 days in field conditions and has a vase life of 10-12 days when harvested at the bud stage.

The floribunda variety Pusa Komal is a cross between an exotic variety Pink Parfait and an indigenous variety Suchitra. Pusa Komal takes 45-55 days to bloom after pruning in the second fortnight of October. It produces 40-45 flowers during winter and 60-65 flowers during spring season per plant. The soft pink blooms remain fresh for 8-10 days in field conditions. The plants are completely thornless.

1.9.2 Gladiolus

An experiment on assessment of 29 gladiolus hybrids along with variety Archana (control) was carried out. The data revealed that the spike emergence was earliest in Berlew open[2] (72.4 days) while it was the last in White Projiate x Lucky Star (87.4 days). Likewise days for bud colour showing were the least in Berlew open[2] (85.4 days) but maximum in Ratna butterfly x Picardy open (110.8 days). The minimum floret diameter (6.4 cm) was observed in Western Miss x Cameltone, White Projaite x *Gladiolus callianthus murielae* and Blue Lilac x Christian Jane while the maximum diameter (9.9 cm) of floret was recorded in Berlew open[1]. Many hybrids showed better number of florets per spike (Mayur x Green Willow: 16.2, Green Willow x Oscar: 15.8 and Smoky Lady: 15.2) while Pusa Archana produced only 12 florets per spike. For spike length, Mayur x Green Willow produced longer spike (86.4cm) followed by Green Willow x Oscar (79.8 cm) though Pusa Archana produced only 77.0 cm spike length. Rachis length was the highest in Pusa Archana (52.8 cm).

1.9.3 Chrysanthemum

In chrysanthemum, two radio-mutants Pusa Anmol and Pusa Centenary were identified by the IARI Variety Identification Committee for release.

Pusa Anmol is an induced radio-mutant of a hybrid Ajay (evolved at NBRI, Lucknow). The variety is a relatively thermo - and photo-insensitive type and flowers thrice in a year during October-November, February–March and June –July when the availability of chrysanthemum is very limited in the market.

Promising chrysanthemum varieties

Pusa Centenary is an induced radio-mutant of a very popular commercial exotic cut flower variety Thai Chen Queen that produces light orange flowers, which are suitable for cut flower purpose. It takes 100-110 days to bloom after transplanting and produces 10-12 flowers per plant during winter season.

Under agro technique studies, a uniform spacing of 25 cm x 25 cm was found optimum for Snow Down, Thai Chen Queen and Poornima varieties. A fertigation regime with a water soluble formulation 20:20:20 (N:P:K) @ 150 ppm on alternate days was found to be optimum.

1.9.4 Marigold

In marigold, crosses involving genetic male sterile lines

of African marigold *(Targets erecta)* inter-varietal *(T. erecta x T. eracta*) and inter-specific *(T. eracta x T. patula)* were attempted in different combinations utilizing promising varieties/lines of these species. Different selections/hybrids developed in previous years were also assessed for various characters with major emphasis on flower quality and yield. Among them, Selection 7, Selection 19, Selection 20, Selection 29, MS 5 x French Selection 1 and French Selection 3 performed very well. French Selection 1 was found suitable for June-July planting and flowered from mid-October to mid-December (festive season). It produces medium sized, compact flowers making them suitable for loose flower production.

1.9.5 Antirrhinum

In antirrhinum, collections were made from various sources and planted during winter season. Being heterozygous material, the whole population was subjected to single plant selection. On the basis of morphological traits, seven lines were isolated which are being purified through inbreeding.

1.9.6 Gerbera

Eight varieties were evaluated in polyhouse conditions. Out of different media tried, cocopeat was found to be the best for rooting. Under post-harvest studies, craft paper was found to be the best among the packaging material.

1.9.7 Tuberose

Four single petalled varieties, namely, Mexican Single, Shringar, Prajwal and Sikkim Selection were evaluated. The cultivar Prajwal performed better when compared with other cultivars. Four double petalled varieties, namely, Pearl Double, Suvasini, Vaibhav and Swarn Rekha were also evaluated. The cultivar Vaibhav performed better than other cultivars. Three varieties, viz., Pearl Double, Suvasini and Vaibhav were evaluated for concrete recovery. The cultivar Pearl Double gave the highest recovery of concrete.

Concrete content (%) in three cvs. of double tuberose

Cultivar	Concrete content %		
	Minimum	Maximum	Mean
Pearl Double	0.0384	0.0752	0.0585
Suvasini	0.0263	0.0366	0.0328
Vaibhav	0.0259	0.0438	0.0321

1.9.8 Lillium

Maximum seed germination (29.3 %) was recorded in the cross combination Alask x Lendar, and Shiraj x Alaska took minimum days (20.5) for germination. Nine new intra-specific crosses were made to create variability for the improvement of the crop. Maximum vase life (17.3 days) was recorded with $AgNO_3$ (10 ppm) followed by sucrose 2 % (16.6 days) in lillium cv. Lendar. The sand medium with growth regulator IBA (200 ppm) was proved best for scale propagation in lillium.

2. GENETIC RESOURCES

2.1 CROP GENETIC RESOURCES

2.1.1 Wheat

2.1.1.1 Genetic stocks registered with NBPGR

The following genetic stocks were registered with NBPGR, New Delhi**:**

Genotypes	INGR No.	Genotypes	INGR No.
Pusa 2022A	05008	5. Pusa 2046A/8	05012
Pusa 2019A/11	05009	6. PWR 4099	05013
Pusa 2099A	05010	7. PWR 4101	05014
Pusa 2338A/20	05011	8. Selection T2600	05015

2.1.1.2 Germplasm characterization and rejuvenation and allied breeding activities

Over 1085 genetic stocks were characterized/ rejuvenated. Around 57 genetic stocks were observed to be resistant to all the three rusts under field conditions in the two crossing blocks. Eight synthetic wheats were characterized for their phenotypic features. Synthetics possessing high number of spikelets/spike were used in hybridization programme.

2.1.1.3 Screening of exotic germplasm

Thirty-five exotics of wild emmer *Triticum dicoccoides* were screened against stripe rust in adult stage. Sixty per cent of them exhibited resistance to stripe rust. Identification of new genetic resources will benefit wheat breeding.

2.1.1.4 Pathological screening

Disease scoring was done in over 2500 lines of different nurseries. Additionally, elite advance lines included in CVT were screened for leaf rust pathotypes.

2.1.2 Rice

2.1.2.1 Evaluation of test crosses

A total of 204 crosses were evaluated and promising restorers and maintainers were identified.

No. of test crosses	Restorer	Partial restorer	Maintainer	Partial maintainer
204	98	37	4	29

2.1.3 Maize

2.1.3.1 Screening and evaluation of maize genotypes for biotic stress (diseases: MLB, BLSB and BSDM) and abiotic stress (low moisture)

Elite maize inbred lines were screened against the respective stress conditions in order to identify resistant/ tolerant lines for their further utilization. Ten inbred lines were screened (at 1-5 scale) against different biotic stresses (Maydis leaf blight and banded leaf and sheath blight in Delhi; and brown stripe downey mildew at Dhaulakuan and Pantnagar). It will help in identifying specific parental lines exhibiting differential responses for a given biotic stress for further genetic analysis.

2.1.4 Pearl Millet

2.1.4.1 Development of cytoplasmic male sterile lines and restorers

Four hundred pairs of A and B lines of thirty-seven advanced stage male sterile lines were grown along with three checks MS 841A, MS 5141A and MS 576A. Four to six crosses in each pair were made to maintain these lines. Two hundred ninety-two new hybrid combinations were made using 60 restorer lines. These hybrids were produced using five newly developed male sterile lines, viz, MS 411A, MS 630 A, MS 540A, MS 589A and MS 549A along with three checks MS 841 A, MS 189 A and MS 576 A with a view to get an idea about the combining ability and disease reaction of the parental lines and hybrids.

2.1.5 Forage Sorghum

2.1.5.1 Genetic stocks

More than hundred genetic stocks for main forage yield contributing traits like better plant height, more leaves/plant, leaf length, leaf breadth, cane thickness, and high T.S.S. % were identified for utilization in breeding programme.

2.1.5.2 Evaluation of CMS lines

Out of 65 CMS lines evaluated for various traits, ten promising CMS lines were identified for utilization in multi-cut hybrid development.

2.1.6 Chickpea

2.1.6.1 Development of extra-large seeded *Kabuli* genotypes

Considering the requirements of international market and national consumers, extra large seeded cultivars are the need of the hour. Twenty-one promising genotypes were identified for future projections with high 100-seed weight ranging from

31.5 to 45.2 g, and seed yield from 1.9 t/ha to 2.64 t/ha.

2.1.6.2 Development of extra-large seeded *desi* genotypes

In India and other countries, no variety of *desi* type having 100-seed weight more than 35g was released so far. It is also pertinent to mention that out of 16000 germplasm lines, only one line was mentioned having 100-seed weight of 40 g. However, in Indian market, the traders are looking for the varieties of *desi* type with 100-seed weight more than 40 g owing to their demand for parching, vegetable, delicacies and high recovery of besan. These varieties fetch a premium price of Rs. 10,000/t, more than do the ordinary varieties in the market. Taking into consideration the market and consumer demand, the breeding programme was diverted for the development of extra-large seeded *desi* genotypes. Twenty-three promising genotypes showed superior yield performance (1.4 to 2.4 t/ha) coupled with extra large seed size (100 – seed wt., 32.3 to 51.0 g).

2.1.6.3 Pyramiding of genes for multiple resistance

Biotic and abiotic stresses are affecting the chickpea crop adversely, and the annual yield losses due to Fusarium wilt dry root rot and Aschochyta blight range between 20% and 35%. Likewise, the yield losses due to drought, low and high temperatures also range between 20% and 40% annually. Taking into consideration these factors, the pyramiding of diverse genes through multiple hybridization to transfer desirable gene pools into new cultivars was done, and various crosses were developed. From these crosses, the segregating populations from F_2 - F_6 were screened in multiple sick-plot environments. From these populations, 40 promising genotypes were selected from preliminary yield trials and 150 single plant progenies were selected for advance and preliminary yield testing.

2.1.6.4 Promising material

Promising chickpea genotypes like *Kabuli* bold seeded green and *desi* green having multiple resistance, extra bold seeds and high yield were identified during this period. One hundred forty extra-large seeded germplasm lines were collected from ICARDA, Allepo, Syria and Washington State University, Pullman, USA for evaluation and further utilization for population improvement programme. In addition to the above, 150 prominent lines including mutant entries and varieties, having variability for different genetic traits in chickpea were maintained.

2.1.6.5 New source of earliness in *Kabuli* chickpea

IARI Centre for Pulses Improvement, Dharwad has developed BGD 132 as a new source of earliness in *Kabuli* chickpea. It was derived from the cross ICCV 2 x ICCV 5. It flowers in 29-30 days after sowing at IARI Centre, Dharwad and reaches maturity in about 65–70 days. It is a higher yielding variety and is earlier by 5-7 days in flowering and 9-10 days in maturity compared to ICCV 2, the first extra-short duration chickpea variety popular in peninsular and central India. The locally adopted control cultivar Annigeri takes about 40–45 days to flowering and 85–90 days to maturity. Its 100-seed weight is 28-30 g and has a grain yield potential of about 1.4-1.5 t/ha under residual moisture conditions. This is in addition to the sources of earliness like BGD 9617, BGD 9812 and BGD 9920 developed by the Centre earlier. These genotypes may act as diverse sources of genes or gene combinations for studying genetics of flowering time, which is inconclusive in chickpea. Identification of such superfast chickpea germplasm has great significance in breeding extra–early varieties suitable for area diversification thus extending chickpea cultivation even to the extreme drought prone environments. The new variability created may also be useful in chickpea breeding aiming to increase and stabilize its productivity in sub–tropical long–duration environments.

2.1.6.6 Wide hybridization

Correlation analysis in 56 *desi* and *Kabuli* chickpea genotypes established negative correlation between protein content and grain yield. SDS-PAGE for total Tris soluble proteins resolved a total of 32 bands with ICC 12239 (*desi* type, wilt resistant) having minimum (16) and ICC 12273 (*desi* type, dry root rot resistant) having maximum (29) number of bands. The Nei and Li's similarity values ranged from 0.69 to 1.0. The polygenetic tree formed two clusters at 0.69 similarity coefficient. The first clusters consisted of 9 *desi* and 8 *Kabuli* chickpea genotypes and all six cultivated varieties. Information generated on significantly superior and genetically divergent genotypes can be utilized for making crosses (*desi/Kabuli* introgression) and selecting superior progenies in the segregating generations.

2.1.7 Pea

2.1.7.1 Pea recombinant lines

Pea recombinant lines of advanced generation ($F_{8/9}$) containing important morphological markers were maintained. These pea genetic stocks having morphologically distinct genetic markers were developed through extensive crossing programme. These genetically stable lines can serve as multi-marker genetic stock for various genetic/molecular studies.

2.1.8 Mungbean

2.1.8.1 Germplasm evaluated and maintained

During spring season, 550 germplasm lines were multiplied, 12 were evaluated for preharvest sprouting

resistance traits and 17 diverse germplasm lines were analyzed for root traits. Likewise in *kharif* season, 50 germplasm lines received from IIPR, Kanpur were evaluated for yield and related traits. Four hundred-thirty germplasm lines were maintained by growing in field.

2.1.9 Lentil and Cowpea

2.1.9.1 Evaluation of germplasm

Three hundred and five accessions of lentil were evaluated for rust disease at HPKVV Regional Station, Dhaula Kuan. One hundred and twenty accessions of cowpea were evaluated at the IARI Centre, Dharwad for powdery mildew reaction. One hundred and thirty accessions of cowpea were evaluated during summer at IARI, New Delhi.

2.1.10 Pigeonpea

2.1.10.1 Evaluation of Germplasm

Five hundred and ten pigeonpea germplasm lines were collected from NBPGR and being evaluated for 26 characters. Accessions with diverse plant types for the characters, viz., basal branching, erect and compact plant type, green pods, purple and bunching pods, soya types and more number of pods were identified.

2.1.10.2 New plant type developed

A new dwarf plant type was developed from the segregating generations of various GMS based bybrids through population improvement programme. Besides, 10 SDT and 25 IDT single plants, characterized for large number of secondary branches having extra-early maturity, were developed.

2.1.10.3 Wide hybridization

Studies are in progress in establishing intergenomic affinities among 95 accessions of 6 wild species of pigeonpea based on morpho-agronomic characters, cross ability, and biochemical parameters, viz., total soluble seed proteins and isozymes.

2.1.11 *Brassicas*

2.1.11.1 Germplasm evaluated and maintained

Six hundred thirty-four germplasm lines including *Brassica juncea* (504), *B. napus* (30), *B. carinata* (36), *B. compestris* (26), *B. nigra* (9), *B. oleracea* (3), *B. tournifortii* (6), *Sinapis alba* (4), *Raphanus. sativa* (1), *R. caudatus* (3), *B. caudatus* (1), *Eruca sativa* (8) and other species (3) were evaluated and maintained. Natural screening against white rust, Alternaria blight, stem rot and aphids was done. Data on fourteen characters were recorded on 270 germplasm lines of *Brassica juncea*. Besides the above, more than 100 quality germplasm lines were also maintained. The identified donars were being used in the hybridization programme for various objectives.

2.1.11.2 Breeding for white rust resistant *Brassica juncea*

Twenty-three white rust resistant cultures of *B. juncea* were evaluated, out of which 15 immune/resistant cultures were maintained after natural screening and four cultures were added from NRCRM, Bharatpur. About 30 yellow seeded cultures showing resistance to white rust were also screened and maintained for further improvement/use in hybridization.

2.1.11.3 Breeding for high erucic strain of mustard

High erucic lines of mustard are important for industrial purposes such as lubricant, surfactants, polymers, etc. A trial consisting of 27 high erucic lines of mustard (more than 45 %) was conducted, and HET 1, HET 9 and HET 11 were found better than the check varieties.

2.1.11.4 Dwarf and early maturing *Brassica carinata*

Twenty-eight somaclones were evaluated and maintained which showed a variation for plant height (45-250 cm) and maturity (145–180 days). This variability is being used in hybridization and selection programme.

2.1.12 Soybean

2.1.12.1 Maintenance of germplasm

Four hundred lines (including checks), procured from indigenous and exotic sources and characterized, were maintained.

2.1.13 Cotton

2.1.13.1 Germplasm registered

Two promising lines BN-ARB 16 and BN-TOM 277 were registered with NBPGR.

2.1.14 Vegetables

Forty-two genotypes of late cauliflower, 50 genotypes of cabbage, 73 genotypes of carrot (temperate type) and 30 germplasm belonging of bell pepper and paprika were maintained at the Institute's Regional Station at Katrain.

2.1.15 Fruits

Fruit germplasms collected during the year are as follows:

Fruit crop	Name	Centre of collection
Mango	Combodiana 31, Combodiana 35, Carabao, Chandrakaran and Sabre	Horticulture Experiment and Training Centre, Basti, U.P.
Citrus	**Malta:** Blood Red, Malta (MS-25) **Grape fruit:** Red Blush, Star Ruby and Marsh Seedless **Sweet orange:** Jaffa, Pineapple and Valencia Late **Acid lime:** ALS 3, ALS 4 and ALS 5 ***Galgal***: GS 4	Regional Fruit Research Station, Abohar, Punjab

Out of 18 germplasms of papaya, the number of plants in 7 genotypes, viz., Co 1, Co 2, Co 3, Co 4, Co 5, Co 6 and Co 7 was very few and died during winter at the IARI Regional Station, Pusa. Among the different traits, a high degree of variability was observed for important parameters, viz., plant height at flowering, height to first flowering, number of nodes to first flower, number of fruit per tree, fruit weight, size of fruit, pulp thickness, size of fruit cavity, number of seeds and T.S.S.

2.1.15.1 Establishment of scion bank of IARI released/recommended fruit varieties

A scion bank (4.0 acre approx.) was established at the Todapur orchard for large scale multiplication of genuine and quality planting material. The released and recommended varieties of mango, grape, citrus and guava were planted. Keeping in view the future expansion, some new genotypes of mango and grape, which were in their advance stage of release, were also planted. During the year, gaps were filled.

2.1.16 Flowers

Nine germplasms of lilium, 28 germplasms of gladiolus and 12 germplasms of carnation were maintained at the Institute's Regional Sation, Katrain.

2.1.17 Organisation of National Off-season Nurseries

During 2005, 37 centres-NARS, SAUs and private sectors-screened their breeding material at IARI Regional Station, Wellington. The Station extended facilities for growing of 34,220 cultures of wheat, 1869 of *Brassica*, 427 of barley, 211 of peas, 218 of lentil, 160 of maize, 91 of linseed and 52 of sugarcane hilly germplasm.

2.1.18 Germplasm Informatics and Divergence Studies

Germplasm data on mungbean (895 accessions), *Brassica* (268 accessions), and chickpea (1284) were processed for storage, retrieval and divergence studies. A strategy for selecting distinct variability as well as for developing core entries was developed for the mungbean germplasm. The strategy is based on the principal component and inertia score.

2.2 MICROBIAL GENETIC RESOURCES

2.2.1 Blue Green Algae Germplasm

The Institute's maintains 536 isolates of blue green algae (both heterocystous and non-heterocystous forms) under controlled conditions of light and temperature in its germplasm collection. Isolates of *Spirulina* are also maintained under optimized cultural collection and are in great demand due to their high protein content. During the period under report, fifteen blue green algal isolates of *Nostoc* (9), *Anabaena* (4), *Cylindrospermum* (1) and *Phormidium* (1) from Hyderabad and adjoining areas were added in the germplasm collection.

2.3 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

2.3.1 Herbarium Cryptogamae Indiae Orientalis (HCIO)

During 2005, 437 fungal specimens, including 38 type specimens, were accessioned in HCIO. The total number of conserved biodiversity stands at 46,022. Out of these, 316 specimens belong to Meliolaceae and allied genera. Forty-six samples were supplied on loan.

New genera and species. Two new genera, one belonging to Hyphomycetes viz., *Manoharachariomyces lignicola* and another to Ascomycetes, namely, *Diatrypoidiella lignicola* were created. Five new species of powdery mildews, viz., *Oidium cassiae-leschenaultianae, O. cassiae-torae, O. crotalariae, O. heliotropii-strigosum and O. royle* collected on *Cassia leschanaultianae L., C. torae L., Crotalaria juncea L., Heliotropium strigosum* Willd., and *Roylea cinerea* (D. Don.) Baill, respectively were described. Besides, *Annelophora catenata*, a new species of Dematiceous Hyphomycetes i.e. *Mollisia dhankutae* Belfour-Browne belonging to the family Dermitiaceae is reported to be the first record from India.

2.3.2 Indian Type Culture Collection (ITCC)

Maintenance and preservation. About 3365 fungal cultures belonging to Mastigomycotina, Zygomycotina, Ascomycotina and Deuteromycotina were maintained by periodic transfer to suitable media. Of these, 150 cultures, in all, were preserved under mineral oil (liquid paraffin). Sensitive cultures were identified and maintained separately as they required more frequent transfers as well as monitoring at required temperatures.

New additions. The culture collection was enriched by new addition of 65 different fungal cultures including some plant pathogens such as *Theilaviopsis* state of *Ceratocystis parodoxa; Rhizopus oryzae*, which is a potent lactic acid producer; *Drechslera halodes; Fusarium palladoroseum* from wheat head; *Macrophomina phaseolina* from *Jatropha*; *Glomerella tucumanensis; Ampelomyces quinqualis; Alternaria alternata* from *safed musli*; *Colletotrichum gloeosporoides* causing bunch rot of oil palm; and *Botryodiplodia theobromae* causing sudden death of *Jatropha*.

Identification services. A total of 145 cultures/specimen were identified up to species level. Some of the important fungi identified during the period were *Alternaria cucumerina* var. *cymopsidis* on cluster bean, *Arachinitos dencalensis* on oil palm, *Syncephalastrum recemosum* on oil palm, *Colletotrichum orbiculare* on luffa, *Thielavia terricola* in grape juice, *Phoma multirostrata* on coconut, *Pestalotia olivacea* on large cardamom, *Embellisia alli* on garlic imported from China, *Ceratocystis paradoxa* from pineapple, *Ampelomyces quinqualis* on apple, and *Sclerotium hydrophyllum* on rice. In addition, *Beauveria bassiana* and *Paecilomyces lilacinus* on *bhindi* fruit fly and on silk worm were identified.

New species and genera. The two new species, viz., *Appendiculella wendlandia* Prameela and Chowdhry *sp. nov.* and *Meliola eugenia-oblata* Chowdhry and Prameela *sp. nov*. were created. Besides, a new Hyphomycetous fungus of Moniliales group, *Botryodeorsum*, gen.nov. was created and described from India, and *Botryodeorsum indicum* was proposed as the type species.

2.3.3 Insect Biosystematics

Under the insect identification service, 642 specimens belonging to the orders, Coleoptera and Hymenoptera, were identified.

Biosystematics studies on the economically important weevils of Cryptorhynchinae were continued. The annotated checklist with its 88 species has been further updated with details of original descriptions and keys to the species and genera. The details on the stridulatory organs and sclerolepidia are being compiled so that these can be explored for taxonomic studies. Redescriptions of *Plococerus denticollis* and *P. viduus* were further evaluated comparing the holotype and paratypes borrowed from the museums. New genus of Cryptorhynchinae closely related to the *Cryptorhynchus*, was further studied and analysed for its taxonomic characters. Efforts are on to check the status of this genus as regards to its newness through review of literature. Seven new species of *Indomias* described earlier were subjected to reevaluation with taxonomic characters of the known species.

A checklist of all 16 genera and 148 species belonging to subfamily Formicinae from the Indian subcontinent was prepared. Eleven species of *genus Camponotus*, viz., *C. angusticollis, C. arrogans, C. camelinus, C. compressus, C. dichorus, C. gigas, C. maculatus,C. nicobarensis,C. paria, C. rufoglacus* and *C. sericeus* were redescribed. The descriptions were strengthened by the incorporation of additional characters, suitable illustrations and morphometric ratios.

As a part of systematic studies on the biodiversity of lepidopterous insects associated with vegetables in India, 44 species were studied for their taxonomic characters and inventories prepared. Taxonomic studies were undertaken on 33 species of Pyralidae and 63 species of Noctuidae. Analysis of their feeding habits revealed that 64% are leaf feeders, 20% fruit borers, 10% stem borers, and 6% leaf miners. The inventory consisting of 87 insect species with cereals, 48 species with pulses and 34 species with oilseeds, 33 insect species with fibre crops, 56 species with fruit crops and 98 insect species associated with vegetable crops with taxonomic studies and identification keys was prepared in the form of a computerized database.

3. CROP AND RESOURCE MANAGEMENT AND ENVIRONMENT

3.1 AGRONOMY

3.1.1 Evaluation of Zinc Enriched Urea in Aromatic Rice

A field experiment was conducted to study the effect of various concentrations of zinc enriched urea on the productivity of aromatic rice cv. Pusa Sugandh 5. Results of eleven treatments comprising prilled urea, 0.5% zinc enriched urea (ZnO), 0.5% zinc enriched urea ($ZnSO_4$), 1.0% zinc enriched urea (ZnO), 1.0% zinc enriched urea ($ZnSO_4$), 1.5% zinc enriched urea (ZnO), 1.5% zinc enriched urea ($ZnSO_4$), 2.0% zinc enriched urea (ZnO), 2.0% zinc enriched urea ($ZnSO_4$), sulphur coated urea (1% S) and control (no nitrogen) showed that zinc enriched urea had a positive impact on yield attributes and yields of aromatic rice. Further, application of 2.0% zinc enriched urea ($ZnSO_4$) recorded significantly higher grains/panicle, grain weight, 1000-grain weight and grain yield compared to prilled urea alone. The increase in grain yield with 2.0% zinc enriched urea ($ZnSO_4$) over prilled urea alone was 25.1%. In general, $ZnSO_4$ enriched urea was a better source than ZnO enriched urea.

Effect of zinc enriched urea on yield attributes and grain yield of rice

Treatment	Panicle length (cm.)	Fertile tillers/ hill	Grains/ panicle	1000-grain weight(g)	Grain yield (t/ha)	% increase in yield over prilled urea
Prilled urea	23.1	7.1	96.7	25.9	4.02	-
0.5% zinc enriched urea (ZnO)	23.5	7.6	100.3	26.1	4.28	6.5
0.5% zinc enriched urea ($ZnSO_4$)	24.2	8.1	104.7	26.7	4.52	12.4
1.0% zinc enriched urea (ZnO)	24.0	7.8	106.0	26.4	4.45	10.7
1.0% zinc enriched urea ($ZnSO_4$)	24.9	8.6	112.3	27.2	4.70	17.0
1.5% zinc enriched urea (ZnO)	24.3	8.3	110.3	26.6	4.61	14.7
1.5% zinc enriched urea ($ZnSO_4$)	25.3	9.1	118.3	27.8	4.90	21.9
2.0% zinc enriched urea (ZnO)	24.7	8.5	116.7	27.2	4.78	18.9
2.0% zinc enriched urea ($ZnSO_4$)	26.1	10.8	125.0	28.3	5.03	25.1
Sulphur coated urea (1% S)	23.8	8.1	103.0	27.0	4.30	6.9
Control (No N)	20.0	5.3	78.7	20.7	3.31	-
SEm±	0.6	0.8	7.1	1.2	0.22	-
CD (P=0.05)	1.7	2.3	20.9	3.6	0.65	-

3.1.2 Effect of Organic Sources of Plant Nutrition on Productivity of Rice-Wheat Cropping System

A field experiment was carried out to find out the most appropriate organic source of plant nutrition to enhance the grain yield of rice and also to see the residual effect on the productivity of succeeding wheat. Newly-released aromatic rice cv. Pusa Sugandh 3 and wheat cv. HD 2687 were taken as the test varieties. The highest grain yield of rice was obtained with *Sesbania* green manuring + FYM @ 10 t/ha, which was on a par with the grain yield obtained with the recommended dose of NPK. The residual effect of *Sesbania* green manuring in conjunction with FYM @ 10 t/ha was more pronounced as compared to that in the rest of the organic sources applied alone or in combination. This combination registered higher values of yield attributes and proved significantly superior in enhancing the yield. Organic sources applied alone or in combination to rice in *kharif* 2005 being statistically at par with the recommended dose of inorganic fertilizer, i.e., 120 : 60 : 40 kg NPK/ha, proved equally effective in recording high yield. However, the impact of *Sesbania* green manuring in combination with FYM @ 10 t/ha recorded more number and weight of panicles, which in turn enhanced the grain yield of rice.

Effect of organic sources on grain and straw yields of wheat and rice (t/ha)

Treatment	Grain yield of rice (2004)	Grain yield of wheat	Grain yield of rice
Control	2.05	2.05	2.09
Recommended dose of fertilizers, i.e., 120:60:40 kg NPK/ha	4.72	3.25	5.14
Sesbania GM	4.30	3.82	4.64
Sesbania GM + wheat straw @ 5 t/ha	3.78	3.44	4.82
Sesbania GM + FYM 10 t/ha	4.79	4.27	5.61
Sesbania GM + FYM @ 5 t/ha + BGA	4.05	3.27	4.57
Sesbania GM + *Azotobacter*	3.48	3.57	4.29
Sesbania GM + PSB @ 5 kg/ha	3.62	3.65	4.72
Neem cake @ 2.5 t/ha	3.52	3.60	4.57
Vermicompost @ 2.5 t/ha	3.53	3.40	4.52
SEm ±	0.17	0.02	0.19
CD (P=0.05)	0.49	0.05	0.55

3.1.3 Effect of Inorganic and Organic Sources of Nutrients on Maize and their Residual Effect on Wheat

A field experiment with nine fertility levels was conducted to study the direct and residual effects of fertility levels on maize-wheat cropping system. Application of 120 kg N + 60 kg P_2O_5 + 50 kg K_2O/ha, being similar to 120 kg N + 10 t FYM/ha, and 120 kg N + 10 t FYM + 25 kg $ZnSO_4$/ha produced the highest grain and stover yields of maize. The yields with the application of 120 kg N + 10 t FYM/ha and 120 kg N + 10 t FYM + 25 kg $ZnSO_4$/ha were also higher than those obtained with the rest of the fertility levels. When 10 t/ha FYM was applied either with 60 kg N/ha or 60 kg N + 25 kg $ZnSO_4$/ha, the grain yield was higher than that of the half recommended dose of NPK (60 N + 30 P_2O_5 + 25 K_2O kg/ha). The residual effect on wheat revealed that the highest grain yield was found when FYM @ 20 t/ha + 25 kg $ZnSO_4$/ha was applied to maize. The fertility levels of 120 kg N + 25 kg $ZnSO_4$ + 10 t FYM/ha and 10 t FYM + 25 kg $ZnSO_4$/ha gave the yields equal to that of 20 t FYM + 25 kg $ZnSO_4$/ha, which was superior to the rest of the fertility levels.

Performance and economics of chickpea (*Chhollia)* - baby corn cropping system as influenced by date of sowing and P fertilization

Treatment	*Chhollia* yield (t/ha)		Maize yield (t/ha)		Net returns (Rs/ha)
	Biological	*Chhollia*	Baby corn	Green fodder	
Variety					
ICCV 96029	9.15	1.47	1.71	26.80	32,963
ICCV 96030	6.95	1.16	1.67	25.57	26,505
SEm±	0.02	0.01	0.04	0.68	-
CD (P=0.05)	0.05	0.04	NS	NS	-
Date of sowing					
30 September	7.49	1.36	1.53	22.94	26,751
8 October	9.15	1.70	1.65	24.72	42,319
17 October	7.51	0.89	1.89	30.91	20,225
SEm±	0.06	0.04	0.07	0.95	-
CD (P=0.05)	0.25	0.16	0.26	3.73	-
P levels (kg /ha)					
	07.22	1.16	1.53	22.94	25,006
13.2	8.28	1.35	1.65	24.72	30,399
26.4	8.64	1.44	1.89	30.91	28,791
SEm±	0.04	0.02	0.04	0.67	-
CD (P=0.05)	0.10	0.07	0.26	1.97	-

Price (Rs/t): *Chhollia* (20,000), baby corn (20,000) and green fodder (2,000)

Direct effect of fertility levels on maize and their residual effect on succeeding wheat

Fertility levels	Direct effect on maize		Residual effect on wheat	
	Grain yield (t/ha)	Stover yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)
Control	3.15	5.11	1.90	3.67
120 kg N + 60 kg P_2O_5 + 50 kg K_2O/ha	6.84	10.08	3.00	5.03
60 kg N + 30 kg P_2O_5 + 25 kg K_2O/ha	4.84	7.41	2.43	4.13
120 kg N + 10 t FYM/ha	6.52	9.06	3.87	4.57
60 kg N + 10 t FYM/ha	5.55	7.06	3.50	4.20
120 kg N + 25 kg $ZnSO_4$ + 10 t FYM/ha	6.62	9.99	4.17	4.93
60 kg N + 25 kg $ZnSO_4$ + 10 t FYM/ha	5.68	7.68	3.70	4.40
25 kg $ZnSO_4$ + 10 t FYM/ha	4.66	6.66	4.10	4.63
25 kg $ZnSO_4$ + 20 t FYM/ha	4.79	7.06	4.60	5.43
SEm ±	0.17	0.33	0.19	0.33
CD (P=0.05)	0.51	0.99	0.56	0.99

3.1.4 Response of Early Cultivars of Chickpea for *Chhollia* to P Application and Residual Effect on Succeeding Baby Corn

Two early cultivars of chickpea were grown for *Chhollia* production under three dates of sowing and three levels of phosphorus. After the harvest of *Chhollia*, baby corn cv. PEMH 2 was grown to assess the residual effect. Among the chickpea cultivars tested, ICCV 96029 out-yielded ICCV 96030 in *Chhollia* production. The crop sown on 8 October gave the highest yield, and, the response to P was significant up to 26.4 kg P/ha. The performance of succeeding baby corn was greater when grown after 17 October-sown chickpea and with 26.4 kg P/ha compared to that of other dates of sowing and levels of P fertilizer to chickpea. The system performance assessed on the basis of net returns indicated that chickpea cv. ICCV 96029 sown on 8 October with 13.2 kg P/ha recorded the maximum returns.

3.1.5 Response to Sulphur and its Sources in Pigeonpea-Wheat Cropping System

A study was made to assess the impact of direct and residual effects of S fertilization in pigeonpea-wheat cropping system. Results indicated that S applied to pigeonpea had a marked residual effect on the productivity of succeeding wheat. Among the sources of S, gypsum and cosavet being on a par, proved superior to elemental sulphur in respect of residual effect on succeeding wheat. Wheat responded to direct application of 30 kg S/ha. Interaction effect of residual and direct effect of applied S revealed that the application of 30 and 60 kg S/ha to wheat being on a par, recorded significantly higher pigeonpea equivalent yield (PEY) over no S to wheat at both levels of S (30 and 60 kg/ha) applied to preceding pigeonpea. Further, pigeonpea fertilized with 60 kg S/ha recorded significantly higher PEY in succeeding wheat over 30 kg S/ha, when wheat did not receive S.

Effect of S fertilization in pigeonpea-wheat system

Treatment	Pigeonpea yield (t/ha)	Wheat yield (t/ha)	PEY (t/ha)
S to pigeonpea (kg/ha)			
Control	1.07	3.27	1.74
The rest	1.57	4.37	2.33
SEm±	0.07	0.15	0.08
CD (P=0.05)	0.15	0.33	0.18
S levels (kg/ha)			
30	1.53	3.98	2.27
60	1.61	4.21	2.39
SEm±	0.03	0.08	0.04
CD (P=0.05)	NS	NS	NS
S sources			
Elemental sulphur	1.59	4.05	2.16
Gypsum	1.68	4.47	2.39
Cosavet	1.81	4.59	2.45
SEm±	0.04	0.09	0.05
CD (P=0.05)	0.12	0.31	0.16
S to wheat (kg/ha)			
0	-	3.88	2.07
30	-	4.52	2.41
60	-	4.69	2.51
SEm±	-	0.08	0.04
CD (P=0.05)	-	0.27	0.12

3.1.6 Agro-techniques for Propagation of *Jatropha* Saplings through Stem Cuttings and Seed

A field experiment was conducted during summer season to evaluate the effect of growth media, portion of cutting, seed size and depth of cutting placement/ sowing on the growth and quality of saplings of *Jatropha curcas* raised in nursery. Raised seedbed of soil + FYM mixture (3:1) was superior in respect of sprouting percentage (96%), plant height (98.1 cm), number of branches per sapling (4.55), collar diameter (3.55 cm), leaf area per sapling (14338 cm^2), total dry weight per sapling (262.5 g), total chlorophyll content (3.1 mg/g tissue), Dickson quality index and sturdiness quotient. In the case of seedlings raised from seed, germination percentage (80.5%), final plant stand before transplanting (75.6%), plant height (90.5 cm), number of branches per seedling (1.93), collar diameter (2.61 cm), root total length per seedling (608 cm), leaf area per seedling (10597 cm^2), total dry weight per seedling (164.2 g), total chlorophyll content (2.92 mg/g tissue), and Dickson's quality index and sturdiness quotient of seedlings were significantly higher under raised seedbed of soil + FYM mixture (3:1 ratio), closely followed by raised seedbed of soil alone. Seedlings grown in polyethylene bags filled with soil + FYM mixture recorded the least values of all these parameters in both types of saplings.

Cuttings obtained from the lower portion of branches and placement of half of the total length of cutting below ground surface recorded significantly higher values of growth parameters and quality index over upper portion of branch and placement of one-third portion of cutting below ground surface. Bold seeds sown at 3 to 4 cm depth produced seedlings in terms of growth and quality parameters significantly superior to those produced with the normal seeds sown at 5 to 6 cm depth. Sapling raised in polyethylene bags recorded 100 per cent survival after transplanting, while saplings produced on the raised nursery bed recorded 95 per cent survival.

Net returns and benefit : cost ratio based on 5000 saplings were higher under raised seedbed of soil alone, closely followed by raised seedbed of soil + FYM and the least in polyethylene bags filled with soil + FYM. Negative net returns and benefit: cost ratio were recorded under polyethylene bags filled with soil + FYM mixture.

Effect of growth media, cutting portion and depth of cutting placement on plant stand, economics and survival after transplanting of *Jatropha* saplings

Treatment	Nursery raising through seed			Nursery raising through stem cuttings		
	Final plant stand (%)	Net returns based on 5000 saplings	Survival after trans-planting (%)	Final plant stand (%)	Net returns based on 5000 saplings (Rs./ha)	Survival after trans-planting (%)
Growth media						
Raised seed bed of soil alone	74.4	6120	93	88.3	7585	95
Raised seed bed of soil + FYM (3:1)	80.5	4700	97	96.0	7155	96
Polyethylene bags filled with soil alone	55.6	1250	100	77.1	4245	99
Polyethylene bags filled with soil+FYM(3:1)	44.3	1315	100	67.0	1770	99
CD (P=0.05)	4.5	-	-	7.1	-	-
Cutting portion						
Upper half of branch	-	-	-	74.8	4090	96
Lower half of branch	-	-	-	89.5	6295	98
CD (P=0.05)	-	-	-	2.6	-	-
Depth of cutting placement						
1/3 of total length of cutting	-	-	-	78.6	4660	96
½ of total length of cutting	-	-	-	85.6	5710	99
CD (P=0.05)				2.6	-	-

3.1.7 Direct and Residual Effect of Applied Nutrients on Mustard in Mungbean-Mustard Cropping System

An experiment comprising three levels of nutrient management was conducted in mungbean, viz., control, recommended doses of N and P, and recommended doses of N, P and S; and two levels of stover incorporation, viz., no stover incorporation and mungbean stover incorporation. Four levels of nutrients management in mustard, viz., control, 40 kg N + 20 kg P_2O_5/ha, 80 kg N + 40 kg P_2O_5/ha and 80 kg N + 40 kg P_2O_5 + 30 kg S/ha were assigned to mustard cv. Pusa Jagannath.

Results revealed that nutrients applied to preceding mungbean, stover incorporation and nutrients applied directly to mustard significantly enhanced the productivity of mustard. Recommended doses of N and P applied to mungbean increased the yield of mustard by 27.3% over that of the control (1.57 t/ha). Similarly, incorporation of mungbean stover also enhanced the mustard yield by 13.7%. Directly applied nutrients showed increase in mustard yield up to the highest level, i.e., 80 kg N + 40 kg P_2O_5 + 30 kg S/ha. Recommended dose of N and P (80 kg N + 40 kg P_2O_5/ha) enhanced the mustard yield by 46.4 and 16.4% over that of control, and half of the recommended dose, respectively, whereas the application of 30 kg S/ha increased the yield by 10.7% over that of the recommended dose of N and P.

Effect of nutrients management on the productivity of mustard

Treatment	Mustard yield (t/ha)
Nutrients applied in preceding mungbean	
Control	1.57
18 kg N + 46 kg P_2O_5/ha	2.00
18 kg N + 46 kg P_2O_5 + 30 kg S/ha	2.05
SEm ±	0.02
CD (P=0.05)	0.08
Stover incorporation	
No stover incorporation	1.75
Mungbean stover incorporation	1.99
SEm ±	0.02
CD (P=0.05)	0.06
Nutrients applied in mustard	
Control	1.40
40 kg N + 20 kg P_2O_5/ha	1.76
80 kg N + 40 kg P_2O_5/ha	2.05
80 kg N + 40 kg P_2O_5 +30 kg S/ha	2.28
SEm ±	0.04
CD (P=0.05)	0.11

3.1.8 Nutrient Management with Aqua-Fertilization in Lentil under Rainfed Conditions

An experiment was laid out to find out the optimum quantity of water and fertility levels for proper germination and growth of lentil cv. K 75 under dryland conditions. Five treatments of aqua-sowing involving varying quantities of water and 4 levels of fertility with and without biofertilizers were included. Results showed that increasing supply of water increased the seed yield of lentil progressively. Dry sowing gave the lowest yield and seed soaking also showed no significant improvement. Application of varying quantities of water resulted in significant improvement in yield compared with dry sowing or seed soaking. The yield was the highest at 20,000 l/ha, which was significantly superior to that of other treatments. The yield improved with fertilizer application over that of control. Application of 20 kg N + 50 kg P_2O_5/ha gave significantly higher grain yield compared to that of 10 kg N + 25 kg P_2O_5/ha alone or along with biofertilizers.

Seed yield of lentil as influenced by various aqua-fertilization treatments

Treatment	Yield (t/ha)
Aqua-sowing	
Dry sowing	1.78
Seed soaking	1.80
10000 l water/ha	1.93
15000 l water/ha	1.96
20000 l water/ha	2.19
CD (P=0.05)	0.11
Fertility levels	
Control	1.65
10 kg N + 25 kg P_2O_5/ha	1.95
10 kg N + 25 kg P_2O_5/ha + PSB + VAM	2.03
20 kg N + 50 kg P_2O_5/ha	2.18
CD (P=0.05)	0.09

3.1.9 Tillage and Residue Management Practices in Maize-based Cropping Systems

An experiment was initiated from *kharif* 2004 to study the effect of tillage, viz., zero and conventional tillage with or without residue management in *kharif* maize, followed by different *rabi* crops. A uniform crop of maize cv. PEMH 2 was raised during *kharif* 2004 under conventional tillage without residue application. After harvest, *rabi* crops, viz., wheat cv. PBW 343, mustard cv. Pusa Jaikisan, chickpea cv. BG 391 and linseed cv. HL 9 were grown during *rabi* 2004-05 under zero tillage (no ploughing) and conventional tillage (3 ploughings). Further, stover of maize was applied @ 3 t/ha after germination in between the rows of *rabi* crops in the respective treatments. In the second cropping cycle, maize was grown in *kharif* 2005 under varying tillage and residue

application of *rabi* crops @ 3 t/ha for wheat, and 2 t/ha each for linseed, mustard and chickpea.

Maize produced a mean grain yield of 2.74 t/ha in the first year when it was grown uniformly under conventional tillage without residue application. *Rabi* crops performed variably, with wheat giving the highest absolute yield, followed by mustard, linseed and chickpea. The wheat equivalent yield of mustard was on a par with that of wheat, whereas linseed and chickpea were significantly inferior to both the former crops. Interaction revealed that wheat yield was significantly lower under zero tillage than that of conventional tillage, but the differences in yield of linseed, mustard and chickpea due to tillage were on a par. There was also no effect of maize stover application on the performance of different *rabi* crops. In the second cropping cycle, zero tilled maize gave about 1 t/ha less grain yield compared to that of conventional tillage. Application of wheat residue showed some improvement in yield particularly under zero tillage. Further, the performance of maize was relatively better after chickpea than those after other *rabi* crops.

Effect of tillage and residue management practices on performance of crops in maize-based cropping system

Treatment	Grain yield of maize (t/ha) (*Kharif* 2004)	Grain yield of *rabi* crops (t/ha) (2004-05)	Wheat equivalent yield (t/ha) (2004-05)	Grain yield of maize (t/ha) (*Kharif* 2005)
Tillage				
CT – R	2.71	2.58	3.74	2.59
CT + R	2.80	2.62	3.80	2.70
ZT – R	2.65	2.40	3.65	1.43
ZT + R	2.80	2.49	3.63	1.73
SE	-	-	0.12	0.10
CD (P=0.05)	-	-	NS	0.35
Rabi *crops*				
Wheat	-	4.54	4.54	2.09
Linseed	-	1.75	2.96	1.89
Mustard	-	2.41	4.45	2.20
Chickpea	-	1.50	2.88	2.34
SE	-	-	0.09	0.10
CD (P=0.05)	-	-	0.26	0.29

CT – conventional tillage, ZT – zero tillage, R – residue

3.1.10 Performance of Wheat under Varying Tillage and Residue Management Practices following Different *Kharif* Crops

In an experiment initiated from 2004, different *kharif* crops, viz., maize cv. PEMH 2, pigeonpea cv. Pusa 991, soybean cv. Pusa 9702 and groundnut cv. PG 1 were raised under conventional tillage. After harvest of *kharif* crops, wheat cv. PBW 343 was raised with no tillage (no ploughing) or conventional tillage (3 ploughings) and with or without residue application of the *kharif* crops. The residues were applied @ 3 t/ha of maize, and 2 t/ha each of pigeonpea, soybean and groundnut after sowing of wheat. In the second cropping cycle, cotton cv. Pusa 2 was also included in *kharif* 2005 and the five crops were grown under different tillage and residue application of wheat @ 3 t/ha.

In 2004, different *kharif* crops grown uniformly under conventional tillage without residue application performed variably, with maize giving the highest absolute yield, followed by soybean, pigeonpea and groundnut. However, maize equivalent yield of pigeonpea and soybean was significantly more than that of groundnut or maize. The performance of wheat in the next season following legumes was comparatively better than that after maize. Further, zero tillage produced significantly lower yield of wheat than that of conventional tillage, and the residue application made no effect under either of the tillage practices. Interaction showed that the decrease in wheat yield under zero tillage was lower when grown in the plots of pigeonpea or soybean compared to that grown in plot of maize. Interestingly, the zero-tilled wheat after pigeonpea performed similar to as that grown under conventional tillage after maize.

In the second cropping cycle, although maize gave higher absolute yield but the equivalent yield of leguminous crops were significantly higher than that of maize. Maize equivalent yield of cotton was lower than those of pigeonpea and groundnut but was on a par with those of soybean and maize.

Effect of tillage and residue management practices on performance of crops in wheat-based cropping system

Treatment	Grain yield of *kharif* crops (t/ha) (2004)	Maize equivalent yield (t/ha) (2004)	Grain yield of wheat (t/ha) (*Rabi* 2004-05)	Grain yield of *kharif* crops (t/ha) 2005	Maize equivalent yield (t/ha) (2005)
***Kharif* crops**	2.54	2.54	3.92	2.13	2.13
Maize					
Pigeonpea	0.97	3.01	4.42	1.15	3.57
Soybean	1.39	3.08	4.28	1.17	2.60
Groundnut	0.82	2.46	4.34	1.20	3.31
Cotton	-	-	-	1.33	2.35
SE	-	0.14	0.12	-	0.09
CD (P=0.05)	-	0.48	0.34	-	0.26
Tillage					
CT – R	-	-	4.47	1.59	3.22
CT + R	-	-	4.55	1.68	3.36
ZT – R	-	-	3.90	1.06	2.12
ZT + R	-	-	4.04	1.24	2.46
SE	-	-	0.11	-	0.07
CD (P=0.05)	-	-	0.32	-	0.19

CT : conventional tillage, ZT : zero tillage, R : residue

All *kharif* crops gave much lower yields under zero tillage than under conventional tillage, but the effect of residue applied during the first two seasons was evident, particularly under zero tillage conditions.

3.1.11 Studies on Organic Farming of Rice-Wheat Cropping System

An experiment was laid out to ascertain the nutritional requirement of rice-wheat cropping system through organic manures and biofertilizers. There were three sets of treatments: in the first set, treatments were applied only to rice, in the second only to wheat, and in the third set to both rice and wheat. A set of treatments consisted of FYM @ 10 t/ha, green manure, green manure + biofertilizer, green manure + FYM @ 10 t/ha, and green manure + FYM + biofertilizer. In addition, there was an absolute control for rice and wheat. *Sesbania* green manuring (SGM) was done in rice, while green leaf manuring (GLM) was done in wheat. The biofertilizers applied were: blue green algae (BGA) in rice and *Azotobacter* in wheat.

Results indicated that application of 10 t/ha FYM to rice increased grain yield over that of control by 1.21 t/ha in rice and 0.54 t/ha in wheat, whereas *Sesbania* green manuring (SGM) increased grain yield over that of control by 1.43 t/ha in rice and 0.73 t/ha in wheat. The combinations of SGM + BGA and SGM + FYM were more effective than FYM and SGM alone and increased grain yield over that of control by 1.58 and 1.70 t/ha in rice and 0.83 t/ha in wheat. The combination of SGM + FYM + BGA was still better and increased grain yield over that of control by 1.94 t/ha in rice and 1.02 t/ha in wheat. Similarly, the application of 10 t/ha FYM, *Leucaena* green leaf manuring (GLM), GLM + *Azotobacter*, GLM + FYM and GLM + FYM + *Azotobacter* increased grain yield over that of control by 1.09, 1.10, 1.92, 1.98 and 2.15 t/ha in rice and by 0.28, 1.24, 1.26, 1.32 and 1.37 t/ha in wheat, respectively. This indicates that application of organic manures and biofertilizers was more effective when applied to wheat. However, the potential yield of both rice and wheat was obtained when the combination of FYM + green manuring + biofertilizers was applied to both rice and wheat.

Direct, residual and cumulative effect of organic manures and biofertilizers on the productivity (t/ha) of rice-wheat cropping system

Treatment	Rice	Wheat	Total
Control	3.19	3.00	6.129
Treatments applied to rice			
FYM	4.40	3.54	7.94
GM	4.62	3.73	8.35
GM + biofertilizers	4.77	3.83	8.60
GM + FYM	4.89	3.83	8.72
GM + FYM + biofertilizer	5.13	4.02	9.15
Treatments applied to wheat			
FYM	3.47	4.09	7.56
GLM	4.43	4.10	8.53
GLM + biofertilizers	4.45	4.92	9.37
GLM + FYM	4.51	4.98	9.49
GLM + FYM + biofertilizer	4.56	5.15	9.71
Treatments applied to both rice and wheat			
FYM	5.24	4.27	9.51
GM	5.24	4.39	9.63
GM + biofertilizers	5.40	5.25	9.65
GM + FYM	5.54	5.35	9.89
GM + FYM + biofertilizer	6.04	5.42	11.46
SEm ±	0.45	0.23	0.50
CD (P=0.05)	1.29	0.65	1.45

3.1.12 Nutrient Management in Broccoli-based Cropping Systems through Organic Sources

An experiment was conducted to study the performance of broccoli-based cropping systems under different organic sources of nutrients. Broccoli-tomato-*Sesbania* cropping system recorded 35.8% and 46.5% higher broccoli curd equivalent yields compared to those of broccoli-*bhindi*-*Sesbania* (17.9 t/ha) and broccoli-bottlegourd-*Sesbania* (16.8 t/ha), respectively. Application of vermicompost @ 3.5 t/ha + PSB + VAM, being on a par with FYM @ 10 t/ha + PSB + VAM, vermicompost @ 3.5 t/ha and FYM @ 5 t/ha + vermicompost @ 1.75 t/ha + PSB + VAM gave the highest curd yield of broccoli, which was significantly higher than those of FYM @ 10 t/ha and control. Response of tomato, *bhindi* and bottlegourd to residual fertility revealed that fertility level of FYM @ 5 t/ha + vermicompost @ 1.75 t/ha + PSB + VAM gave the highest productivity. Application of vermicompost @ 3.5 t/ha and vermicompost @ 3.5 t/ha + PSB + VAM was equal to application of FYM @ 5 t/ha + vermicompost @ 1.75 t/ha + PSB + VAM. Further, application of FYM @ 10 t/ha alone or with PSB + VAM was also superior to control both in terms of direct effect on broccoli and residual effect on succeeding crops.

Effect of organic manuring in broccoli-based cropping systems

Treatment	Curd yield of broccoli (t/ha)	Fruit yield of tomato (t/ha)	Fruit yield of *bhindi* (t/ha)	Fruit yield of bottlegourd (t/ha)
Cropping systems				
Broccoli-tomato-Sesbania	15.5	29.2	-	-
Broccoli-bhindi-Sesbania	15.1	-	6.9	-
Broccoli-bottlegourd-Sesbania	15.2	-	-	8.2
SEm +	0.4	-	-	-
CD (P=0.05)	NS	-	-	-
Fertility levels				
Control	8.4	22.6	5.6	6.8
FYM @ 10 t/ha	12.7	29.8	6.7	7.9
FYM @ 10 t/ha + biofertilizers (PSB+VAM)	13.6	30.4	6.9	8.0
Vermicompost @ 3.5 t/ha	13.6	30.9	7.3	8.5
Vermicompost @ 3.5 t/ha + biofertilizers (PSB+VAM)	14.1	30.9	7.4	8.9
FYM @ 5 t/ha + vermicompost @1.75 t/ha + biofertilizers (PSB+VAM)	13.6	31.0	7.5	9.0
SEm +	0.4	0.6	0.1	0.2
CD (P=0.05)	1.1	1.8	0.5	0.6

3.1.13 Performance of New Wheat Genotype under Irrigated Saline Conditions

A new genotype of wheat KRL 99 was evaluated against established checks, i.e., Kharchia 65, and KRL 19 for its suitability in saline condition. It was observed that the new genotype KRL 99 performed on a par with the best checks at medium to high fertility level but at lower fertility levels, the checks performed better than the new genotype.

3.1.14 Performance of New Wheat Genotypes at Different Dates of Sowing under Irrigated Condition

Two new wheat genotypes PBW 532 and PBW 533 were evaluated against five established and released varieties of the zone under normal as well as late sowings. The results revealed that both the new genotypes had good potential of yield. Both under normal and late sown conditions, these new genotypes, i.e., PBW 532 and PBW 533 were either on a par or superior in yield to the best checks at the IARI Regional Station, Pusa, Bihar.

3.1.15 Screening of Suitable Wheat Varieties under Conventional as well as Zero Tillage Conditions

Out of the 12 common varieties of this zone, HD 2733, HUW 234, NW 1014, and PBW 373 proved superiority both under conventional and zero tillage conditions when sown in the first fortnight of December. Considering the last year's result it appears that varieties HD 2733 and HUW 234 have better stability because both these varieties continued to show their presence in higher producing group of varieties in two consecutive years under both tillage options.

3.2 SEED SCIENCE AND TECHNOLOGY

3.2.1 Seed Production Technology

3.2.1.1 Rice

Effect of transplanting date on seed yield and quality of Pusa Sugandh 4. The effect of transplanting dates on days to flowering, seed yield and quality was significant. Days to flowering reduced progressively with delay in planting from June 25 to July 30. Seed yield remained unaffected up to July 9 compared to the crop planted on June 25; further delay in transplanting reduced the yield by 18.2, 28.8 and 46.3 % at the dates, July 16, 23 and 30, respectively. Seed germination remained unaffected up to July 16 compared to the crop planted on June 25. However, significant reduction in germination was observed in July 23 and July 30 transplantings compared to June 25 transplanting. Higher electrical conductivity of leachate was observed in July 16 to July 30 transplantings indicating poor membrane stability in late transplanting.

Effect of date of transplanting on seed yield and quality of Pusa Sugandh 4

Date of trans-planting	Days to 50% flowering	Seed yield (t/ha)	Germi-nation (%)	Seedling dry weight (mg)	Electrical conductivity m S/cm
June 25	83.25	5.83	96.0	11.3	0.19
July 2	83.0	5.68	96.0	10.7	0.20
July 9	77.7	5.26	92.5	10.1	0.20
July 16	73.2	4.77	93.0	9.1	0.29
July 23	71.0	4.15	90.5	8.5	0.30
July 30	68.7	3.13	83.5	7.1	0.36
CD (P=0.05)	1.40	0.77	3.28	2.13	0.09

Effect of irrigation schedule on seed yield and quality of scented rice. The scented rice cultivars, viz., Pusa Sugandh 3 (PS3), Pusa Sugandh 4 (PS4) and Pusa Basmati 1 (PB 1) were raised with different irrigation treatments (stagnant water conditions up to 15, 30, 45 and 60 days after transplanting followed by irrigation three days after disappearance of ponding water). Seed yield and quality of

aromatic rice remained unaffected by different irrigation schedules confirming the results of first year. Both seed yield and quality were found to be significantly different among the cultivars. Number of irrigation under different irrigation schedules varied from 17-24 without any significant effect on seed yield and quality. Hence, retaining the stagnant water conditions for 15-30 days after transplanting followed by irrigation three days after disappearance of ponding water saved 20-23 % of irrigation water without any detrimental effect on seed yield of aromatic rice.

Effect of irrigation schedule on seed yield and quality of scented rice cultivars

Irrigation schedule	Number of irrigation[@]	Seed yield (t/ha)	Germination %	Vigor index
*I_1	17	4.10	92.3	853.0
I_2	20	4.33	92.3	863.6
I_3	22	4.24	92.1	906.7
I_4	24	4.29	93.5	876.7
CD (P=0.05)	2.3	NS	NS	NS
PB 1	21.7	4.33	88.0	817.6
PS 4	21.7	3.92	93.1	906.1
PS3	19.5	4.48	90.6	1216.4
CD (P=0.05)	0.98	0.43	2.04	73.2

*I_1, I_2, I_3 and I_4 represent stagnant water conditions up to 15,30,45 and 60 DAT followed by irrigation three days after disappearance of ponding water. [@]Total number of irrigation including ponding.

Seed production in rice hybrid PRH 10. Supplementary pollination of female line through rope pulling of the male line twice from 10:30 to 11:30 a.m. along with application of 90 g GA_3/ha at 5% panicle emergence gave a hybrid seed yield of more than 3.1 t/ha in Pusa Rice Hybrid 10. It was also observed that the deposition of one pollen per stigma was enough for obtaining fertilization and seed set.

Nicking behavior of parental lines (Pusa 6A and PRR 78) of PRH 10 for hybrid seed production. Preliminary investigations were undertaken to assess the nicking behavior of parental lines (Pusa 6A and PRR78) of PRH 10 for hybrid rice seed production under Karnal conditions. Among the different gaps (0, 2, 4, 6, 8, 10 and 12 days) studied, the nicking was appropriate at gaps of four, six and eight days between female parent (Pusa 6A) and male parent (PRR 78) under Karnal conditions.

3.2.1.2 Tomato

Hybrid seed production of tomato is taken up in southern India, which has mild temperature and higher relative humidity that favour the longer time required for emasculation and pollination. In order to provide similar conditions in northern India, hybrid tomato seed production was tried under poly-house conditions during winter season.

Higher hybrid seed yield was obtained in tomato hybrid Pusa Divya under poly-house conditions as compared to the under open field condition. Higher stigma exsertion in the female and more pollen production of male parent were observed under the poly-house conditions. Repeated pollination (thrice) of flowers of female line of tomato gave higher seed yield under both the field and poly-house conditions.

3.2.1.3 Brinjal

In studies on hybrid seed production of brinjal, it was observed that emasculation of only long style and medium style flowers should be undertaken to produce hybrid seed. Studies showed that pseudo style did not set any fruit after pollination. The female parent had varied fruit weight ranging from 100 to 400 g, and the number of seeds per fruit increased with the increasing fruit weight. More than 1000 hybrid seeds per fruit can be harvested if the fruit weight is more than 400 g, in Pusa Brinjal Hybrid 5.

3.2.2 DUS Testing for Plant Variety Protection

Morphological characteristics suitable for establishing distinctness of 55 varieties and hybrids of rice including parental lines and aromatic rice varieties were identified. These characters will be helpful in conducting DUS of rice. In maize, considerable variability for most of the morphological characters was observed within the varieties, inbreds, hybrids and composites. Hence, permissible limits for character expression in different types of varieties of maize need to be standardized for fulfilling the uniformity criteria of DUS testing. Similarly, characters which exhibit less variability within the variety need to be identified for DUS.

3.2.3 Seed Testing

3.2.3.1 Improvement in uniformity of seed testing

Monitoring of 14 State Seed Testing Laboratories (SSTLs) in the year 2005 revealed that the primary factors contributing to high disparity of seed testing results (> 20%) between the CSTL and SSTLs are: (a) long time gap (3 months or more) between the time of testing samples at two laboratories, (b) use of poor quality germination paper in many SSTLs, and (c) lack of laboratory facilities and trained manpower in SSTLs. Hence, the SSTLs should maintain seed samples in controlled storage condition and dispatch the 5% referee samples soon after testing the same. In order to improve the technical capabilities of the Seed Testing Officials, the Division of Seed Science and Technology of the Institute conducted two trainings and 37 personnel from different State Seed Testing Laboratories were trained in seed testing.

3.2.3.2 Seed dormancy in *Plantago ovata*

Seed testing protocols, including investigation on dormancy behaviour and treatments to release the same, were standardized for isabgol (*Plantago ovata*). Fresh seeds exhibited thermo dormancy that requires pre-chilling at 10-12^{0}C or GA_3 application for release. Complete loss of dormancy was noted after one year of storage or more.

Per cent germination of seeds of isabgol (*Plantago ovata*) at different temperatures of testing and storage period

Storage periods (months)	Temperature in ^{0}C			
	10-12	20	25	30
0	85	10	0	0
6	86	78	43	15
12	-	88	65	32
18	-	86	85	68
24	-	82	83	80

3.2.3.3 Genetic purity testing in cotton hybrid seed

Genetic purity of 10 commercial seed lots of cotton hybrid were tested through: (a) field grow-out test, and (b) electrophoresis of seed globulins. Though the electrophoresis data (based on 100 seeds) compared fairly well with those of field data (based on about 400 plants) in respect of detection of selfed female seed, they overestimated the presence of off-types. This indicated that mere presence or absence of one band in the electrophoresis profile may not truly be indicative of the presence of off-types, unless their genetic control is known.

Comparison of field grow out and electrophoresis tests for genetic purity assessment in hybrid cotton

Lot No.	Grow out		Electrophoresis	
	Female (%)	Off-types (%)	Female (%)	Off-types (%)
109304	9.0	0.0	7.0	2.0
109305	7.5	0.0	8.0	1.0
109327	7.0	0.0	8.0	0.0
109329	9.5	0.0	10.0	0.0
109330	25.0	0.0	16.0	1.0
109334	4.0	0.0	5.0	1.0
109369	9.0	0.0	6.0	1.0
109383	4.5	0.0	6.0	1.0
109384	7.0	0.0	8.0	1.0
109385	10.0	0.0	10.0	1.0

3.2.3.4 Seed health management

Incidence of *Bipolaris oryzae* in paddy hybrids and the parental lines seed is a major problem (ranging from 1.0 to 8.5%). Seed treatments with vitavax, thiram and mancozeb 2.5 g/kg seed were effective in controlling the fungi almost completely, and the efficacy of these fungicides remained fairly high up to 6 months of storage, as indicated by the effective inhibition zones caused by these fungicides.

Effect of seed treatments on inhibition zone (mm^2) against *B. oryzae* in rice after storage

Treatment	On PDA	Inhibition zone (mm^2)			
		Months of storage			
		0	2	4	6
Mancozeb	977.23	908.32	869.64	707.25	606.13
Thiram	1701.57	1626.96	1573.35	1452.60	1385.84
Vitavax	1735.34	1698.43	1644.44	1590.83	1503.84

3.2.4 Seed Quality Enhancement and Deterioration

3.2.4.1 Seed coating for quality enhancement in soybean and paddy

Seeds of soybean cv. Pusa 24 were coated with Polykote, a water soluble polymer having 25% solids; pH 5.5-6.0; Sp.Gr. 1.05 @ 4 ml per kg, alone or in combination with fungicides. Similar treatments were given to paddy seeds of cvs., Pusa 6A, 6B, IR58025A and 25B @ 5 ml/kg. Coated seeds of soybean were packed in cloth bag, polythene (500 gauge) and Super bags (two layers of 0.078 mm PE fused with a gas barrier in between) and stored under ambient conditions for 12 months. Significant improvements in the storability of soybean seed were recorded as a result of treatment with Polykote (singly or with fungicides) and with the use of Super bags.

Storability (germination %) of soybean (cv. Pusa 24) seeds after 12 months of ambient storage

Packaging	Treatment				Mean
	Untreated	Polykote	Polykote + thiram	Polykote + vitavax	
Cloth bag	70	76	82	76	**76**
Polythene	60	68	75	78	**70**
Super bag^{TM}	78	82	85	88	**83**
Mean	**69**	**75**	**81**	**81**	

*Seed moisture content = 10.6%

In paddy, coating seeds with polykote was effective both in maintaining high germination during storage and in improving field emergence in the cytoplasmic male sterile (IR58025A) and maintainer (IR58025B) line seeds.

Effect of seed coating on % field emergence of paddy parental lines

Treatment	IR 58025B	IR 58025A
Control	75.0	75.0
Polykote	83.0	84.0
Polyloc	83.0	82.5
Polykote + Super red	84.5	84.5
Polyloc + Super red	84.0	84.0
Polykote + vitavax	85.0	85.0
Polyloc + vitavax	83.5	84.0

3.2.4.2 Seed characters and vigour parameters in chickpea

Field emergence (FE) is generally poor in large seeded *Kabuli* chickpea varieties, as compared to that in *desi* varieties. A study undertaken with *Kabuli* and *desi* chickpea varieties revealed that though standard germination reduced with increased seed size both in *Kabuli* and *desi* varieties, there was no effect of seed size on FE (%) and speed of germination (SOG) of *desi* varieties. The thin seed coat in *Kabuli* chickpea caused poor field emergence.

Vigour parameters of different groups of chickpea genotypes

Varieties	Test wt.	SC wt.	Ger. (%)	FE (%)	SOG
Desi	13.96	2.21	95.44	79.25	23.66
Desi Bold	22.76	2.79	88.92	81.56	24.16
Kabuli Bold	24.92	1.12	89.08	61.00	17.91
Mean	**20.55**	**2.04**	**91.15**	**73.94**	**21.91**
Range	12.23	0.69	78.00	41.50	10.17
	28.18.	3.08	98.67	90.50	27.77

As the test weight increases, the vigour parameters (Germination %, FE and SOG) decrease

3.2.4.3 Seed deterioration in cytpolasmic male sterile (CMS) lines of rice hybrids

Seeds of rice hybrids and cytoplasmic male sterile (A) lines generally exhibit poor longevity compared to their respective maintainer (B) and restorer (R) line seeds. A comparative assessment of physical and physiological parameters between A and B lines with respect to (i) husk characters; (ii) activities of mitochondrial enzymes, viz., malate dehydrogenase and cytochrome C oxidase; and (iii) activities of free radical scavenging enzymes revealed that wider glume openings in hybrids and A lines compared to those in B and R lines and lower activities of cytochrome C oxidase and malate dehydrogenase in A line compared to those in B line possibly contributed to the poor longevity of their CMS (A) line as compared to their respective B lines.

3.2.5 Beneficial Effects of Solid Matrix Priming in Bittergourd and Okra Seeds

Studies were carried out at the Institute's regional station, Karnal, to improve planting value of horticultural seeds at optimal and sub - optimal temperatures. Bittergourd seeds of cv. Pusa Vishesh were primed and seedling emergence tested at 15^0 C, 20^0 C and 25^0 C. Solid matrix priming improved the emergence by 10% over control at optimum temperatures (25^0 C). However, solid matrix priming and osmopriming improved emergence significantly by 35% under sub-optimal temperatures (15^0 C).

Efficacy of solid matrix priming alone or in combination with *Trichoderma* in improving emergence in okra cv. Pusa A 4 was evaluated. Solid matrix priming + *Trichoderma* treated seeds had more uniform and faster emergence compared with untreated seeds. Under optimal temperatures, the rate of emergence was faster in primed seed but overall final emergence percentage remained unaffected. Improved emergence by priming was linked to increased activity of enzymes like malate dehydrogenase and isocitrate lyase in okra.

3.2.6 Comparative Appraisal of Vegetable Seed Germination Standards of India with Developed and Developing Region Countries

In continuation of the last year's study, a comparative appraisal of vegetable seed germination standards of developed regions (viz., UK and USA) and the developing regions (Nepal and FAO standards as applied to less developed countries) with those of Indian Minimum Seed Certification Standards (IMSCS) revealed that the prescribed germination standards for Solanaceous vegetables are at par in the case of brinjal (except USA), and lower in the case of tomato, and variable in the case of chillies. Nevertheless, the germination percentages achieved by IARI Regional Station, Karnal are much higher than those of the prescribed minimum germination standards in this category.

3.2.7 Seed Production

At the Seed Production Unit of the Institute (Delhi) and at

Seed production (t)

Crop	Nucleus seed	Breeder seed	IARI seed	Total seed
Seed Production Unit (Delhi)				
Cereals	-	-	66.65	66.65
Oilseeds	-	-	7.9	7.9
Pulses	-	2.45	2.6	5.05
Vegetables	-	0.2	2.96	3.16
Flower	-	-	59.65(kg)	59.56(kg)
Regional Station, Karnal				
Cereals	3.20	77.68	50.14	131.02
Forage	0.03	0.56	0.43	1.02
Oilseeds	0.01	1.07	0.55	1.63
Pulses	0.06	4.02	0.93	5.01
Vegetables	0.03	3.33	0.56	3.92
Regional Station, Pusa Bihar				
Fruit crop (Papaya)	-	-	14.80(kg)	14.80(kg)
Regional Station, Katrain				
Vegetables	0.139	0.369	1.798	2.306
Regional Station, Indore (Breeder seed produced under farmers participatory programme)				
Cereals	-	151.50	-	151.50
Oilseed (Soybean)	-	4.00	-	4.00
Fruit (Papaya)	-	8 (kg)	-	8 (kg)

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, 1283 saplings of fruits and flowers were produced at the Seed Production Unit (Delhi). At the Regional Station, Karnal, more than 5000 horticultural plants were produced. At Regional Station, Pusa (Bihar) 6000 seedlings of papaya (c.v. Pusa Dwarf), 250 plants of mango and 600 plants of litchi were produced.

3.3 SOIL MANAGEMENT

3.3.1 Comparative Studies on Rice-Wheat and Maize-Wheat Cropping Systems

3.3.1.1 Mineralogical investigations

In rice-wheat system, there were more vermiculite and mixed-layer vermiculite than those found in maize-wheat system; and in maize-wheat system, there was more smectite content than that found in rice-wheat system. Transformation of micaceous minerals to smectite and smectite-kaolinite minerals through mica-vermiculite and vermiculite minerals was found to be slower in soil profile continuously growing rice-wheat than that growing maize-wheat. It seems that in terms of mineralogy, rice-wheat cropping system could be more sustainable.

3.3.1.2 Kinetics of silica release from clay organic complex before and after humus removal

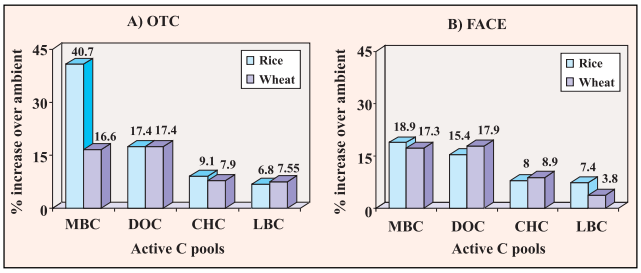
For clay organic complex of rice-wheat system, the silica release maintained a constant rate or zero order reaction, both before and after humus removal, although the rate of silica release was much higher after humus removal. Surface and deepest layers showed the least rate of Si release. For clay-organic complex of maize-wheat system, Si release maintained a constant rate after the removal of humus. As usual, the rate of Si release was much higher after humus removal. Removal of adsorbed humus made soil clay more vulnerable to weathering by organic acid with respect to Si release; all samples showed linear relationship between silica release and potassium release.

3.3.1.3 Release of zinc by clay-organic complexes

Studies on the release from repeated extraction of clay-humus complexes from soil samples of rice-wheat cropping system by 100 mg/L tartaric acid before and after the removal of humus showed that in the lower layers of soil profiles continuously growing maize-wheat, the removal of humus resulted in a very high rate of Zn release from clay whereas in the upper layers the trend was opposite. In the soils of rice-wheat, the humus removal from clay organic complex decreased the rate of Zn release.

3.3.2 Nutrient Transformation in Crop Rhizosphere under Impending Climate Change

Both pot culture (OTC) and field (FACE) experiments recorded increase in various active carbon pools: microbial biomass C (MBC); dissolved organic C (DOC); carbohydrate C (CHC) and : labile C (LBC) in rice and wheat rhizosphere grown under elevated (600±50 ppmV) atmospheric CO_2 concentration over the ambient (370 ppmV) treatment; the order of increase generally followed the sequence of their relative lability. The total soil C did not differ at OTCs for any crop; while in FACE, the surface soil (0-10 cm) exhibited significant increase (2-3% over ambient condition). This was ascribed to long-term (during past 7 years) exposure of soil to elevated CO_2, and the observation was indicative of the possible C sequestration under elevated CO_2 in semi-arid tropical environment. The NH_4^+-N in rice and NO_3^--N in wheat rhizosphere were significantly reduced due to increase in atmospheric CO_2. The total plant biomass of both the crops



Per cent increase in different active carbon pools in rhizosphere of rice and wheat due to elevation of atmospheric CO_2 (averaged over all the plant growth stages)

increased by around 30%, showed greater allocation of biomass and C to below ground portion, and caused decrease in C:N ratio of all the plant parts at higher CO_2, when compared to ambient condition. The root nitrogen content and the fraction of plant-assimilated C, translocated belowground, have emerged as the most important predictors for active C and inorganic N pools. The decomposition of wheat and rice raised under elevated CO_2 condition was slowed down (4-9%) under elevated CO_2, compared to the respective ambient-CO_2 grown residues.

3.3.3 Diagnosis and Amelioration of Iron Deficiency under Aerobic Rice

A field experiment was conducted on the iron-deficient Typic Haplustept of IARI farm to evaluate the relative effectiveness of soil and foliar application of Fe in alleviating Fe deficiency using four rice cultivars (IR 36, IR 64, IR

71525-19-1-1 and CT 6510-24-1-2). Foliar application of Fe (3% $FeSO_4.7H_2O$ solution, thrice at 40, 60 and 75 days after sowing of rice) was most effective and economical in correcting Fe deficiency in aerobic rice, followed by 150 kg $FeSO_4.7H_2O$ + 10 t FYM/ha and 305 kg $FeSO_4.7H_2O$/ha. Among the rice cultivars, CT 6510-24-1-2 and IR 71525-19-1-1 performed better under aerobic condition compared to IR 36 and IR 64. Differential response of rice cultivars to applied Fe was not related to Fe-nutrition; rather it was apparently dictated by the inherent characteristics of cultivars to grow under water-stress condition. Ferrous-iron (Fe^{2+}) content in rice plants proved to be a better index of Fe-nutrition status compared to total plant Fe and chemically extractable soil Fe. The Fe^{2+} content of ≥37 mg kg^{-1} in plants appeared to be an adequate level at 60 days after sowing for direct seeded rice grown under upland aerobic condition.

Effect of sources and methods of Fe application on the grain yield (t/ha) of rice cultivars

Applied Fe	Cultivars				Mean
	V_1	V_2	V_3	V_4	
T_1	1.10	0.733	2.28	2.25	1.59
T_2	2.39	1.82	3.13	3.25	2.65
T_3	1.98	1.53	2.48	2.75	2.18
T_4	2.81	1.82	3.43	3.76	2.95
Mean	2.07	1.48	2.83	3.00	
CD (5%)	Fe	Cultivar	Fe×cultivar		
	0.257	0.257	NS		

T_1: control, T_2: (30 kg Fe/ha) through $FeSO_4.7H_2O$ + 10 t FYM/ha, T_3: 60.95 kg Fe/ha through $FeSO_4.7H_2O$ and T_4: three foliar sprays of $FeSO_4.7H_2O$ (3%) at 40, 60 and 75 DAS; V_1: IR 36, V_2: IR 64, V_3: IR 71525-19-1-1, and V_4 : CT 6510-24-1-2

3.3.4 Complexation of Lead and Nickel by Rhizo-deposits of Wheat and Maize

The rhizo-deposits of wheat and maize were collected, identified and quantified. The binding of root exudates with metal ions (Pb and Ni) was studied using an equilibrium dialysis procedure. A function similar to that of Langmuir was used for computing maximum binding ability (MBA) and overall stability constant of the association (K). The MBA values were 150 and 205 me 100 g^{-1} for Pb and Ni for root exudates of maize while the corresponding values were 110 and 168 me 100 g^{-1} for root exudates of wheat. The higher values of MBA of metals for root exudates of maize may be perhaps due to higher content of proteins and uronic acids. The overall stability constants (Log K) varied from 4.334 to 4.548 suggesting similar kinds of sites for Pb and Ni in wheat and maize root exudates.

In another study, the kinetics of uptake of lead and nickel by maize and wheat in Mollisol and Inceptisol at two different ranges of concentrations, lower and higher, of available metal was studied. The Michaelis Menten parameters, i.e., V_{max} (maximum rate of uptake) values of Pb (0.022 to 0.221 at low concentration, and 0.291 to 1.613 for higher concentration) are more compared to Ni (corresponding values were 0.012 to 0.032 and 0.068 to 0.245) when expressed in terms of µg day^{-1} cc^{-1}. The V_{max} values are in general high in wheat compared to maize and decreased with the age of crop. This may be due to greater affinity of wheat to accumulate heavy metals aided by low complexing ability of its rhizo-deposits. The K_m values followed the same trend as in V_{max}. The V_{max} and K_m values have shown a sudden jump at higher concentrations.

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

Brinjal and cauliflower grown in Madanpur Khadar village irrigated with either sewage effluents of Okhla Sewage Treatment Plants or tube well water were analyzed for metal contents. Zn, Cu, Mn, Fe, Cd and Pb concentrations in brinjal (fruit) were 38, 153, 98, 304, 36 and 17%, respectively, higher in sewage irrigation practice, as compared to the brinjal grown with tubewell water. Such increases in the case of cauliflower (curd) were 17, 221, 47, 134 and 59 %, respectively, except for Pb which could not be detected in cauliflower curd.

In a net house study, *Brassica juncea* (cv. Pusa Bold), *Brassica carinata* (cv. Pusa Swarnima) and *Brassica napus* (ISN 121 line) were grown in Cu and Ni spiked soils (separately) for quantifying their tolerance to these metals. These species of *Brassica*, in general, could tolerate Cu up to 125 mg kg^{-1} soil, as at both 250 and 500 mg Cu kg^{-1} soil levels, the biomass yields exhibited a decrease whereas the interaction effect showed that *Brassica carinata* could tolerate 250 mg Cu kg^{-1} soil level. *Brassica juncea* is significantly more tolerant of high levels of Cu than the other species. In contrast to Cu, the biomass yields of various *Brassica* species were not influenced by Ni spiking up to the maximum dose of 100 mg Ni kg^{-1} soil tried in this experiment**;** *Brassica juncea* showed greater tolerance to Ni spiking.

Effect of Cu spiking in soils on the growth of various *Brassica* species in a net house study

Species	Levels of Cu applied (mg kg^{-1} soil)				Mean
	0	125	250	500	
	Biomass yield (g pot^{-1})				
Brassica juncea	8.02a¶	7.13b	6.27cd	5.29ef	6.68A§
Brassica carinata	5.92de	5.88de	6.20cd	3.13h	5.29B
Brassica napus	6.80bc	6.83bc	4.96f	3.91g	5.62B
Mean	6.91A§	6.62A	5.81B	4.11C	

¶ Values in the same column or row followed by a different lower case letter signify the interaction effect of species and levels of Cu on biomass yield; § values in the last column and row followed by a different upper case letter signify the average effect of species and levels of Cu, respectively. These are significantly different at P = 0.05 according to Duncan's Multiple Range Test for separation of means

Effect of Ni spiking in soils on the growth of various *Brassica* species in a net house study

Species	Levels of Ni applied (mg kg^{-1} soil)				Mean
	0	25	50	100	
	Biomass yield (g pot^{-1})				
Brassica juncea	8.02a¶	6.05cde	7.96a	7.95a	7.49A§
Brassica carinata	5.92de	6.58cd	5.73e	6.15cde	6.10B
Brassica napus	6.80bc	6.40cde	6.32cde	7.35cde	6.72B
Mean	6.91AB§	6.34B	6.67AB	7.15A	

¶Values in the same column or row followed by a different lower case letter signify the interaction effect of species and levels of Ni on biomass yield; § values in the last column and row followed by a different upper case letter signify the average effect of species and levels of Ni, respectively. These are significantly different at P=0.05 according to Duncan's Multiple Range Test for separation of means.

3.3.6 Hastening of Composting Process of Rice Straw by Chemical and Biological Means

Pre-treatment of chopped rice straw used as substrate with 0.1*N* HNO_3 significantly reduced the organic C content during composting due to enhanced rate of decomposition of rice straw. Among the chemical pre-treatments, the highest total N was observed with 0.1*N* NaOH (1.55%) and was closely followed by 0.1 *N* HNO_3 (1.53%) and cow dung extract (1.51%) after 150 days of incubation. On the other hand, among the biological pre-treatments, *P. crysosporium* either alone or in combination with *T. viride* recorded significantly higher N content (1.43%). The narrowest C/N ratio (13.8) was observed in cow dung extract treated material on the 150th day, followed by 0.1 *N* HNO_3 (15.0).

3.4 WATER MANAGEMENT

3.4.1 Water Resources Utilization through Technology Development and Improved Water Management Practices for Sustained Agricultural Production System

3.4.1.1 Controlling deep percolation losses in surface irrigation methods

In order to design a surface irrigation system for higher water application efficiency, a study was conducted to determine the deep percolation losses as a function of soil infiltration and resistance to the movement of waterfront. The study was based on the following assumptions:

- The distance travelled by the water front is a logarithmic function of the elapsed time
- The infiltration rate function is represented by the Kostiakov's infiltration equation of the form
- The dyke provided at the downstream end of the border-checks does not allow surface runoff
- After the water has spread all over the border-check initially, the rest of the water introduced into the field is uniformly available over the entire area.

Based on these assumptions, Kostiakov's equation was used to develop various mathematical expressions to determine the total water infiltrated in the field and that infiltrated in the root zone of the crop. Percolation losses were then expressed as the ratio of the difference between the total water infiltrated and the water infiltrated in the crop root zone to the total volume of water infiltrated in the field. The percolation loss was then found as the function of the ratio of the opportunity time (T_d) at the lower end of the field to the total recession time (T).

3.4.1.2 Use of a modified Geomorphologic Instantaneous Unit Hydrograph (GIUH) technique for estimation of surface runoff from ungauged watersheds

The study focused on the capability of a modified exponential distributed geomorphologic instantaneous unit hydrograph (ED-GIUH) model in generating direct runoff hydrographs (DRHs). The ED-GIUH concepts were developed to generate the DRHs for the Banha watersheds under Upper Damoder Valley, Jharkhand, India. The estimated runoff using the ED-GIUH concept was compared with the original NRCS Curve Number (CN) generated runoff and validated with the observed runoff data of the watershed. The model input data, including natural drainage network and Horton's morphological parameters were prepared using a watershed morphological estimation tool (WMET) interface of ArcGIS®. The path probability of channel and overland flow were estimated from the generated feature classes of watershed topology and drainage networks to derive the instantaneous unit hydrograph (IUH). It was observed that the ED-GIUH technique was better than the CN approach and resulted in accurate prediction (20<error % < 4) of peak discharge and time to peak when compared with the observed DRH resulting from short duration (<6 h) events. However, for longer duration events (6 h to 16 h), this method did not perform better than the CN method and resulted in higher error % (60< error %<14). Thus, by using ArcGIS®, the ED-GIUH model could be used to predict DRHs from small duration events more accurately than the CN approach for ungauged watersheds having similar geomorphology as that of the Banha watershed.

3.4.1.3 Development of a Ground Water Information System (GWIS) as an interface in ArcGIS®

A Ground Water Information System (GWIS) interface

was developed within ArcGIS® environment for estimation of GW potential and to target potential ground water recharge zones, using advanced computer tools and modeling capabilities. The interface was coded in Visual Basic for Application (VBA) programming language, which is the built-in macro programming language of ArcGIS®. The input to the interface includes the feature class thematic maps of land use, soil type, digital elevation model or contour map, tube well/pizeometer location points with the water table readings, the well log information and fence diagram. The out put of the model gives the annual GW recharge estimates and the location of land area for construction of water harvesting structures for GW recharge and point and linear locations for taking up GW recharge using injection wells and recharge shafts. This developed interface was validated using the information of IARI watershed. It was revealed that the interface generated location was in line with the already constructed water harvesting structures in the IARI farm. The interface can be applied to any watershed locations with the desired input information for estimation of GW potential and targeting the effective recharge zones.

3.4.1.4 Meteorological data analysis for crop planning and water management strategy

Weekly minimum air temperature during winter period in the IARI farm based on the last 30 years (1976-2005) was analysed in 3 ranges, namely, $\leq 5^0$C, 5-10^{0}C and $\geq 10^0$C. Decadal variation was studied for 1976-85, 1986-95 and 1996-2005 with respect to the above minimum temperature ranges.

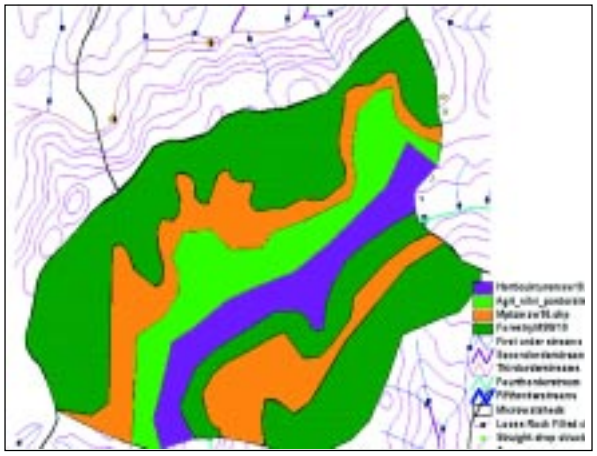
During the 4 weeks of January, the percentage number of days in a week having $\leq 5^0$C was high (30-60%) during the decade, 1976-85, 30% during the decade, 1986-95, and 40% during the decade, 1976-85. Under the range 5-10^{0}C, the percentage of days in a week was about 79 (1976-85), 50-70 (1986-95) and 63-76 (1996-2005) during December. For minimum temperature of $\geq 10^0$C, the percentage number of days was 37-59 (1976-85), 40-56 (1986-95) and 47-71 (1996-2005) both in the first week of February and March.

These types of analytical studies form a useful input in the experiments of both fruits and vegetable crops as they are subject to ground frost as well as cold injury.

Rainfall data of IARI farm for last 30 years (1976-2005) were analyzed under 3 different time scales: weekly, monthly and seasonal to know the drought frequency, particularly in *kharif* season. On a weekly basis, it was found that from the last week of June to mid-July, 18 drought weeks occurred. However, during the peak monsoon period, from the first week of July to mid-August, the drought weeks declined to 12. Again the drought frequency weeks increased to 17 during September. On a monthly basis during monsoon months 1976-2005, September experienced 10 droughts as compared to 6 droughts in August. Season-wise, *kharif* crop period had 9 droughts seasons and *rabi* crop season had 17 droughts. This information can help in crop planning and water management strategies.

3.4.1.5 Integrated watershed management planning for treatment and restoration of the Wah Dainthelen watershed, Cherrapunjee, Meghalaya

Considering the various climatic, topographic and management constraints in Wah Dainthelen watershed in Cherrapunjee, a detailed watershed management plan was formulated to arrest degradation. Watershed management plans for 35 micro-watersheds were proposed. A proposed model land use plan of micro watershed No. 18 (MSW-18) is given in the figure.



Proposed land use for micro-watershed MSW 18 (in phase-I) in Wah Dainthelen Watershed, Cherrapunjee (to be varied from one micro-watershed to the other)

3.4.2 Development of Appropriate Technologies for Water and Nutrient Use for Enhancing Crop Production

3.4.2.1 Maximization of water use efficiency in rice production

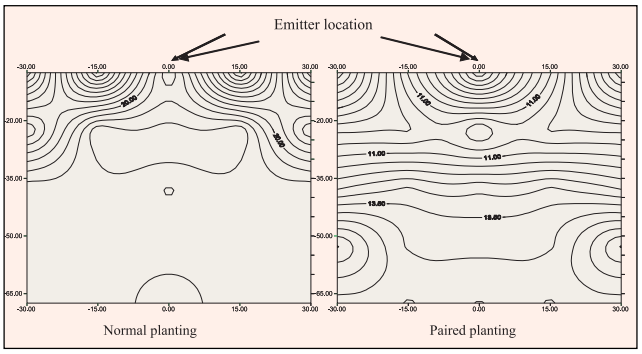
Rice production under traditional puddled-transplanted low land is one of the most water intensive enterprises as it uses more than 50% of irrigation water. A change from traditional rice production system to aerobic rice production is imperative to mitigate the occurrence of water related problems. Eighteen rice genotypes were evaluated under aerobic rice production system under three irrigation levels, viz., irrigation at zero kPa, 20 kPa and 40 kPa soil moisture tension. Rice genotypes, Pusa Rice Hybrid 10, Proagro 6111

(hybrid), Pusa 834, IR 55419-04 and IR 74371-54-1-1 produced a grain yield of 4 to 4.5 tonnes per ha under aerobic production system, irrigated at 20 or 40 kPa soil moisture tension, which saves > 50 % of irrigation water compared with that required for conventional transplanted rice.

Experiments were also initiated in three farmers fields during *kharif* (wet season) 2005 to evaluate the effect of three irrigation treatments, i.e., I_0 (control) irrigated at zero kPa soil moisture tension, and I_{20} and I_{40} irrigated at 20 kPa and 40 kPa soil moisture tension, respectively, on three rice cultivars, viz., Proagro 6111, Pusa Sugandh 3 and Pusa Sugandh 4. Data on farmers' practice (traditional transplanting of rice after puddling) with two varieties Pusa Sugandh 3 and Pusa Sugandh 4 were also collected. Results showed that Pusa Sugandh 3 gave better performance at all levels of irrigation compared to that given by other two cultivars and the hybrid Proagro 6111. Pusa Sugandh 4 gave minimum yields. There were no significant differences in the yields due to the irrigation treatments. However, a good deal of water saving was obtained in the aerobic rice without compromising the yields, which was on a par with the yield recorded in farmers' practice.

3.4.2.2 Water requirement of groundnut under different planting methods and irrigation schedules in drip irrigation

An experiment was carried out on groundnut crop in drip irrigation system. The drip system was laid out with 60 cm lateral spacing and 50 cm emitter spacing along the lateral. One lateral line was placed for two rows of crop. Soil water distribution was observed around the point source emitter under different treatments. Soil samples were collected along the lateral (12.5 and 25 cm from emitter) and across the lateral (near emitter, 15 cm and 30 cm from emitter) and at five depths (0-15, 15-30, 30-45, 45-60 and 60-75 cm below the ground) to determine the soil moisture using gravimetric method. The figure shows the water distribution in the treatment T_1 (daily irrigation) under normal planting (flat bed) and paired row (flat bed) planting system. The observations were recorded 24 h after irrigation. The figure shows that soil moisture distribution was uniform in the case of paired row planting system in the upper layers of the soil (40 cm). The reasons could be attributed to the better soil moisture extraction in paired row planting. However, these are early results, which need to be further investigated. Considering the three basic factors, namely, soil moisture depletion, crop growth stage and evapotranspiration, the crop water requirement for groundnut under trickle irrigation system was estimated.



Water distribution under normal and paired row plantings: Soil water distribution pattern in groundnut under drip irrigation (point source emitter, 2.5 l/h)

Estimation of water requirement of groundnut under drip irrigation

Crop growth stage	Duration (days)	Percentage shaded area	Water requirement (l/day/plant)
Initial	0-25	1.0-33.0	0.1-0.25
Vegetative and flowering	25-75	33.0-67.0	0.25-0.45
Pegging and pod formation	75-100	>67.0	0.45-0.6

3.4.2.3 Production potential of pearlmillet – chickpea cropping system under limited water supply

A field experiment was conducted on pearlmillet under rainfed condition during *kharif* and chickpea during *rabi* season. Findings revealed significant response of nitrogen up to 90 kg/ha. Similarly, one irrigation at grain filling, due to the early cessation of monsoon rain, gave favourable response as compared to no irrigation. In the case of *rabi* season, chickpea significantly responded to 2 irrigations, each applied at flowering and soft dough seed stages as compared to one and no irrigation. Phosphorus application had a favourable effect on nodulation and total biomass up to 75 kg P_2O_5/ha. However, significant increase in seed yield was noticed up to 50 kg P_2O_5/ha only.

3.4.2.4 Effect of phosphorus on soybean seed yield and crop residue management, irrigation and N level on succeeding wheat yield

Experiment on soybean was conducted during *kharif* season with 4 levels of phosphorus, viz., 0, 25, 50 and 70 kg/ha. Experimental results suggested that P application had significant effect on nodulation, biomass and seed yield of soybean. Soil incorporation of crop residue had favourable effect on soil properties as well as grain yield of succeeding wheat crop when compared with the treatment where crop residue was removed. Irrigation applied as per climatological approach and soil moisture depletion not only produced similar yield of wheat but also saved about 60 mm of

irrigation water as compared to 5 irrigations applied as per physiological crop stages.

3.4.2.5 Sulphur – water interaction in onion

An experiment on onion consisting of three water regimes, namely, irrigation at 30 kPa (I_{30}), 50 kPa (I_{50}) and 80 kPa (I_{80}) and four doses of sulphur- 0, 20, 40 and 60 kg/ha was conducted. Fresh bulb yield was recorded maximum (41.99 t/ha) under $I_{30}S_0$ treatment and minimum (16.63 t/ha) under $I_{80}S_{60}$ treatment. Under I_{30} water regime, the average bulb yield increased by 22.64 per cent over I_{50} treatment and 119 per cent over I_{80}. Response of sulphur (only up to 40 kg/ha) was observed in I_{80} only. There was no response of sulphur in I_{30} and I_{50} water regimes.

3.4.2.6 Performance of wheat varieties under Aqua-Ferti Seed Drill (AFSD) and conventional sowing (CS) in rainfed condition

The treatments comprised 4 varieties (HD 2687, HD 2865, HD 2228 and HD 2329) and two methods of sowing (AFSD and conventional (CS) in RBD with three replications. Rainfall received during crop growth period was 47.4 mm, out of which 32.4 mm was received only in February, 2005. Sowing by AFSD gave significantly higher average grain yield (2.44 t/ha) as compared to conventional method of sowing (1.68 t/ha). Under AFSD in all wheat varieties, germination and growth were better than that of conventional method of sowing. Performance of wheat variety, HD 2865 was statistically higher and maximum (2.86 t/ha) followed by HD 2285 (2.05 t/ha) and HD 2687 (2.03 t/ha); the least grain yield was recorded with HD 2329 (1.69 t/ha). Moisture use by wheat under AFSD in respect of seasonal consumptive use, moisture use rate and crop water use efficiency was higher compared to that in conventional method.

Grain yield (t/ha) of wheat during 2004-2005

Method of sowing	HD 2687	HD 2865	HD 2228	HD 2329	Average
AFSD	2.44	3.36	2.77	1.97	2.44
Conventional	1.62	2.35	1.34	1.41	1.68
Average	2.03	2.86	2.04	1.69	
CD (P=0.05)	Method of sowing (t/ha) 0.21		Variety (t/ha) 0.20		

Moisture use rate by wheat under AFSD and conventional sowing in rainfed condition during 2004-2005

Method of sowing	Seasonal consumptive water use (Cu) in mm	Daily moisture use rate (mm)	Crop water use efficiency (CWUE) (kg grain/ m^3 water used)
AFSD	163.4	1.28	1.49
Conventional	146.8	1.15	1.14

3.4.2.7 Effect of saline water on cultivars of Indian mustard (*Brassica juncea)*

A study was conducted in micro plots (2m x 2m) with four levels of salts in irrigation water with EC_{iw} of 0.4, 4.0, 8.0 and 12.0 d Sm^{-1} applied to five Indian mustard varieties, i.e., Pusa Bold, Pusa Kranti, Pusa Agrani, Pusa Bahar and Varuna. The growth characteristics, seed yield and oil content of all mustard varieties were significantly increased with moderate salinity of irrigation water (EC_{iw} = 4 dSm^{-1}) and *Varuna* was best among all the varieties in seed yield. However, increased EC_{iw} of 8.0 and 12.0 dSm^{-1} decreased the above parameters. Contents of nitrogen, phosphorus and potassium in plants and seeds were higher with EC_{iw} of 4.0 dSm^{-1} and decreased at higher salinity (EC_{iw}) of 8.0 and 12.0 dSm^{-1}. However, calcium and magnesium tended to increase with increase of EC_{iw} both in plants and seeds.

Interactive effect of saline irrigation water (EC_{iw}) and cultivars of Indian mustard on seed yield

EC_{iw} d Sm^{-1}	Seed yield (g/plot)					
	Pusa Bold	Pusa Kranti	Pusa Agrani	Pusa Bahar	Varuna	Mean
0.4	487.73	605.90	489.03	533.43	741.00	571.42
4.0	649.60	860.70	652.57	680.00	906.00	749.77
8.0	634.87	811.93	538.60	585.93	795.00	673.27
12.0	606.90	605.50	496.63	454.83	760.00	584.77
Mean	**594.78**	**721.01**	**544.21**	**538.77**	**772.50**	-
EC_{iw}	**SEm±** 6.026			**CD at 5%** **17.223**		
Variety	5.390			**15.405**		
EC_{iw} x V	12.052			**34.446**		

3.4.3 Development of Water Management Technologies for Irrigated and Rainfed Agriculture

3.4.3.1 Development of design guideline for basin irrigation systems practised in Northern India

Design guidelines were developed using a two-dimensional simulation model for basin irrigation layouts. The effect of aspect ratio, longitudinal slope, local irregularities on irrigation performance in a hypothetical single basin was analysed. The model used for the study was the modified version of two-dimensional Contour Basin Model (COBASIM). The model was modified to incorporate characteristic features of the level basins commonly used in the canal command areas of northern India. The model's governing equations are based on a zero-inertia approximation to the two-dimensional long wave equations of motion. The equations of motion are transformed into a single non-linear advection-diffusion equation in which the friction force is described by Manning's formula. The

empirical Kostiakov equation is used to model the infiltration process in the model. The governing equations are solved numerically using method of characteristics coupled with Two-dimensional Taylor series expansion. The basin size selected for the analysis was 30 x 50 m with spatial discretization of 217 grids. The inflow rate selected was 0.00033 $m^3s^{-1}m^{-1}$. The scenarios were analyzed based on irrigation performance in terms of application efficiency, water requirement efficiency and distribution uniformity. It was found that the best efficiency can be achieved for the aspect ration of basins ranging from 0.4 to 0.9. The effect of slope on irrigation performance indicated that slope should range from 0.04% to 0.07%. The effect of local irregularities was pronounced in terms of improving distribution uniformities. These local variations should be removed regularly to improve irrigation application uniformity.

3.4.3.2 Salt uptake by *Acacia biflora* saplings and development of a bio-drainage decision support system for land reclamation

Three-month old saplings of *Acacia biflora* were irrigated with saline water of salt concentrations varying from 590 ppm (control) to 2300 ppm. The leachate was analyzed for its salt content. The plant leaf sap salinity was measured once before the experiment and once after the experiment, which lasted for 6 months. Conclusions were drawn on the basis of analysis of leaf sap salinity before and after six months of saline irrigation water treatments and salt balance analysis among the irrigation water, salt content in the soil of the pots growing the saplings and the leachate collected during the experiment. The salient findings of the experiment and the interpretation of the results are:

- Saplings could extract salt from soil and store it in leaves that increased with higher irrigation water salinity.
- Estimated salt removal/ha with 400 plants is 20 kg/ year. Sub-surface drainage removes salts in tonnes.
- At the current level of knowledge regarding salt tolerance of certain tree species, suitability of bio-drainage as a land reclamation alternative cannot be confirmed.

The results of this investigation were coupled with the available secondary data related to different high water consuming species (Hydrophytes) to develop a support system in VB programming language for generation of alternative scenarios on the possible plant types, planting density and the reclamation period for a given water table condition. The input to the support system includes the average water table depth, the waterlogged land area, choice of hydrophyte species, average annual rainfall, soil type, recharge from other sources and soil salinity. The output generates the plantation density and the reclamation period to bring water table below safe limit and the reduction in soil salinity of the desired location. The developed software can be used for any location with specific input information to decide the planting density, salt uptake and land reclamation period for the waterlogged area under bio-drainage systems.

3.4.3.3 Investigation on initial abstraction for runoff estimation

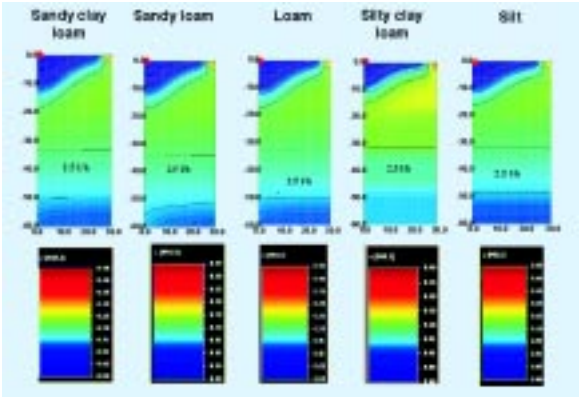
Initial abstraction (Ia) and potential maximum abstraction (S) from rainfall before runoff can start from a watershed are variedly related as Ia = 0.1S, Ia = 0.2S and Ia = 0.3S, the first and the last being for Indian watersheds, as adopted by the water Management Division of the Ministry of Agriculture, Government of India, based on limited information. In the present study, storm-wise rainfall-runoff data were used to generate the above type of relationship for small watersheds having different land uses.

Ia vs. S relationships for watersheds under different land uses

Watershed description	Ia mm	S mm	Ia vs. S relation
Good forest cover; 0.744 ha	10	48	Ia = 0.22 S
Banana crop; 1.4 ha	5	52	Ia = 0.1 S
Agriculture (1.45 ha) and thin forest (13 ha); rainfall up to 50 mm	6	25	Ia = 0.24 S
Agriculture (1.45 ha) and thin forest (13 ha); rainfall 50 – 150 mm	25	58	Ia = 0.4 S

3.4.3.4 Modeling of water and nitrogen movement under drip fertigation

A finite element model Hydrus-2D was used to simulate the water and nitrogen dynamics in the root zone of onion (*Allium cepa*) crop. It was calibrated and validated with observed field data. Five soils, namely, sandy clay loam,



Simulated nitrogen distribution in different types of soil with the emitter discharge of 2.5 l/h.

sandy loam, loam, silty clay loam and silt were selected for simulation. A total of 45 scenarios consisting of different combinations of soil type, emitter discharge rates and fertigation strategies were considered for simulations. Calibration and validation results revealed that Hydrus-2d could be used for simulation of water and nitrogen movement under drip fertigation with reasonably good accuracy. However, it is very sensitive to the percentage clay, silt and sand content even for the same textural class of the soil. Therefore, true values of clay, silt and sand should be used as input to the model. Values selected from soil catalogue may give erroneous results. Simulation results revealed that irrigation scheduling with emitter discharge of 2.5 l/h on alternate day basis is appropriate for onion crop grown in sandy clay loam soil.

Fertigation strategies like fertigation in the beginning of irrigation, fertigation at the end of irrigation and irrigation on daily bases did not affect nitrogen leaching much as commonly perceived. Simulated leaching of N below the root zone was the highest for sandy loam soil. Nitrogen leaching was negligible for silty clay loam soil. For sandy clay loam, loam and silt soil, N leaching varied from 0.02 to1.54 %.

Effect of emitter discharge on nitrogen distribution was observed in upper layers only except in sandy loam soil in which emitter discharge rate affected the nitrogen distribution in lower layers also. Effect of emitter discharge on N leaching was more in coarse textured permeable soil like sandy loam. In the case of other soils, emitter discharge did not influence nitrogen leaching. Simulation results revealed that in all type of soils, emitter discharge rates of 1 l/h and 2.5 l/h were appropriate from the points of view of nitrogen saving, distribution and leaching.

3.4.3.5 MICROS - software for designing and evaluation of micro sprinkler system

A cost-effective and user-friendly software, namely, MICROS was developed in Visual BASIC 6.0 for the design and evaluation of Micro-sprinkler system. The developed software package consists of two modules. Module-I was developed for the design of Micro-sprinkler system. Module-II facilitates the evaluation of the Micro-sprinkler system for different orchard and vegetable crops. Both the modules of the software were tested using the available published data. The developed computer codes proved to be more efficient and reliable for the design and evaluation of appropriate Micro-sprinkler systems. The developed software provides different design alternatives through the output in tabular as well as in graphical format. 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.

3.4.3.6 Hydraulic evaluation of subsurface drip in onion

Subsurface application of water aimed directly at the root zone improves yields by reducing the incidence of diseases and weeds. The SDI system 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 30.0 cm, each with an application rate of 2.75 l/h. It was found that when drip laterals were placed at 12.0, 15.0 and 18.0 cm soil depth there was less upward movement of soil moisture that resulted in water stress to the plants roots. One of the reasons could be the shallow root system of onion and soil type. The capillary water movement is limited in sandy soils; therefore, shallow placement is recommended. Onion yield is affected by the depth of placement of lateral pipe. Maximum yield (26 t/ha) was obtained when pipe was placed at the depth of 10.0 cm.

Onion crop under subsurface drip irrigation system

3.4.3.7 Groundnut yield under different irrigation scheduling criteria and method of sowing in drip irrigation system

A field experiment was conducted during *kharif* season

Groundnut crop under drip irrigation system

on groundnut. The treatments consisted of 3 methods of sowing and 5 irrigation schedules. Results of the experiment revealed that flat bed sowing or sowing in ridge produced almost the same pod yield of groundnut (var. GG20). Irrigation applied daily as per the evapo-transpiration demand produced comparable yield with irrigation given 2 days after, at 30, 40 and 50 MAD (management allowed deficit). The uniformity in the pod yield was attributed to the even distribution of effective rainfall of 200 mm during crop growing season.

Groundnut pod yield (t/ha) as influenced by irrigation schedule and method of sowing

Irrigation schedule	Method of sowing			
	S_1	S_2	S_3	Average
I_1	2.30	2.12	1.52	1.98
I_2	2.33	1.68	1.50	1.84
I_3	2.17	2.03	1.77	1.99
I_4	2.38	2.15	1.82	2.12
I_5	2.37	2.12	1.52	2.00
Average	2.31	2.02	1.63	-

Note: S_1, S_2 and S_3 are sowing in flat bed and paired row sowing in flat bed and bed, respectively. I_1, I_2, I_3, I_4 and I_5 are daily irrigation as per ET demand, 2 days after, at 30%, 40% and 50% of MAD, respectively.

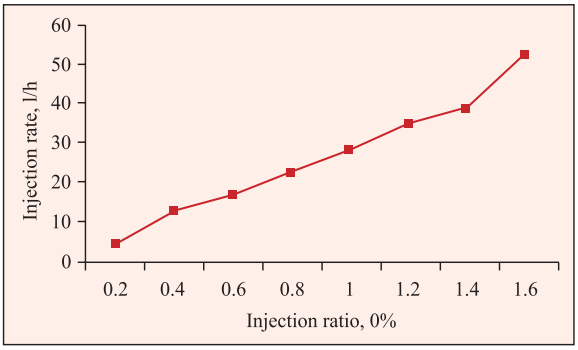
3.4.3.8 Performance evaluation of subsurface drip irrigation system

Estimation of uniformity coefficients and coefficient of variation of subsurface drip systems at different operating pressures was done to evaluate the performance of subsurface drip system. Drip tapes were placed at five depths of 0.0, 5.0, 10.0, 15.0 and 20 cm below the soil surface and the operating pressure of system was kept varying from 0.3 to 1.5 kg cm^{-2}. The coefficient of variation of flow rates was found to be 0.044 at an operating pressure of 1.0 kg/$cm^{2.}$ The lesser values of CV indicated good performance of the system. The value of SU was found to be more than 95.0% at an operating pressure of 1.0 kg cm^{-2}.

3.4.3.9 Performance evaluation of a fertigation pump

A fertigation pump, namely, Dosatron International, DI-16, was evaluated under a large range of operating pressures from 0.0 to 2.50 kg/cm^2. The pump started operating at a minimum operating pressure of 0.5 kg/cm^2. Increasing operating pressure (0.5 to 2.50 kg/cm^2) increased the flow of water (2400 to 3460 l/h). The pump had a provision of adjusting the fertilizer injection rate as a function of flow of water from 0.2 to 1.6%. At each operating pressure, setting of function knob from 0.2 to 1.6% resulted in successively increased fertilizer injection rate. For example, at an operating pressure of 0.75 kg/cm^2, adjustments from 0.2 to 1.6 % resulted in the fertilizer injection rates of 3.38 to 38.1 l/h. Lower temperatures increased viscosity of fertilizer solution resulting in reduced injection rates.

Testing of injection pump



Change in injection rate and injection ratio

3.4.3.10 Resources utilization and optimal rice production in an irrigated area in western Uttar Pradesh

A study to find out resources utilization in paddy cultivation was carried out in Bulandshahr district, U.P. which is part of the Indo-Gangetic plains in the *doab* of Ganga and Yamuna rivers. Three groups of farms were purposely selected to represent the three sources of irrigation, namely, canal, tubewell and diesel pumps. The Target MOTAD model – a modification of MOTAD (minimization of total absolute deviations) was employed to find out various levels of farm income and the associated input utilization. Thus, the model provided optimal rice production strategies and resources availability constraints, if any. The Existing Average Plan and four more efficient plans at various levels of farm income were obtained from the model. Plan of crop activities of best farmer in each category of paddy cultivators suggested an income of Rs. 30,268/ha which is 77.6 per cent higher than that of the income under the Existing Average Plan. In the rest of the plans also, an income of Rs. 27,468/ha, 24,864/ha and Rs. 22,124/ha was obtained which is nearly 61.2 per

cent, 46.0 per cent and 30.0 per cent higher than that of Existing Average Plan. Under these plans, farmers spent less money than that of the Existing Average Plan and obtained higher yield and income. Farmers under efficiency plans utilized less inputs in raising paddy crop in comparison to the Existing Average Plan.

3.4.4 Watershed Based Management for Sustainable Agriculture

3.4.4.1 Studies on water use patterns by small and large farmers

In order to study the water use patterns by both these categories of farmers in the Shikohpur watershed, the actual irrigation practices adopted by them with the standard criteria were compared. The study was conducted for wheat crop during 2004-2005. The small farmers (SF) in the area with a holding size equal to or greater than 1 ha but less than 2 ha and the large farmers (LF) with a holding size equal to or greater than 4 ha were selected. The study included the collection of soil samples both before and after an irrigation event from time to time in the commands of the tube-wells for determining the amount of water applied in the field during an irrigation event. The performance of existing irrigation systems of these farmers was evaluated in view of the erratic power supply situation in the area. Farmers were motivated to record the power supply hours and pumping duration of tube-wells in the proforma developed for this purpose.

It was found that the small farmers applied more than double of the required quantity of water during the entire period of the wheat crop and the large farmers applied more or less equal to the required quantity of water as per the developed criteria. Secondly, the small farmers applied each irrigation at the right time according to the need of water at different stages, whereas the large farmers applied each irrigation more than ten days later than the right time. This is because of the varying sizes of their land holdings commanded by the tube-wells having the same discharge. A tube-well with a smaller command can, therefore, irrigate the area quickly inspite of more hours taken per ha than the required hours, and apply the next irrigation in time. On the other hand, the tube-wells with larger commands take longer time to complete the irrigation of the full command such that the irrigation period exceeds the irrigation interval between two successive irrigations. As a result, the successive irrigation is delayed. Here, we see that the field water use efficiencies for wheat in respect of small and large farmers are worked out as 0.042 and 0.084 t/ha-cm, respectively.

Comparative statement of the water use patterns by small and large farmers in Shikohpur watershed area

Particulars	Small farmers	Large farmers
Type of the pumping unit	Mono-block	Mono-block
Size of the delivery pipe, mm	50	50
Size of the suction pipe, mm	100	100
Water table level bgl, m	24	26
Depth of water applied during the crop season, cm	119.5	57.5
Volume of water pumped during the crop season, cubic metres/ha	11942.6	5745.0
Yield, t/ha	5.03	4.84
Field water use efficiency, t/ha-cm	0.042	0.084

3.4.5 NCR Groundwater Nitrate Levels Vis-a-Vis Chemical Load in Soil

^{18}O stable isotope signatures of rainfall, groundwater and surface water suggest that urbanization induced significant shrinking of the exposed land surface has limited the amount of recharge from rainfall (<1-5% in most parts). Lateral groundwater flow from surrounding parts is the significant source. Significant amount of chemical load is accumulated in topsoil owing to increase in nitrogen fertilizer application in peri-urban agricultural areas and anthropogenic wastes. Leaching of these in many parts has severely affected the groundwater by nitrate pollution as low as 20 mg/l to abnormally high levels (100-740 mg/l). Lateral spreading of contamination takes place through specific flow-pathways, induced by indiscriminate pumping of groundwater causing depletion of fresh groundwater potential. High nitrate levels in groundwater, associated with ^{18}O enrichment, suggest existence of two or more isotopically distinct non-point sources, imbalance between plant uptake and nitrate availability, and low plant density to fully utilize the soil nitrate. Year to year increase in groundwater contaminants levels in some parts clearly suggest increasing vulnerability of groundwater to pollution in these parts, with a wide range of nitrate, fluoride F (<1-16.0 mg/l) and heavy metal contaminants. Vulnerability to contamination depends on recharge and surface run-off characteristics, water table fluctuations, groundwater-surface water interactions, and soil physical processes. Three different flow systems seem to exist vertically: (i) Uppermost local flow (rapidly circulating, low in salinity, and more vulnerable to overexploitation), (ii) Relatively slow circulating intermediate zone (more vulnerable to salinity and depletion), and (iii) Deeper, highly saline, stagnant pockets (most vulnerable to salinity and least vulnerable to depletion).

3.4.6 Role of Clay Minerals and Isotopic Evidences in Chemical Evolution of Groundwater

Variations of naturally occurring stable isotope Oxygen-18 and chemical constituents in groundwater system in Delhi region provided improved understanding of the chemical evolution of groundwater, as related to clay mineralogy. By and large, chemical composition of the groundwaters in the area has resulted from dolomite weathering by carbonic acid, favoured by the presence of 'Kankar' carbonates in the alluvial sediments and occurrence of metamorphosed dolomitic limestones in Aravalli rocks. However, the groundwaters in Alipur and Nangloi Blocks indicate calcite weathering by sulphuric acid also, possibly produced by SO_2 emissions (from power stations and automobile pollution) dissolved in rainwater. The excess of Na can be attributed to silicate weathering. Regional dispersion of fluoride is mostly consistent with the major fluoride-bearing minerals such as fluorspars (fluorite), rock phosphates and phosphorites.

3.5 INTEGRATED NUTRIENT MANAGEMENT

3.5.1 Effect of Integrated Nutrient Management on Soil Quality under Soybean-Wheat Cropping System

The effect of integrated nutrient management on the dynamics of organic carbon (C) in a Typic Haplustept of the IARI farm was studied under soybean-wheat cropping system. The treatments consisted of three levels of N, i.e. 0, 30 and 45 kg/ha for soybean and 0, 120 and 180 kg/ha for wheat. Nitrogen was supplied to both the crops through urea or farmyard manure (FYM) alone or in combination (1:1). Since the continuity of carbon supply depends both on the total pool size and the labile ($KMnO_4$-oxidizable) carbon, carbon management index (CMI) was computed as a product of carbon pool index (total carbon under treatment/total carbon under absolute control) and lability index (lability of carbon under treatment/liability of carbon under absolute control). Application of N (180 kg/ha) through FYM resulted in much higher CMI compared to other treatments after three cropping cycles. Supplementation of N @ 120 kg/ha through urea was at par with control (without N) in respect of the value of CMI, which was significantly inferior to that of 180 kg N/ha. Integrated sources at both the levels of N application were equally effective in sustaining the carbon supplying capacity of the soil.

3.5.2 Evaluation of Enriched Organo-mineral Fertilizers on Crop Productivity and Soil Fertility in a Mungbean-Potato Cropping Sequence

The effectiveness of three 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] was evaluated during 2004-2005 through a field experiment at the Institute experimental farm (MB-8B), at New Delhi on a mungbean-potato cropping sequence. Application of compost-C resulted in significantly higher yield compared to that of compost-A or compost-B. The grain yield of mungbean due to organo-mineral fertilizers was 65.2 to 98.2% of that obtained with the recommended dose of NPK. These values for N, P and K uptake were 62.5 to 100, 31.6 to 147 and 101 to 217%, respectively.

Organo-mineral fertilizers applied to the first crop resulted in higher tuber yield of potato grown on residual fertility over control. The yield of potato tuber was of the order of 103 to 264% of that harvested with the recommended dose of NPK. Significant build-up of organic C, available N, P and K was also observed at the end of the second potato crop. Among the enriched organo-mineral fertilizers, the build-up of organic C, available N, P and K were in the order of Compost-C > Compost-B > Compost-A. The results clearly showed that use of enriched organo-mineral fertilizers prepared out of low-grade rock phosphate, waste mica and rice straw is an effective and viable technology.

3.5.3 Development of Basic Data and Soil-test-based Fertilizer Recommendations for Wheat

From a soil test crop response correlation field

Basic data and soil test based fertilizer adjustment equations for wheat cultivar WR 544

Nutrient	NR	%CS	%CF	%CFYM	Fertilizer adjustment equations
Without FYM					
N	25.5	24.1	46.2	-	FN = 55.2 T – 0.52 SN
P_2O_5	8.1	55.8	27.2	-	FP_2O_5 = 29.8 T – 4.70 SP
K_2O	30.5	30.6	110.4	-	F K_2O = 27.6 T – 0.33 SK
With FYM					
N	25.5	24.1	58.4	15.7	FN = 43.7 T – 0.41 SN – 1.34 FYM
K_2O	30.5	30.6	132.5	26.4	F K_2O = 23.0 T – 0.28 SK – 0.84 FYM
P_2O_5	8.1	55.8	34.0	9.2	FP_2O_5 = 23.8 T – 3.76 SP – 1.85 FYM

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

experiment on wheat (WR 544), basic data were generated on nutrient requirement of crop and per cent utilization efficiency of soil, fertilizers and manure nutrients. Also the soil test based fertilizer recommendations for targeted levels of wheat yield production were developed.

3.5.4 Effect of Soil-test Based Fertilizer Recommendations on Wheat Yield and Soil Fertility

A field trial was conducted on wheat under pearlmillet-wheat sequence. The grain yield obtained was 5.37 t/ha with a fertilizer dose of 95-20-39 kg/ha of N-P_2O_5-K_2O with 10 t FYM/ha compared to 4.98 t/ha with a dose of 136-45-53 kg/ha without FYM. The grain yield was 3.52 t/ha only in treatment of 20 t FYM/ha alone. In the case of the FYM alone, comparable increase in soil fertility parameters was observed as in the case of fertilizer + FYM treatment, though the yield obtained was quite low. Thus, from the point of view of improved soil fertility and crop productivity the integrated fertilizer use (FYM + Fertilizer) seems to be a better option compared to the application of either chemical or organic nutrient sources alone.

3.5.5 Influence of Long-term Application of Fertilization and Manure on Crop Productivity and Soil Quality 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.

3.5.5.1 Yield responses of maize and wheat

In both, maize and wheat crops, the application of NPK solely as fertilizer at super-optimal (150% of recommended) rate out-yielded optimal NPK, indicating thereby a need for upward revision of optimal fertilization rates that have become inadequate to sustain a high productivity under intensive cropping. The use of 15 t/ha FYM during monsoon season along with 100% NPK, nonetheless, gave yields similar to super-optimal NPK. A comparison of the average yields (1993-94 to 2004-05) with the current yields revealed an increasing significance of balanced nutrition, especially with respect to P and S in wheat. The current response to P in wheat (as indicated by yield differences in N and NP treatments) was 0.75 t/ha as against the averaged response of 0.22 t/ha. Similarly the response to S in wheat (2004-05) was 0.28 t/ha as compared to an average response of 0.09 t/ha. The application of N alone was detrimental, as the yields of maize and wheat were smaller by 0.40 and 1.06 t/ha, respectively, compared to the yields obtained with optimal NPK rate.

Grain yield (t/ha) of maize and wheat under different treatments

No.	Treatment details	Mean grain yield (t/ha) (1993-94 to 2004-05)		Current grain yield (t/ha)	
		Maize	Wheat	Maize	Wheat
T_1	50 % NPK	1.73	4.02	1.46	3.80
T_2	100 % NPK	2.09	4.46	1.83	4.31
T_3	150 % NPK	2.40	4.82	2.05	4.64
T_4	100% NPK+ hand weeding	2.07	4.46	1.69	4.38
T_5	100 % NPK+ Zn	2.19	4.55	1.66	4.44
T_6	100 % NP	1.81	4.13	1.51	4.00
T_7	100 % N	1.65	3.91	1.43	3.25
T_8	100 % NPK+ FYM	2.47	4.92	2.05	4.79
T_9	100 % NPK+ S	2.19	4.55	1.85	4.59
T_{10}	Unfertilized (Control)	1.16	2.42	1.02	2.48
	CD 5%	-	-	0.25	0.49

100% NPK for maize or wheat means 120-26-33 kg N-P-K/ha. FYM @ 15 t/ha was applied to maize, and zinc sulphate @ 10 kg/ha was applied to wheat only

3.5.5.2 Changes in soil fertility status

An analysis of surface (0-15 cm) soil samples after completion of 34 crop cycles revealed a significant build-up in organic C status under NPK+FYM, while it was maintained almost at the initial level of 0.44% under super-optimal NPK, NPK+Zn or NPK+S treatments. A sharp decline in organic C, compared with the initial content, was noticed in unfertilized-control as well as treatments receiving unbalanced NPK application. A general build-up in available K was noticed under NPK applied at the recommended/super-optimal rates, or in combination with S, Zn or FYM. Among the micronutrients, DTPA-Fe content declined sharply, whereas DTPA-Mn content remained nearby unchanged over the initial content. Regular application of $ZnSO_4$ or FYM increased the DTPA-Zn status of the soil; otherwise the values declined in all treatments.

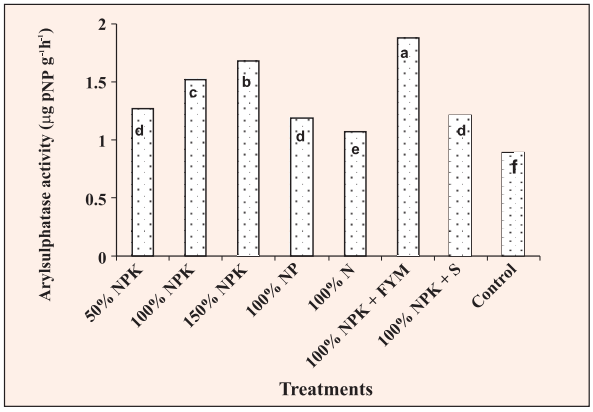
Changes in soil fertility status under different treatments after 34 cropping cycles

Treat-ment No.	Treatment details#	Organic C (%)	Available K (kg/ha)	DTPA micronutrients (mg/kg)			
				Zn	Fe	Cu	Mn
T_1	50 % NPK	0.34	196	0.76	6.04	1.66	12.67
T_2	100 % NPK	0.39	248	0.92	6.53	1.84	10.57
T_3	150 % NPK	0.42	253	0.80	6.68	1.88	8.91
T_4	100% NPK+hand weeding	0.38	236	0.86	8.41	1.64	9.99
T_5	100 % NPK+ Zn	0.41	240	1.55	7.32	1.80	10.66
T_6	100 % NP	0.34	175	0.78	6.28	1.59	10.13
T_7	100 % N	0.33	198	0.86	7.28	1.68	9.14
T_8	100 % NPK+ FYM	0.50	245	1.20	6.83	1.57	11.11
T_9	100 % NPK+ S	0.41	226	1.05	5.82	1.65	11.45
T_{10}	Unfertilized (Control)	0.28	197	0.98	5.30	1.45	8.42
	CD 5%	0.04	22.7	0.11	0.78	NS	1.46
	Initial content	*0.44*	*155*	*1.1*	*10.6*	*1.4*	*20.0*

100% NPK for maize or wheat means 120-26-33 kg N-P-K/ha. FYM @ 15 t/ha was applied to maize, and Zn @ 5 kg/ha was applied to wheat only

3.5.5.3 Soil biodiversity, carbon sequestration and nitrogen cycling

Soil samples drawn during winter 2004-05 season at different growth stages of wheat crop showed the highest values of dehydrogenase, acid and alkaline phosphatase activity in the case of NPK+FYM; control plots showed invariably low activity. The activity of enzymes was generally the highest at tillering (48 days after sowing - DAS) followed by flowering (85 DAS) and dough (105 DAS) stages. There was a greater increase in arylsulphatase activity due to optimal (100% NPK) and super-optimal (150% NPK) doses over sub-optimal dose of NPK (50% NPK). There was a spectacular increase in arylsulphatase activity due to conjoint application of FYM with 100% NPK.



Effect of long-term manuring and fertilization on arylsulphatase activity in soils. Bars with different lower case letters are significantly different according to Duncan's multiple Range Test at P=0.05

A significant gradual reduction in the ammonium, nitrate and mineralizable N status during crop growth was noticed. The share of MBN (microbial biomass N) in mineralizable N was higher and MBC (microbial biomass C)/MBN ratio was low at dough stage. The contribution of mineralizable N to total N in the soil samples varied from 12 to 17%, and the contribution of microbial biomass N to mineralizable N was in the range of 65 to 77% at different stages. Mineralizable N was highly correlated (r = 0.57**, n = 54) with the MBN, and the ratio of MBN.

Among the major microbial groups (i.e., bacteria, fungi and actinomycetes) in the soil samples (*kharif* 2005), actinomycetes were dominant, ranging from 3.94 x 10^8 in control plots to 6.66 x 10^8 cells g^{-1} soil in 150% NPK-treated soil. Bacterial population varied from 1.70 x10^7 in control to 2.76 x10^7 cells g^{-1} in 100% NPK + FYM. Fungal population was much lower than the population of bacteria or actinomycetes, the lowest being in control (1.03 x 10^5) and the highest being in 150% NPK (3.11 x 10^5). Fungal population was found to be comparable between the 100% N and 100% NPK, and so also between 100% NPK and 100% NPK + S. Though control plots showed the lowest density of these organisms, unlike enzyme activity, no clear pattern on the relationship among the enzyme activity, population level of these culturable organisms and fertilizer treatments were obtained.

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

3.5.6.1 Integrated nutrient supply and management in pearlmillet-mustard sequence

A field experiment was conducted for developing an integrated nutrient supply system for pearlmillet-mustard cropping sequence making use of either FYM @ 10 and 20 t/ha or sulphitation pressmud (SPM) @ 5 and 10 t/ha. Among the NPK fertilizer treatments applied with FYM or SPM, the sources of P were DAP, SSP and rock phosphate-enriched biogas slurry (RPEBGS). The results indicated that the application of FYM or SPM (10 t/ha each) along with N, P_2O_5 and K_2O supply through fertilizer (100:50:50) had 0.33 to 0.39 t/ha higher grain yield, significantly higher P and K uptake and P use efficiency in pearlmillet over the corresponding N, P_2O_5 and K_2O alone application. Among the P sources, RPEBGS was as efficient as inorganic sources, viz., DAP and SSP with respect to grain yield, K uptake and

P use efficiency in pearlmillet. The application of recommended levels of N, P_2O_5 and K_2O supply (100:50:50) along with FYM (20 t/ha) was as good as the application of the highest level of N, P_2O_5 and K_2O alone (150:75:75) in pearlmillet.

3.5.6.2 Integrated nutrient management in pigeonpea-wheat cropping system

A field experiment was established during 2004-05 with 15 treatments. Treatments included soil-test based supply of nutrients through fertilizers alone or in combination with farmyard manure (FYM) or sulphitation pressmud (SPM). The application of fertilizer NPK along with SPM or FYM produced significantly higher yield of pigeonpea and wheat as compared to fertilizer alone treatments. Induced defoliation (ID) in extra-short duration pigeonpea through foliar spray of 10% urea solution at physiological maturity increased the litter fall by about 1.0 t/ha, and thus helped additional recycling of 27-30 kg N/ha besides other macro and micronutrients. Induced defoliation in pigeonpea also increased the yield of subsequent wheat crop, as the highest yield was recorded in NPK+SPM+ID treatment. The advantage of ID on soil organic C or available nutrient content was, however, not significant during the initial year.

3.5.7 Integrated Sulphur Management for *Kharif* Mungbean

A field experiment was conducted during *kharif* 2005 on mungbean to study the effect of different sources of sulphur application along with the recommended dose of NPK and with or without FYM. Gypsum emerged as the superior source of sulphur for mungbean over elemental sulphur and pyrite at a similar application rate of 30 kg S/ha. Integrated use of gypsum, FYM and optimum NPK maximized the productivity of mungbean as well as S uptake by the crop. The use of gypsum and the recommended dose of NPK with FYM and also without FYM significantly increased the available soil sulphur content over control and the recommended dose of NPK alone. The use of gypsum as sulphur source along with the recommended dose of NPK + FYM was found to be the most suitable treatment for sustainable higher production of mungbean under Delhi conditions in *kharif* season.

3.5.8 Integrated Nutrient Management in Wheat under Different Planting Systems

An experiment was planned to find out appropriate planting system and optimum nutrient management practice in wheat. The FIRBS was found superior to conventional planting system with respect to grain and straw yields. Application of 75% NPK + 5 t FYM/ha, 75% NPK + 5 t FYM/ha + 25 kg $ZnSO_4$/ha or 100% NPK + 5 t FYM/ha produced equal grain yields. However, application of 75 % NPK + 5 t FYM/ha + biofertilizer or 75 % NPK + 5 t FYM/ha + 25 kg Zn SO_4/ha + biofertilizer produced significantly higher yields than that of 100% NPK. No significant differences were observed in yield between 75 % NPK and 100 % NPK when they were applied with 5 t FYM/ha, 5 t FYM/ha + biofertilizer, 5 t FYM/ha + 25 kg Zn SO_4/ha or 5 t FYM/ha + 25 kg Zn SO_4/ha + biofertilizer.

Effect of integrated nutrients management and planting systems on yield of wheat

Treatment	Grain yield (t/ha)	Straw yield (t/ha)
Planting systems		
Conventional	4.24	6.12
FIRBS	4.52	6.46
SEm±	0.10	0.11
CD (P=0.05)	0.23	0.33
Nutrient management		
Control	2.60	4.34
100% Recommended dose (120:60:60)	4.00	5.73
75% RDF + 5 t FYM/ha	4.31	6.27
75% RDF + 5 t FYM/ha +25 kg $ZnSO_4$/ha	4.45	6.45
75% RDF + 5 t FYM/ha + biofertilizer	4.70	6.58
75% RDF + 5 t FYM/ha +25 kg $ZnSO_4$/ha + biofertilizer	4.84	6.66
100% RDF + 5 t FYM/ha	4.48	6.30
100% RDF + 5 t FYM/ha +25 kg $ZnSO_4$/ha	4.66	6.59
100% RDF + 5 t FYM/ha + biofertilizer	4.83	6.88
100% RDF + 5 t FYM/ha +25 kg Zn SO_4/ha + biofertilizer	4.93	7.10
S.Em±	0.18	0.30
CD (P=0.05)	0.51	0.84

3.5.9 Integrated Nutrient Management in Fruit Crops

3.5.9.1 Mango

The highest yield per plant (22.10 kg) was observed in Amrapali under high density with 400g N/plant treatment (370 g applied as basal and 30 g applied as foliar spray) which also showed better quality of fruits (20.5% TSS) in comparison to the quality of fruits of plants treated with higher doses (applied in soil along with phosphorus and potash).

To estimate the effect of organic manures alone and in combination with different bio-fertilizers, an experiment was carried out in Amrapali mango using FYM, vermicomposts, *Azotobacter*, *Azospirillum*, AM fungi (mixed strain) and phosphate solubilising bacteria (PSB strain of IARI). Maximum number of fruits(190.03), fruit weight (173.6g/

fruit), TSS(20.7%), ß- carotene (15850 µg/100 g fruit pulp) and ascorbic acid (35.8 mg/100 g pulp) content were recorded from treatment T8 [FYM (50 kg), vermicompost (16.5 kg), *Azotobacter* (10 g) and PSB (10 g) per plant. Among nutrients, P, Cu and Zn were affected significantly as far as the uptake was concerned. Correlation was calculated with yield to different parameters and found highly significant with photosynthetic rate, proline, P and Zn content.

Fruits of mango variety Amrapali produced under INM

3.5.9.2 Citrus

In Mosambi sweet orange, out of the various INM treatments, the treatment comprising ¾th N (300 g) + ¾th P (250 g) + mixed strain of VAM (5 g) + *Azospirillum* (5 g) along with spray of 0.4% micronutrients (Cu + Fe + B + Zn) was found superior in respect of number of fruits (162 per plant), higher juice content (59.5%) and TSS: acid ratio (12.2).

Kinnow fruits produced under INM

In Kinnow, the treatment comprising of *Azotobacter* (10 g/plant) + PSB (10 g/plant) and micro-nutrients (combined spray of Fe, Cu, Mn and Zn at 0.4% each) was found superior for growth, yield (120 fruits /tree) and physico-chemical qualities as compared to those in control (72.0 fruits/tree) and other treatments.

FYM, vermi-compost, Municipal Solid Waste (MSW) compost and composted biosolids were applied in pre-bearing and bearing lemon cv. Kagzi Kalan plants. Maximum increase in plant height (16.5%), girth (11.6%) and plant spread (13.6%) were recorded with MSW compost. MSW treated plants also gave higher fruit yield (6.9 kg/tree) compared to that in control (4.2 kg/ tree).

The integrated nutrient management system in Kinnow mandarin and Mosambi sweet orange reduced the application of inorganic fertilizers considerably (30-40 %) and also improved the fruit size, yield and quality substantially.

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”, over 1500 soil samples were collected during the year. Soil samples representing 10 districts and 9 agro-ecological sub-regions (AESRs) were analysed, and were grouped into fertilizer responsive (low and medium fertility) and non-responsive (high fertility) categories.

The deficiencies of N and K were universal. More than 80% soil samples from Banaskantha, Mehsana, Aurangabad, Ganjam and Baleswar containing =0.75% organic C were placed in N-responsive category. The organic C content was relatively high in soils of hilly and *Tarai* regions of Kangra, Jammu and Udham Singh Nagar. The magnitude of response to K varied from 28% in Nasik to as high as 100% in Udham Singh Nagar. In the soils of Banaskantha, Mehsana, Jammu, Kangra and Ganjam, more than 70% of the samples fell in K-responsive category. Soils’ responsiveness to P was recorded in all the districts, except Udham Singh Nagar, and the magnitude varied from 12% in Chhindwara to 84% in Aurangabad. Widespread deficiencies of S were observed in the soils of Chhindwara and Mehsana with 66 and 34% samples, respectively falling in S-responsive category. The S inadequacy problem was not of much significance in the remaining districts. Among the micronutrients, Zn deficiency occurred in more than half of the samples from Aurangabad and Jammu districts, whereas Fe deficiencies were spectacular in Nasik and Banaskantha.

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

AESR No.	District	No. of samples	Samples in fertilizer-responsive category for							
			OC (N)	P	K	S	Zn	Cu	Fe	Mn
2.3	Banaskantha	100	97	29	74	11	1	33	8	-
4.2	Mehsana	100	99	50	90	34	-	9	-	-
6.2	Nasik	54	25	21	15	6	22	33	-	-
6.2	Aurangabad	25	20	21	-	1	16	6	-	-
10.4	Chhindwara	100	37	12	56	66	27	-	-	-
14.2	Jammu	100	35	70	97	2	53	1	-	-
14.3	Kangra	106	37	58	90	5	31	-	-	1
9.1	U.S. Nagar	51	3	-	51	4	-	-	-	-
18.4	Ganjam	50	50	20	43	9	-	-	-	-
18.5	Balasore	50	42	29	24	6	-	-	-	-

Multi-nutrient inadequacy of varying magnitude was present in all the AESRs, though the nutrient adequacy groups

were different. Whereas N and K inadequacies were frequently observed in Banaskantha, Mehsana and Ganjam, P and K constituted the dominant inadequacy group in Kangra; P, K, and Zn in Jammu; K and S in Chhindwara; N and P in Baleswar, N, P, and Zn in Aurangabad, and P and Fe in Nasik. Across the districts and AESRs, N and K appeared the most widespread multi-nutrient inadequacy combination, followed by N, P, and K; N and P; P and K; and P, K, and Zn.

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

An experiment conducted in 2004 *kharif* season with the rice variety Pusa Sugandh 3 under transplanted un-puddled raised bed condition by the use of ^{15}N gave a yield of 6.38 t/ha compared to 5.72 t/ha under transplanted puddled flat bed continuously flooded conditions. Also, the fertilizer N-use efficiency of fertilizer urea showed an increase of nearly 8.3% under raised bed condition from 37.4% of flat bed condition. The direct dry seeding under raised bed or conventional flat bed conditions gave significantly lower yields. The added advantage of raised bed planting was less use of irrigation water to the tune of nearly 22.3%. The following wheat crop in *rabi* 2004-05 raised under minimum/ zero tillage after rice showed a yield increase of 11% under raised bed conditions compared to that under conventional flat bed well pulverized soil conditions. In the following rice crop (*kharif* 2005) also there was 8.4% more rice grain yield under raised bed conditions. There was higher build-up of ammonia in flood water under conventional flat bed conditions as compared to that under raised bed planting after the second split of fertilizer N application and also the flood water pH reached a value of greater than 10. Under raised bed conditions, an increase in nitrate concentration in flood water was recorded. The below ground biomass residues under wheat were found to be ~ 3.7 to 4.1 Mg/ha and required nearly 31.3 to 34.7 kg N/ha.

3.6.3 Studies on the Availability and Mobility of Iron and Zinc in Soils for Crop Nutrition and Bioavailability/Biofortification in Food Products for Human Nutrition

Studies on reversion of applied zinc into unavailable forms showed that only 20% of the added zinc remained in available form after 15 days of application and after six months, less than 4% remained in available forms. At higher levels of application, i.e., 25, 50 and 75 mg kg^{-1} rate, no visual effect on two wheat varieties was observed. In 117 wheat genotypes tested, zinc was in normal range except in two in which it was higher – more than 50 ppm. In most of the genotypes, Fe, Cu and Mn was in the normal range. The two high Zn containing genotypes have been identified for further testing for consistency in the next generation so that they can be used for biofortification.

3.6.4 Effect of Potassium Fertilizer Application on Transfer Factor (TF) of ^{137}Cs in Rice

TF values of ^{137}Cs were higher in rice straw compared to those in rice grain, and the values decreased significantly with the increase in the level of potassium fertilizer application.

3.7 AGRICULTURAL ENGINEERING

3.7.1 Development of Onion Detopper

Onion detopping is done manually with a sickle or *khurpa*. The process is low in output and is full of drudgery. A mechanical onion detopper was developed for enhanced capacity and low drudgery. It consists of a hopper, belt conveyor, oscillating conveyor, cutting unit, power transmission and a frame. The onion bulbs with leaves are fed through the hopper to a moving belt conveyor and then to an oscillating conveyor. During this movement, the leaves are oriented downwards where a rotating cutter is provided to remove the leaves. There is provision to adjust the height of cut. Since the onion bulbs do not come in contact with the cutter, no damage is done to the bulbs. A 2-HP motor can provide the required power. The estimated capacity of the machine is 0.3 t/h with 90% detopping efficiency.

An onion detopper

3.7.2 Design and Development of Single Row Maize Planter

A lightweight, low horsepower engine operated maize planter was designed and developed for planting of maize crop. The machine was powered with 1.5 hp petrol engine. The common chasis was designed for reduced rolling resistance and adequate traction ability. The engine power was transmitted to ground wheel with a periphery of 120 cm through a specially designed reduction gear- box and chain and sprocket system. A detachable seed-cum-fertilizer box was provided for the use of the machine as seed-cum-fertilizer drill. The seed metering was through a nylon roller with seed carrying cells. The number of cells on the roller determined

the seed rate. It is a walk behind type of machine with an average ground speed of 2.5 km/h. The machine is able to maintain a row-to-row distance of 20 cm and a plant-to-plant distance of 55 cm. The field capacity of the machine was 0.15 acre/h when tested in small fields of experimental farms. The average fuel consumption was observed to be 350 ml/h.

A single row maize planter

3.7.3 Development of Rotating Screen Grader

A rotating screen grader suitable for fruits like lemon, *ber and aonla* was developed to grade the samples in 4 homogenous grades. The grader was tested for capacity and optimum grading performance as a function of rotating speed of screen, diameter of screen, exposure length and input, each at four levels, by using second order response surface design in 80 design points. Maximum capacity of the grader was found to be 465 kg/h. The maximum grading efficiency for lemon, *aonla* and *ber* was 79, 93.8 and 97.96%, respectively.

3.7.4 Development of Jigs and Fixtures for Wheel Hoe

In mass production of machines, the developemnt of jigs and fixtures add to the quality of product, reduces the cost of fabrication, assures the production of interchangeable parts, reduces the production time and improves the overall reliability of the products. Accordingly, fixtures were developed for various components, namely, handle bending, shank bending, welding fixtures for spoke and frame bars and cross bars of a manually operated wheel hoe.

3.7.5 Development of Rice Mill

A small capacity rice mill consisting of a rubber roll sheller, a blower for husk separation, and a polisher was developed. The overall size of the mill is 105x92x150 cm. The rubber roll sheller is of 200 kg/h capacity and consists of two rubber rolls (21.5 cm dia. x 15 cm length) rotating in opposite directions and at differential speeds. The machine has the provision to adjust the clearance between the rollers. The machine runs with an 5-hp, 3-phase electric motor. The polisher is of huller type consisting of metallic rolls.

3.7.6 Development of *Atta Chakki*

A traditional *atta chakki* was modified by providing a gap adjusting mechanism. The gap adjustment is necessary to get the desired particle size of the product. The *chakki* is manually operated and consists of two stones, one fixed and another rotating through a wooden handle. A provision has been made for collection of *atta* in this. The whole *chakki* is portable.

3.7.7 Farm Machinery Use Pattern in the State of Haryana

A study on farm machinery use pattern was conducted in Karnal and Gurgaon districts of Haryana. Data were collected from randomly selected farmers on annual use, agricultural and non-agricultural use, crop- wise use and repair and maintenance cost of tractor- machinery system and combine harvesters. Karnal area has mainly rice–wheat-cropping system with a large portion of arable land under irrigation whereas Gurgaon is basically a dry land area with mustard-pearlmillet as the main cropping system. The present mechanization scenario in Haryana is a paradigm shift from so called traditional mechanization in Indian agriculture. The availability of tractor machinery system and combine harvesters on custom hiring would lead the Indian agriculture to optimum level of mechanization overriding the barrier of land holdings.

The following conclusions can be drawn from this study:

(i) Majority of farmers of this area owned their own tractors. All the tractor owners also possessed cultivators and harrows. A total of 40% tractor owners had seed drill.

(ii) The annual use of tractor machinery system varied between 400 and 1200 hours.

(iii) The availability of combines was the main attraction of mechanization in this region. In a single village, Shyamgarh there were 135 combines. However, this was not the general situation.

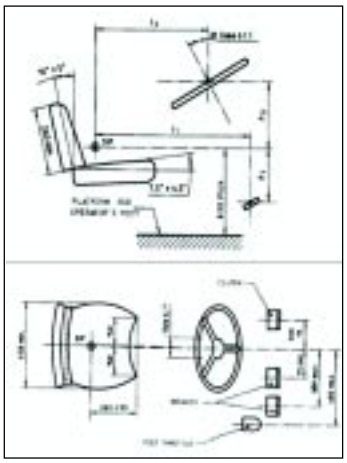
(iv) Average earning by the individual combine owners, from custom hiring of combine, was to the tune of Rs. 3 lakh per year. In one crop season, a combine team covered four states.

3.7.8 Comparison of Control Layout for Indian Tractors

The present study was aimed to carry out comparative evaluation of different tractor models with respect to workspace envelop and ISO standard for displays and controls. Anthropometric dimensions of body parts for Indian population were generated from measured and available data from literature and these were used for the development of workspace envelopes. A control layout-measuring device was used for carrying out comparative evaluation of different

tractor models, displays and controls. The tractors selected for the experimentation were commonly used tractors both in terms of horsepower as well as models.

The location of controls was compared with the workspace envelopes and standards (ISO 4253, 1993 and IS 12343, 1998). The standard defines the dimension of control with respect to seat index point (SIP) for the tractors with track width greater than 1150 mm. It is mentioned that SIP is 140 mm ahead and 90 mm above the seat reference point (SRP). The location for steering wheel, foot clutch, foot brake and foot accelerator are specified. It specifies that steering wheel must lie 425 to 525 mm forward and 175 to 385 mm above SIP. The angle of steering column should be in the range of 0-40^0.



Location of controls (IS 12343, 1998)

Results of the study are as follows: The location of controls on Indian tractors falls in optimum, maximum and outside the workspace envelope. The controls like PTO, depth control lever, horn, light switch, engine lever, high and low lever needs adjustment in vertical plane to make them located in workspace envelopes. However, the controls like steering foot clutch, foot brake, and foot accelerator are located in areas defined by IS12343 standard in some tractors whereas these are not placed in workspace envelopes resulting in mismatch between workspace envelope of Indian population and location of controls as defined by standard.

The controls need a complete change in their layout to be in the workspace envelopes, as this cannot be achieved by providing seat movement in horizontal and vertical direction in the present tractor design. However, the seat should have provision for horizontal and vertical movement to accommodate the maximum population for comfortable operation of tractor controls once they are located within the workspace envelopes.

3.7.9 Densification Characteristics of Some Crop Residues

Densification characteristics of straws of maize, gram, *arhar* and sorghum were evaluated at different compaction pressures and straw moisture contents. Bulk densities of loose straws at different moisture contents were also determined. Bulk densities 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.

3.7.10 Use of Renewable Sources of Energy in Agriculture

Mathematical modeling of a cabinet dryer was done to predict the temperatures of the cabinet dryer and crop. The model has been validated experimentally for a typical day in the month of December. The inputs for the program are climatic parameters such as ambient temperature, solar intensity (both averaged over one hour period) and design parameters of cabinet dryer, viz., area of dryer, volume of dryer and absorptivity, transmissivity, etc. The output of the program provides the hourly average temperatures of the crop and cabinet dryer. The crop and cabinet dryer temperatures have been predicted on hourly basis. As evident from the graph, there is a fair agreement between the experimental and predicted values of the greenhouse air temperature. The correlation coefficient between the experimental and predicted dryer was 0.99.

3.7.11 Drying Studies on Cauliflower

Drying studies on cauliflower was done in solar cabinet dryer and open sun drying. The moisture content of cauliflower in solar cabinet dryer (SCD) was reduced from 92% to 11% in 22 h while in open sun drying (OSD) it took about 32 h to reduce to 13%. 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 in OSD.

3.7.12 Development of Micro-controller for Precision Farming

An attempt was made to develop a controller along with sensors for measuring temperature, humidity and light intensity to control environment parameters. Sensors were specially designed using silicon diodes connected across a bridge measuring mho changes as per change in resistance of silicon diode per unit change in temperature.

The controller has the capacity of recording these parameters at any defined scan rate and controlling the various devices, e.g., fan, cooling pad pump, and humidifiers, etc., as per the defined daily set points. The controller is being designed to have the intelligence to readjust the daily set points of these parameters based on data recorded on the previous day. A self-activating software for the system was

developed integrating the decision making truth tables and the control parameters with their set limits. The controller is based on Intel 386 board with AD/DA 16 channel I/O. Each channel has an accuracy of 0.015% of reading ±1 BIT. As a safety measure, all output channels were connected to the triggering devices through OPTO couplers. The micro controller was installed in an experimental 500 m^2 greenhouse.

3.7.13 Mathematical Modeling of a Greenhouse

Mathematical modeling of a greenhouse was done to evaluate the performance of greenhouse for different climatic regions and for evaluation of greenhouse structure. Energy balance equations for different components of greenhouse such as crop surface, ground and greenhouse air were developed. The Liu and Jordan formula was used for determination of solar intensity on each wall and roof of the greenhouse. The model will be now validated using an existing greenhouse design and then environmental data of various agro climatic regions will be used to design appropriate greenhouses from these regions. Data from Leh and Orissa were acquired, and data for Delhi condition are being recorded.

3.7.14 Drying of Bio-materials

Aonla with various pretreatments, viz., blanching for 1,2,3,4, and 5min, and unblanched *aonla* were dried in a greenhouse type solar dryer and also under ambient conditions. Blanching, for all times, was found to improve the drying rate and product quality in terms of microbial load reduction and vitamin C content. Also, the rate of drying was faster and the quality better in the greenhouse type solar dryer.

3.7.15 Farm Operation Services

3.7.15.1 Field operation

The Farm Operation Service Unit (FOSU) is catering to the experimental needs of all the divisions who are conducting the experiments at the research farm of IARI. In order to achieve this objective, the use of a number of precision machinery such as laser leveler was encouraged to get uniform germination and stand of crop.

The laser leveler purchased by Water Technology Centre was fully utilized and about 50 acres areas were laser leveled. With this technique, a lot of irrigation water was saved.

After harvesting of wheat and other *rabi* crops, deep ploughing was done so as to recharge the ground water and destroy the hard pan, which occurred due to several years of continuous shallow cultivation. Also it has reduced the loss of soil owing to drainage. In order to enrich the soil fertility, a massive program of green manuring was undertaken during *kharif*. During the year under report a massive programme of cleanliness was undertaken and 80% roads and *nalas* were cleaned by using manual, chemical and power sources.

The Unit has three very old plot combines, which are in working condition. The large areas under field experiments were harvested with this machine before the on-set of monsoon, and without breakdown.

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

3.7.15.2 Irrigation distribution management

The Unit is providing irrigation to all the crops. The existing tube wells are shallower and, their discharge has reduced to 50 per cent; also the water table has gone down. In order to meet the water requirement, 6 tube wells were cleaned with the help of a compressor resulting in increased discharge of these tube wells (10-20 per cent), which is remarkable keeping in view the water scarcity at IARI Farm.

3.8 INDO-ISRAEL PROJECT

3.8.1 Crop Production Technology

3.8.1.1 Vegetable crops

Evaluation of summer squash under plastic low tunnels. Five summer squash varieties were evaluated under plastic low tunnels during winter for off-season production. The cost-benefit ratio of this off-season crop was found to be 1:3.5.

Performance of off-season summer squash grown under plastic low tunnels

Variety	Days to first harvest from transplanting	Av. no. of fruits/plant (kg)	Av. fruit yield(t/ha)	Shape and colour of fruits
Australian Green	60.0	3.6	52.5	Long (green)
Pusa Alankar	61.0	3.4	50.2	Long (green)
Goldy	63.0	2.8	38.6	Long (yellow)
Crystal	65.0	2.2	35.8	Long (yellow)
Chandrika	58.0	2.5	40.5	Round (light green)

Evaluation of sweet pepper grown under insect-proof net house. A sweet pepper crop (var. Indira) was grown under protected environment of insect-proof net house made with 40 mesh nylon screen for a period of 7 months from October to May. The crop was unaffected by the viruses, and green fruit yield of 40 t/ha was harvested with minimum pesticide application. The cost benefit ratio of sweet pepper cultivation under insect-proof net house was found to be 1:1.74.

Effect of plant spacing and stem pruning on plant growth, fruit yield and fruit quality in greenhouse grown sweet pepper. Plant density and canopy structure of greenhouse sweet pepper are important factors influencing productivity and fruit quality. These parameters were optimized by growing sweet pepper (var. Indira) in greenhouse at 3 levels each of plant spacing (S) and stem pruning (P) as follows:

S1= 30 cm, S2 = 45 cm, S3 = 60 cm

P1 = no pruning, P2 = two branches/plant, P3 = four branches/ plant

The highest fruit yield of 52.60 t/ha was obtained when the sweet pepper crop was planted at 30 cm plant to plant spacing and four main branches in each plant were allowed to grow, whereas the highest quality of fruits was obtained when the crop was transplanted at a plant spacing of 60 cm and two main branches were allowed to grow.

Effect of plant spacing (S) and stem pruning (P) on growth, yield and fruit quality of greenhouse grown sweet pepper

Treat-ment	Plant height (cm)	Av. no. of fruits/ plant	Fruit size index	Av.fruit weight (g)	Fruit yield per plant (kg)	Fruit yield (t/ha)	Percentage of A grade fruits
S_1P_1	08.0	31.0	50.94	80.0	2.3	38.2	12.0
S_1P_2	180.0	17.0	66.55	120.0	2.8	46.8	36.0
S_1P_3	160.0	28.0	60.50	95.0	2.9	52.6	20.0
S_2P_1	98.0	36.0	56.40	95.0	2.5	37.5	21.0
S_2P_2	168.0	22.67	71.60	140.0	2.9	40.3	48.0
S_2P_3	148.0	31.00	65.80	118.0	3.1	45.5	30.0
S_3P_1	92.0	46.33	60.90	112.0	2.9	35.2	36.0
S_3P_2	160.0	26.67	78.40	160.0	3.3	38.6	62.0
S_3P_3	142.0	42.67	74.30	140.0	3.6	40.2	45.0
CD at 5%	1.956	2.1555	0.2458	6.947	0.2294	0.9731	-

3.8.1.2 Flower crops

Hormonal response studies in gerbera and chrysanthemum. The effect of different doses (0,100,200,300,400, or 500 ppm) of GA_3 on plant growth and flower quality of gerbera and chrysanthemum was studied under greenhouse conditions. It was observed that 300 ppm GA_3 produced better plant growth, quality blooms and maximum flowers in both the crops.

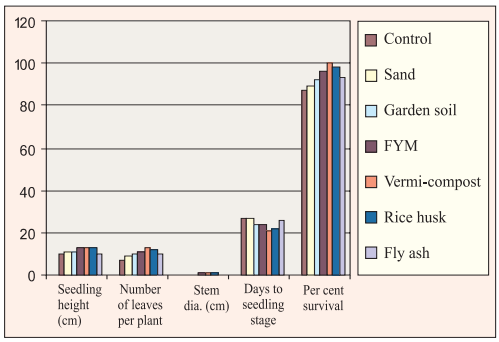
Response of GA_3 on plant growth and flowering in gerbera (var. Cabana)

GA_3 concen-tration (ppm)	Plant height (cm)	Stem length (cm)	Stem dia. (cm)	Flower dia. (cm)	Vase life (days)
0 (Control)	62.5	57.2	0.48	9.8	11
100	75.9	68.3	0.55	10.2	15
200	78.2	70.4	0.64	11.2	17
300	83.9	73.8	0.68	11.6	21
400	78.5	70.3	0.53	10.2	18
500	72.1	65.4	0.51	10.1	15

Response of GA_3 on plant growth and flowering in chrysanthemum (var. Snowdon White)

GA_3 concen-tration (ppm)	Plant height (cm)	Stalk length (cm)	Stem dia. (cm)	Flower dia. (cm)	Vase life (days)
0 (Control)	48.2	46.3	0.65	6.8	7
100	58.3	56.1	0.70	8.2	9
200	59.7	57.5	0.72	8.7	9
300	61.5	58.2	0.80	9.2	11
400	57.3	53.7	0.77	7.4	10
500	55.4	50.2	0.70	7.3	8

Studies on substrate composition for growing seedlings of different flowers in greenhouse nursery. Different substrates were studied for raising self rooted cutting of carnation, chrysanthemum and dahlia in plastic pro-trays under greenhouse nursery. It was found that vermi-compost amended media (coco-peat, perlite and vermiculite in 3:1:1 ratio) produced the best self-rooted transplants in shorter time followed by rice husk.



Response of substrate amended media on chrysanthemum seedlings in greenhouse nursery

3.8.2 Machinery Development

3.8.2.1 Development of deep tillage plough

Consistent use of fertilizer through drip irrigation for vegetable crops has been found to cause accumulation of salts and consolidation of soil within the root zone during a crop cycle. Deep ploughing after each crop cycle is recommended to break the consolidation of layers to allow leaching of salts. A deep tillage plough with two tynes was designed and fabricated. Depending on the size of tractor, the number of tynes may be altered. Field evaluation of the deep tillage plough showed enhanced efficiency of leaching and reduced density of soil in the root zone.

A deep tillage plough in operation

3.9 ENVIRONMENTAL SCIENCES

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

Temperature sensitivity of soil carbon decomposition is a key factor in determining the response of the carbon balance to climatic change. The effect of temperature on soil carbon mineralization was examined studied by laboratory incubation studies with soils from five different climatic zones of India. Q_{10} declined with increase in temperature in a predictable manner in high carbon (OC > 1.0 %) and low carbon (OC <0.5%) scenarios, while it remained constant in soils with medium carbon (OC, 0.5-1.0 %). Decomposition of the SOC was well described by the first order kinetic two-compartment model and temperature dependent rate constants.

3.9.2 Effect of High Temperature on Pollen Germination

Pollen germination is a temperature sensitive physiological process. Increasing global warming may affect crop yields through its effect on pollen germination. Pollen germination of five different rice varieties, sown at twelve different dates was studied. Pollen germination percentage on the stigma of all the varieties decreased with the increase in maximum day temperature; beyond 32°C, the reduction was higher in *basmati* varieties than in high yielding non-*basmati* varieties.

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

To quantify the effect of tillage and organic matter on the emission of green house gases, a field experiment was conducted with rice and wheat crops. There was a 15% decrease in GWP in the urea and urea +FYM treatment under no tillage conditions in wheat. The CO_2-C emissions decreased by 19% and N_2O-N emissions increased by 13% in no-till urea treatment as compared to those in conventional tillage in wheat. In rice, a 10% increase in GWP was observed in urea + FYM treatment. The emission of N_2O-N increased by 12-24%, CO_2-C emissions decreased by 8-11% but there was no significant impact on emission of CH_4 in non-puddled rice soil.

3.9.4 Impact of High Temperature on Growth and Yield of Rice

To understand the effect of increased short-term climatic extremes during various phenophases, a field experiment was conducted with rice cultivar Pusa 44. High temperature stress during reproductive growth phase caused maximum reduction in biomass and grain yield (23% and 27%) followed by vegetative (26% and 23%) and ripening (8% and 7%) growth phases, respectively. Among the yield components, panicles/m^2 and grains/panicle showed greater sensitivity to high temperature, while 1000-grain weight was least affected. Reduction in grain yield of rice under high temperature during vegetative growth phase was mainly attributed to marked reduction in the number of panicles/m^2 followed by grains/panicle, whereas during reproductive growth phase the loss was due to decline in the number of panicles/m^2 as well as grains/panicle.

3.9.5 Impact of High Temperature on Plant-Pathogen Dynamics

To understand the probable effect of global warming on crop-pathogen interactions, growth and sporulation in *Fusarium oxysporium* sp.*ciceris*, a pathogen causing wilt disease in chickpea, was studied at different temperatures between 20^{0}C and 37^{0}C in laboratory. At 25^{0}C, 28^{0}C, 30^{0}C, 35^{0}C and 37^{0}C, the growth of *Fusarium* (in terms of colony diameter) was 70 mm, 85 mm, 80 mm, 78 mm and 20 mm, respectively. This incidence of *Fusarium* associated wilts will vary with global warming scenarios depending upon the current environmental conditions. If the temperatures were 28 - 30^{0}C, there would be some increase in *Fusarium* incidence. However, in locations where the current temperatures are above 35^{0}C, global warming is likely to reduce the incidence of wilt disease. More experiments are being done to confirm these results.

3.9.6 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, and will eventually enhance the energy security of the country. In continuation of previous field experiments on agri-management of *Jatropha*, intercropping was studied in 3-year-old *Jatropha* plantations with shade loving turmeric crop. It was observed that the yield of intercropped turmeric was 15% lower than that of the sole turmeric. Moreover, the *Jatropha* seed yield was high from saplings developed from seeds directly as compared to saplings developed from twigs.

3.9.7 Adsorption and Desorption Capacity of *Jatropha* Seed Coat for Copper

Major byproducts obtained during the production of biodiesel from *Jatropha* are seed shell, seed coat, seed cake and glycerine. Quantitatively, 1 kg *Jatropha* seeds give 320 g oil, 400 g seed coat and 280 g seed cake. Seed coat of

Jatropha, a waste product left out after the extraction of oil, provides a reasonable adsorption capacity for copper (II) from aqueous solution (82-89%) in 70-80 minutes. Elovich equation provided the best correlation of the experimental kinetic data at an initial solution pH of 4 and 5 and a seed coat particle size of 55 microns. For adsorption isotherm both Freundlich as well as Langmuir isotherm models provide considerably better fits to the experimental data. The most plausible mechanism of adsorption seems to be electrostatic attraction towards the lignocellulosic polar groups. Desorption of Cu (II) from metal loaded seed coat was carried out using different strengths of HCl. The percent recovery of Cu (II) from seed coat was observed to be 60%, 71%, 82%, 94% and 99.4% by 0.025, 0.05, 0.10, 0.20, and 0.25M HCl, respectively. It can be concluded that utilization of *Jatropha* seed coat for removing heavy metals from wastewater will be very useful for pollution control.

3.9.8 Effect of Salinity and Osmotic Stress on Seed Germination of *J. curcas*

To assess the adaptability of *J. curcas* on degraded and saline soils, a pot experiment was conducted for evaluating salt tolerance potential of *J. curcas* at different salinity levels. It was observed that seed germination of *J.curcas* decreases with the increase of salinity level (2.86 to 6.10 dSm^{-1}) and osmotic stress (-.25Mpa to-8 Mpa). No seed germination was observed at EC level 6 dSm^{-1} and – 4 Mpa osmotic stress.

3.9.9 Screening of Maize Varieties for Bioethanol Production

Indian maize has good potential for ethanol production. Maize varieties procured from different parts of the country were analyzed for starch, amylose, reducing sugar, total soluble protein, nitrogen and protein. The starch, amylose and reducing sugar vary from 50 to 75, 11 to 20 and 7 to 15 per cent, respectively. Popcorn varieties (PC 1 and PC 2) also showed good potential for ethanol production.

3.9.10 Impact of Bt Cotton on Microbial Community Structural Pattern in Soil of Sri Ganganagar District

The release of transgenic products from root exudates as well as from left over crop residue in field might alter the microbial community structure and function. In a Sri Ganganagar farmer's field, where different transgenic cotton (Ankur 651,Ankur 2534, MRC6301, MRC6304 and RCH317) varieties were grown, the effect of expression of Cry endotoxin by Bt cotton on soil microbial community structure and function was assessed using phospholipid fatty acid (PLFA) profile pattern and soil enzymes activity. Differences in PLFA profiles due to Bt varieties account for 42% of the total variability in the dataset, and this was reflected in the differences in bacterial and fungal PLFA profiles. This was further corroborated by the preliminary significant difference in the type of organic acids in root exudates of Bt cotton as compared to its near isogenic lines.

Rhizospheric soil samples were analyzed for the activities of soil phosphatase, dehydrogenase and urease enzymes. In general, the activity of all enzymes was significantly lower in transgenic rhizosphere as compared to nontransgenic, which may indirectly affect the rate of organic matter decomposition, phosphorus mineralization and transformation of urea. These studies will be continued next year to confirm the results.

3.9.11 Qualitative and Quantitative Response of Different Food Crops to Heavy Metal Stress

In order to examine the uptake and distribution of different metals in various plant parts of wheat, Triticale and maize crops were exposed to heavy metals, viz., Cu, Zn, Pb and Cd @100 mg/kg soil. The results showed that wheat and Triticale have greater accumulation of Zinc in grain, while maize registered greater level of Cu in grains. However, all the three crops showed low translocation of Cd to grains. From the preliminary data it is indicated that castor can be used for phytoremediation of heavy metals especially copper from metal contaminated soils.

3.9.12 Agro-Industrial Effluent Utilization in Agriculture

The effect of different levels of paper mill effluent from Shreyansh Paper Mill, Ahmedgarh, Punjab applied along with irrigation water and recommended dose of NPK on rice (var. Pant 4) and spinach (*Spinacea oleracea L.*) crops were tested. The rice yield was maximum (5.58 t/ha) at 75% level of effluent application. The ground water quality in deep tubewells (30-45 m) and piezometers (4-5 m) was monitored in distillery effluent irrigated farmer's field (mainly sugarcane). The monthly changes in EC do not exhibit any typical pattern to suggest relation with effluent application during the first two years.

3.9.13 A Spatial Resource Characterizing System (ResourCeS) for National Capital Region

A query based regional resource characterizing system

(ResourCeS) was developed. The developed user-friendly tool can provide spatially distributed digital information (as maps in real world co-ordinates) on any region's land use, cropping pattern, location of polluting industrial units, authorized full supply discharge, quality and water rotational plan of different feeder systems/distributaries; under ground water depth and its salinity/alkalinity and heavy metal contamination; type, extent and distribution of saline/sodic/waterlogged/heavy metal contaminated soils; and crop-specific actual/potential/target yields, cost of cultivation and minimum support price(s) during any cropping season. A user can view, query and process this information at any scale, from village to block/district boundary, in a region and formulate optimal local/regional-management plans for priority areas of concern.

3.9.14 Ground Water Helium Survey for Earthquake Studies and Disaster Management

Ground water can respond physically and chemically to tectonics activities. The isotope ratios of helium in groundwater along the alignments of the geological faults have considerable potential to help in defining the sources of these gases. The hydrochemical data and the associated geological and geophysical data were integrated to identify possible relations between ground water circulation and seismically active structural features. Geological and hydrogeological data from the seismogenic areas in parts of the Sabarmati basin and Bhavnagar, Gujarat, and Jaisalmer district, Rajasthan suggested that although, alluvial aquifers and deeper groundwaters had higher helium concentration, in basaltic aquifers this may not necessarily be the case. The data on ^{14}C indicated that ground water is of meteoric origin with subsurface residence times of around 500 to 20,000 years. The results suggest that helium gas anomalies show a clear association with deep fault zones. The ground water anomalies are closely related to the structural peculiarity of each monitoring point. Because of the obvious relationship to tectonics, these gases may even have promise for earthquake forecasting and disaster management, although this has not yet been demonstrated.

3.9.15 Evidences of Climatic Uncertainties Linked Groundwater Variability

The characteristics of ^{13}C discrimination in air-CO_2 and lower C_i/C_a ratio in plant tissues suggest that during warmer months and under water limiting conditions, the water-use-efficiency in plants adapted to low water availability is expected to increase. Modeling of rainfall characteristics suggest that during 1993-1996, normal rainfall and less temperature anomaly kept the water table relatively stable. In 1979 and 1989, 1999 and 2002, because of very low rainfall and high temperature anomaly, the water table declined considerably. It is likely that changes in temperature and precipitation could cause relatively large changes in run-off.

3.9.16 Impact of Different Environments on Grain Yield Components of Rice

In scented and non-scented rice cultivars, the impact of different environments on grain yield and its components was evaluated by transplanting the crop early, normal and late for two years in *kharif* season. The results showed that among the high yielding cultivars, Pusa Sugandh 2 was more adapted to both high and low temperatures during anthesis period than Pusa 44. In the medium yielding group, PRH 10 was better adapted to temperature changes than Pusa Basmati 1. In early sowing, prevailing high temperature increased the percentage of spikelet sterility and contributed to reduced grain yield. In late sown crop, the reduction in yield was due to both reduced number of panicles/m^2 and increased spikelet sterility. The local traditional *basmati* was more sensitive to day length than to temperature and its yield was affected only in the late sown crop due to reduced number of panicles/m^2 under low temperature conditions.

3.10 MICROBIOLOGY

3.10.1 Evaluation of Nutrient Quality of Mature Compost Prepared from Various Substrates using Microbial Consortium

Comparative effectiveness of fungal consortium comprising four mesophilic fungal strains, viz., *Aspergillus awamori* (F18), *Aspergillus nidulans* (ITCC 2011), *Trichoderma viride*, (ITCC 2211) and *Phanerochaete chrysosporium* (NCIM 1073), were evaluated for the decomposition of paddy straw, bagasse trash, mustard, maize and pearlmillet stover. The C/N ratio of all the substrates was adjusted to 50:1 by addition of poultry droppings. Rock phosphate was also added @ 1% to all the substrates as P source. Moisture was adjusted to 60% throughout composting. In each case, an un-inoculated control was also maintained. Evaluation of compost parameters revealed that pearlmillet waste was most effectively degraded resulting in C/N ratio of 12.54 and humus content of 12%. It was followed by paddy straw compost with C/N ratio of 13.41 and humus content of 9%. Mustard stover was most resistant to microbial attack. Although maize stover and bagasse trash compost had the acceptable C/N ratio, they were comparatively poor in humus and showed phytotoxicity.

Chemical analysis of compost prepared from different agro-wastes

Substrates		pH	EC (mS)	OM (%)	C (%)	N (%)	C/N ratio	Humus (%)
Paddy straw	U	7.8	4.55	49.22	28.55	1.16	24.61	7.6
	I	8.0	3.05	33.99	19.72	1.47	13.41	9.0
Mustard stover	U	7.3	4.15	56.84	32.39	0.84	38.56	4.2
	I	7.5	4.00	55.35	32.11	0.98	32.76	6.3
Pearl millet stover	U	7.2	3.50	62.56	36.28	2.02	17.96	12.5
	I	7.6	2.90	51.01	29.59	2.36	12.54	12.6
Maize stover	U	7.2	3.85	37.82	21.94	0.84	26.11	4.6
	I	7.4	3.05	28.92	16.78	1.12	14.98	7.0
Bagasse trash	U	6.7	4.30	63.21	36.67	1.40	26.20	6.1
	I	6.9	4.10	57.27	33.22	1.68	19.77	9.1
P < 0.05		0.4	0.78	8.63	4.17	0.23	-	1.5

I: inoculated; U: uninoculated; OM: organic matter; C: total organic carbon; N: total Kjeldahl's nitrogen

3.10.2 Role of Nitrogen and Zinc Fortification on Quality of Compost

In the Indo-*Gangetic* plains, the deficiency of micronutrients (zinc, iron and manganese) limits rice and wheat yields. Therefore, an attempt was made to convert wheat straw into zinc enriched compost using above-mentioned microbial consortium. Wheat straw has wide C:N ratio (130:1) which was lowered to 50:1 by the addition of poultry droppings, neem cake and grass clippings separately. Rock phosphate was added @ 1% and zinc sulphate @ 0.1%. Moisture content of the substrates was maintained at 60% throughout the decomposition period. To judge the progress of composting, the samples were withdrawn at monthly intervals. On the basis of results, it was observed that the addition of grass clippings hastened the decomposition process resulting in a C:N ratio of 14.5:1 within 60 days. It was also realized that inoculation did not improve the decomposition process where neem cake was added as a nitrogen source.

3.10.3 Development of *Azotobacter* Bio-inoculants for Low Organic Carbon Conditions

Azotobacter, a plant growth promoting bacterium is a poor competitor and thus, is unable to attain a high population in soil. Its population in soil rarely exceeds $1x10^3$ cfu per gram. To provide *Azotobacter* with a competitive edge over other soil micro flora, strains capable of utilizing complex carbon sources like products of lignin biodegradation, which are not, preferred carbon sources were identified. Five strains of *Azotobacter* (JL 17, JL 18, JL 104, JMS 100b, A 41) initially showing potential were selected for detailed studies. Syringaldehyde, gallic acid and benzoic acid were observed to support good growth of *Azotobacter* both in the presence and absence of nitrogen source. However, carboxymethyl cellulose was observed to support good growth only in the presence of nitrogen source.

3.10.4 Influence of C-sources on *Azotobacter* and Development of Liquid Bio-inoculants

Sucrose and glucose as carbon sources were evaluated for improving cyst production in the presence of n-butanol. In 72 h old cultures, butanol (0.2%) was added to the broth to initiate cyst formation. For enumerating the cyst population, broth was first subjected to 50°C heat treatment in a water bath for 30 min to kill the vegetative cells and plated on Jensen's N-free medium and incubated at 30°C. *Azotobacter* population was estimated at periodic interval. Maximum cyst production (32%) was observed with glucose plus butanol as compared to sucrose (21%) plus butanol. However, overall survival of cells in the presence of butanol was affected.

Temperature stress on the cyst production was evaluated. Seventy-two hours old culture was subjected at 30, 40 and 50°C for 30 min followed by viable cyst count. Maximum enhancement (20%) of cyst production was observed at 50°C.

Three concentrations of poly vinyl pyrrolidone (PVP) were evaluated for their effect on long-term survival of *Azotobacter* culture in broth, and the 72 h old culture was subjected to PVP and the population monitored at monthly intervals up to a period of four months. By the third month, there was drastic reduction in *Azotobacter* population in control, whereas PVP acted as protective agent on *Azotobacter* strain W-5, and 1% PVP was observed to be the best treatment for long term survival of *Azotobacter* culture in broth.

PVP as protectant, and for viability (CFU/ml) of *Azotobacter* sp.

PVP conc. (%)	Incubation time (months)				
	0	1	2	3	4
0	422×10^9	227×10^8	83×10^7	13×10^5	3×10^2
1.0	934×10^9	367×10^8	19×10^8	47×10^7	35×10^5
2.0	504×10^9	123×10^9	73×10^9	87×10^5	15×10^5
3.0	749×10^9	300×10^9	5×10^9	25×10^6	53×10^4

3.10.5 Effect of n-Butanol to Initiate Encystment in *Azotobacter* Strain –W5

In an attempt to develop liquid inoculants, various stresses were evaluated to induce cyst production of induction of dormancy in *Azotobacter* strains. In this direction, n-butanol up to 0.4% was added in the growth media. However, n-butanol did not show any positive effect on cyst formation in W-5 strain. Hence, butanol was coupled with sucrose. Initial study indicated that 2% sucrose + 0.10% n-butanol

treatment initiated 98.72% cyst formation and was on a par with 2% sucrose alone. Increasing the concentration of either input did not enhance cyst production.

Combined effect of n-butanol and sugar concentration on cyst formation in *Azotobacter chroococcum* strain W-5

Treatment	*A. chroococcum* cells x 10^6/ml		Cyst (%)
	Cfu	Cyst*	
2 % sucrose (Normal)	51.0	45.5	89.22
2 % sucrose + 0.1 % n-butanol	39.0	38.5	98.72
2 % sucrose + 0.2 % n-butanol	143.5	82.0	57.14
2 % sucrose + 0.3 % n-butanol	14.0	1.5	10.71
2 sucrose + 0.4 n-butanol	133.5	0.5	0.37
3% sucrose only	130.0	42.0	32.31

Note: Initial count 78 x 10^8 cfu/ml; cyst formation was initiated by keeping vegetative cells at 50°C for 30 min.

3.10.6 Development of *Azotobacter* Inoculants for Low Carbon Conditions

Twenty-six strains of *A. chroococcum* were grown at 1.5, 1.0 and 0.5 % sucrose/l of Jensen's medium (normal 2.0%). It was observed that out of 26 strains, only four, JMS-100b, RJ-1, CBD-15 and M-4, had shown better growth at 0.5% than at normal 2% concentration. Four strains selected on the basis of qualitative studies were further grown on 0.5% sucrose concentration and cfu was determined. Results showed that only CBD-15 was superior in terms of growth/ survival (3.65 x 10^9 cfu/ml). However, M-4 strain could not grow. Attempts were further made to reduce the sucrose concentration, hence, all the four strains were grown at 0.25% sucrose. Again the CBD-15 strain was found to be the best (1.65 x10^9 cfu/ml). It indicated that *Azotobacter* CBD-15 would survive in soils of poor carbon content.

3.10.7 Formulation of Liquid Phosphate Solubilizing Bio-inoculants (PSB)

In an attempt to physiologically condition the *Pseudomonas* cells to survive in liquid formulation, organism was cultured under different nutrient regimes, viz., (100% C + 100 % N, 100% C + 50% N, and 100% C + 25% N. Two weeks' old culture suspended in sterile distilled water (0.64 OD ~560 nm) and Poly hydroxy butyrate (PHB) content was measured. Results showed that the maximum PHB content (50.7%) was accumulated at 25% N + 100 % C, whereas at full nutrient level, PHB content was the least. This reflects that manipulation of cultural condition stimulates the cells to alter their metabolism so that cells can overcome stress conditions. PHB is a storage bio-molecule, which imparts capacity to tide over adverse environmental effects under N limiting concentration, which induces PHB synthesis.

Effect of nutritional manipulation on PHB content of *Pseudomonas* sp.

Nutrient level	DW (mg/ml)	PHB content	Dry weight (%)
100% carbon + 50 % N	0.17+0.02	339±0.52	399
100% carbon + 25% N	0.18 + 0.05	4.56 ±0.33	50.7
Complete medium	0.49 + 0.03	5.2 ± 0.08	3.6

Induction of sporulation in the case of *Bacillus* sp was also attempted by manipulation of nutritional (C, N) and physical (temperature) parameters. Temperature exposure varied from 15° to 50°C along with possible effect of culture pH and the bacterial population. Statistically significant differences were recorded at 15°, 28° and 37° C with reference to sugar utilization as compared to control on 7, 14, 21, and 28 days of inoculation. As compared to control, the maximum utilization of sugars by *Bacillus* species was recorded at 28°C and 37°C at 7, 14, and 21 DAI. Least metabolic activity at 50°C represented low sugar utilization that may be due to sporulation at this temperature. This condition is suitable for preparation of liquid formulation where the viable propagules are metabolically dormant. In contrast, at 50°C the least metabolic activity was observed as reflected by minimum sugar utilization up to 21 DAI. However, at 28 DAI, some utilization of sugars was recorded. Maximum utilization of sugars was recorded at 37°C at 28 DAI. A parallel trend was observed in a pH fall of the culture broth. The maximum decline in pH (5.83) was recorded at 37°C.

3.10.8 Influence of AM Fungi and PSB on Yield of Soybean under Rainfed Conditions

Glomus lamellosum (AMF) and *Pseudomonas striata* (PSB) along with *Bradyrhizobium japonicum* were examined for BNF parameters. Nodule number ranged from 6.7 to 26 per plant, nodule dry weights from 49.3 to 82.7 mg and shoot dry weights from 3.74 to 6.01g. Results show that the combination of *Glomus lamellosum* + *P. striata* increased the yield marginally (1639 kg/ha) over that of absolute control (1629 kg/ha). However, maximum yield (1689 kg/ha) was obtained with the treatment *B. japonicum* + SSP @ 60 kg P_2O_5 /ha. Colonization percentage of AM fungus in the plant roots increased to 55% in the treatment *G. lamellosum* + *P. striata*. Microbial biomass carbon values (ì g/g soil) ranged from 69.6 to 179.1 for treatment *B. japonicum* + SSP @ 40kg P_2O_5 /ha.

3.10.9 Co-inoculation Response of PGPRs with *Bradyrhizobium japonicum* on Rainfed Soybean

Co-inoculation of *B. japonicum* with bacterial isolates RP-7 and RP-24 gave maximum soybean yields of 1941 kg and 1963 kg/ha, respectively, in variety Pusa 22. Nodule numbers were the highest when PGPR strain *Klebsiella* was

inoculated singly (22 plant^{-1}). The nodule number in co-inoculation treatments of *B. japonicum* and PGPR ranged from 4.5 to 16.6. The nodule weights and shoot weights ranged between 6.0 and 46.7 mg/plant and 1.5 and 3.2 g/plant, respectively. For three consecutive years, the co-inoculation treatment of RP-7 with *B. japonicum* has been able to increase the yield of soybean over that of other treatments. This inoculation technology is to be recommended to the farmers.

Co-inoculation of *B. japonicum* and PGPR on soybean under rainfed conditions

Treatment	Nodule		SDW/ plant (g)	Yield (kg/ha)
	Number	mg dry wt.		
Absolute Control	14.3	40.0	1.5	1904
B. japonicum	12.3	26.7	2.2	1616
B. japonicum+ PFI	16.6	39.3	2.6	1682
B. japonicum + PF IV	10.0	15.3	2.1	1556
B. japonicum + *Proteus*	14.8	35.3	2.5	1873
B. japonicum + *Bacillus*	13.5	36.7	1.8	1371
B. japonicum + *Klebsiella*	9.1	19.3	2.5	1473
B. japonicum + *RP-7*	15.2	46.7	2.6	1941
B. japonicum + *RP-24*	10.4	35.3	2.6	1963
Pseudomonas (PFI)	6.7	6.0	2.2	1696

3.10.10 Biochemical Characterization of Antifungal Compound Against *Rhizoctonia bataticola*

Of the large number of endophytes screened under *in vitro* conditions, 9 were selected and screened against four fungal pathogens of soybean performing plate assay. The fungal isolates used were *Rhizoctonia bataticola, Macrophomina phaseolina, Sclerotium rolfsii* and *Fusarium udam.* After *in vivo* screening with the pathogen challenged host, HKA-15 was selected for further studies.

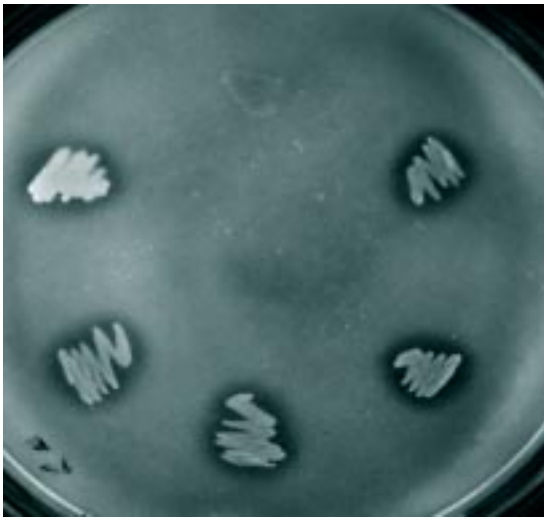
To assess the bio-control ability of HKA-15, antifungal metabolite defective (AFM-1) mutants were developed through EMS mutagenesis and used as negative control. EMS @ 100 µg/ml was used to cause mutations. Out of 1000 mutant clones of HKA-15 screened for antifungal activity, 4 clones were identified as defective for antifungal metabolites (AFM-1). Of this, three mutants (DM1, DM2, DM3) lost their activity completely whereas mutant DM4 showed less activity in terms of reduced zone of inhibition compared to the parent HKA-15.

PCR based gene detection assay using specific primers demonstrated the presence of *phl*D (DAPG production) and *phz*CD (phenazine production) genes in HKA-73 isolate and *phz*CD gene in HKA-107 isolates. None of the other isolates showed the amplicons of expected size, i.e., 745 bp and 1150 bp for *phl*D and *phz*CD genes, respectively.

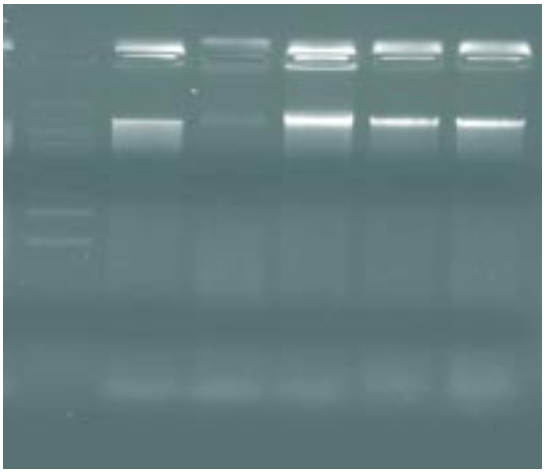
3.10.11 Development of Transgenic Biofertilizer Cyanobacteria (*Nostoc muscorum*) with Cloned *mps* Genes from *P. striata*

Cosmid library. Cosmids were isolated from one of the positive clones and restricted with EcoR1. It showed 6 bands including cosmid. These bands were purified and ligated with EcoR1 digested pUC18 and transformed into DH5á and plated in HAM agar plate with amp50 and IPTG-Xgal. Twenty positive sub-clones (mps activity) were screened. The first sub-cloned plasmids were isolated from these clones through boiling lysis and ALM; further plasmids were restricted with EcoR1 for checking inserts. It was shown 15-19 kb insert.

These inserts were restricted with EcoRI, Sal1, Sac1, HindIII, and BamHI for analyzing restriction mapping of



EcoRV sub-clones on HAM plates



EcoRV restricted 2nd sub-clones

insert and 2nd sub-cloning. The restricted products (DNA) were purified and ligated with digested pUC18, transformed into DH5á and plated in HAM agar plate with amp50 and IPTG-Xgal, two positive clones (mps activity) were obtained. Recombinant plasmid was isolated from these two clones and restricted with EcoRI; it released 7-8.5 kb insert. These inserts were restricted with rare cutter restriction enzymes for analyzing restriction mapping of insert and 3rd sub-cloning. For the purpose of 3rd sub-cloning due to the wide option of restriction sites in Blue Script, this insert is transformed to the EcoRV site of Blue Script. These transformed Blue Script colonies were further confirmed for P-solubilization. Eight clones were screened for P-solubilization, plasmid isolation and restriction. The insert size seems to be 8kb.

3.10.12 Genetic Evaluation of Cyanobacteria for H_2 Production and N_2 Fixation

A number of cyanobacterial isolates were used to study total soluble proteins, extra cellular ammonia release, N assimilatory enzymes (nitrate reductase, glutamine synthetase and nitrogenase) and hydrogen production. A distinct variability was recorded with respect to these attributes amongst cyanobacterial isolates examined. Cyanobacterial isolates examined for hydrogen production and nitrogenase activity under aerobic and argon environments exhibited enhanced nitrogenase activity and detectable hydrogen evolution under argon environment.

3.10.13 Molecular Characterization of Cyanobacteria

RAPD was used as a genetic tool to discriminate genotypes in twenty-four isolates from three cyanobacterial genera. Similarity percentage ranged from 53% to 91% amongst the isolates analyzed and the maximum percentage similarity was shared between isolates of *Calothrix* (Ca4 and Ca5). Phylogenetic analysis exhibited overlapping of isolates from three genera studied, hence, in-depth evaluation is required using more primers for RAPD study. 16S rRNA PCR amplification and studies on RFLP were standardized amongst the cyanobacterial isolates.

Whole cell protein profile presented variability. Dendrogram showed 90-100% similarity amongst *Anabaena* isolates. However, a few clusters with overlapping dominated either by *Nostoc* or *Calothrix*, exhibited relatedness between the strains of distinct genera.

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3.10.14 Isolation and Identification of BGA from Low Input Rice Growing Areas

In order to develop a need-based BGA biofertilizer for low input *basmati* rice, soil samples were collected from rice fields amended with green manure or that received 25-30 kg N/ha. A total of 25 BGA were isolated from seven locations comprising 22 heterocystous and 3 non-heterocystous forms. *Nostoc* was the most abundant (nine isolates) with 17.24 – 191.44 ARA n moles C_2H_4 mg^{-1} chl h^{-1} followed by *Anabaena* (4 isolates, 22.49 – 121.58 n moles C_2H_4 mg^{-1} chl h^{-1}) and *Calothrix* (3). The remaining were *Tolypothrix*, *Hapalosiphon*, *Westiellopsis* and *Scytonema* with an ARA ranging from 12.16 to 65.62 n moles C_2H_4.

3.10.15 Organic Cultivation of Rice and Wheat

To develop a protocol for organic cultivation of rice and wheat, field experiments were conducted in scented rice-wheat-green gram cropping system for the past two years. Organic inputs *Azolla* @ 1t/ha, BGA @15 kg/ha, FYM @ 5t/ha and vermi-compost @ 5 t/ha were used. Control, as recommended fertilizer dose ($N_{80}P_{30}K_{30}$), was also maintained. In wheat crop, *Azotobacter* replaced *Azolla*, while other treatments remained the same. Rice variety Pusa

Effect of different organic treatments on grain yield of wheat (Var. HD 2687) and scented rice (Var. Pusa Basmati 1) during 2005

Treatment	Grain yield (t/ha)	
	Wheat	Rice
Azolla (A)*	2.18	2.43
BGA (B)	2.11	2.35
FYM (F)	2.24	2.06
Vermi-compost (V)	2.44	2.53
A+B	2.48	3.03
A+F	2.58	3.38
A+V	2.64	3.67
B+F	2.70	3.43
B+V	2.67	3.47
F+V	2.75	3.64
A+B+F	2.74	3.79
A+F+V	2.87	3.81
B+F+V	2.90	3.88
A+B+F+V	3.04	4.08
$N_{80}P_{30}K_{30}$	3.36	4.21
$N_0P_0K_0$	1.67	1.76
CD at 5 %	0.24	0.31

**Azotobacter* replaced *Azolla* in wheat crop experiment

Basmati1, and wheat variety HD 2687were taken. Grain yield (4.08 t/ha) of rice obtained under combined application of four organic amendments was on a par with the yield recorded under recommended dose of chemical fertilizer (4.21 t/ha) application. However, the grain yield of wheat under organic amendments was low (3.04 t/ha) and it was significantly lower than the yield obtained under $N_{80}P_{30}K_{30}$ dose.

The results obtained in organic rice farming at the Institute farm were further verified through on-farm testing (OFT) at Bhurgarhi village, Ghaziabad district (U.P). The treatment showing the best performance at IARI farm was compared with farmers' traditional fertilizer management practice in U.P. Two rice varieties Pusa Basmati1 and Pusa Sugandh 4 were used in OFT. Results showed that the grain yields of 4.0 t/ha and 4.2 t/ha from Pusa Basmati 1and Pusa Sugandh 4, respectively, were on a par with the yields of the same varieties grown under traditional fertilizer management. Similar results were also obtained at Sanoli village, Panipat district (Haryana).

Analysis of rice for Fe and Zn contents showed a significant increase in Fe contents (1.91ppm) in the treatments having two or more organic amendments (added together) over those of control (1.31 ppm). Though Zn content in grain also increased but the increment was not statistically significant. Owing to organic cultivation of rice-wheat, microbial population (actinomycetes, bacteria, fungi and BGA) in the soil was enhanced in comparison to that of the recommended fertilizer application. The over all microbial activity was reflected in enhanced dehydrogenase. In organic field, no serious insect pest attack or disease was recorded both in rice and wheat crops.

3.10.16 Biofertilizers in Integrated Nutrient Management in Rice-Wheat Cropping System

Organic inputs, viz., *Azolla* @ 1 t/ha, BGA @ 15kg/ha and FYM@ 5 t/ha were integrated with the application of nitrogen at two levels (N_{40} and N_{80}) in rice-wheat cropping system. In wheat, *Azotobacter*, and in rice, *Azolla* were used. Rice variety Pusa Basmati 1 and wheat variety HD 2687 were taken.

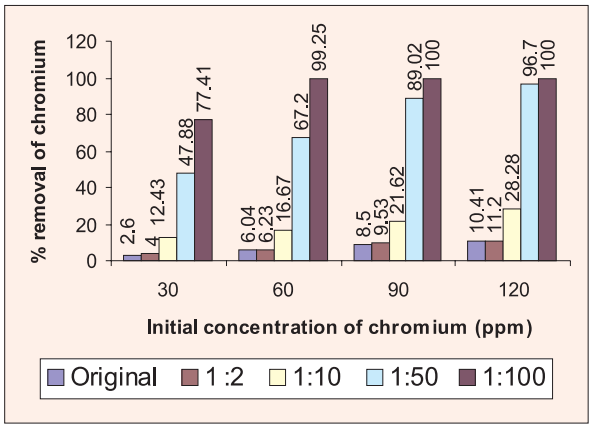
It was found that the grain yield of rice and wheat increased significantly because of the application of biofertilizer or organic material alone or in combination with chemical fertilizers. In rice, there was a significant increase in grain yield due to the application of biofertilizer or organic materials over $N_{40\ or}$ N_{80} but the increase was marginal with single organic input. Grain yields of rice (5.02 t/ha) and wheat (4.14t/ha) were on a par with or better (at N_{80} +A+B+F) than that of the recommended dose of nitrogen (N_{120}). Rice grain analysis for Zn and Fe contents showed an increase in Fe and Zn contents in the treatments having IPNS over those of control as well as sole chemical fertilizer application. Addition of organic material/biofertilizer increased the Fe content significantly in grain as compared to that of control. However, the increase in Zn content was not significant. Soil analysis for microbial population count at rice harvest stage showed an increase in actinomycetes, bacteria, fungi and BGA population and soil enzymatic activity under INM as compared to those of control ($N_0P_0K_0$) as well as sole chemical fertilizer application. Organic amendments alone or in combination resulted in higher availability of P than inorganic N alone. Alkaline phosphatase activity was enhanced when organic inputs were used with inorganic N with maximum activity due to *Azolla* inoculation followed by BGA inoculation.

3.10.17 Bioactive Compounds from Cyanobacteria Strains

Cell free filtrates of cyanobacterial strains belonging to genus *Anabaena* were screened for their algicidal activity against *Synechocystis* sp. and fungicidal activity against *Rhizoctonia bataticola* and *Pythium debaryanum*. One strain of *Anabaena* was selected for further characterization. A significant enhancement in the biocidal activity was observed when the culture was grown under high light intensity (4700 lux and 40^0C) and increased levels of K_2HPO_4 (80mg/l). Chemical characterization of these biocidal compounds is in progress.

3.10.18 Bioremediation of Heavy Metal Chromium by Micro Algae

The bioremediation potential of micro algae in removing chromium was examined. Cultures were grown at 10, 15, 20, 25 ppm of chromium (VI). Analysis of residual chromium



Removal of chromium by *Chlorella vulgaris* from tannery effluent

in cell free supernatant showed that *C. vulgaris* was most efficient in chromium removal. No chromium could be detected in the cell free supernatant at 21 days of incubation at 10 ppm and 15 ppm of chromium suggesting that the removal is efficient at lower concentrations. Further, the influence of pH, metal concentration and contact time was studied on chromium removal efficiency by *C. vulgaris* keeping cell density and age of organism constant. The results revealed that metal removal was better at pH 6.0 and 7.0. There was initial rapid uptake of Cr by alga within 30 minutes resulting into a gradual uptake later up to 120 minutes. However, it took 90 to 120 minutes for 100% removal at initial concentrations of 10 ppm and 15 ppm. Uptake of chromium by *C. vulgaris* from tannery effluent showed that it was more effective in diluted than in undiluted effluent. There was about 100% uptake after 60 minutes when the effluent was diluted 100 times, and it reduced to 89% and 96.7% after 90 minutes and 120 minutes, respectively at 1:50 dilution. *Chlorella vulgaris*, which is one of the most abundant algae in wastewater treatment and stabilization ponds, appears to be a potential candidate for chromium removal from industrial effluents.

3.10.19 Bioremediation of Waste Waters using *Azolla*

Up flow Anaerobic Sludge Blanket (UASB) sewage effluents were treated with *Azolla microphylla* to assess the possibility to recycle the sludge for application to crops. The anaerobically treated effluents were collected from sewage treatment plant at Faridabad, which receives domestic as well as industrial wastewaters. The characterization of effluents showed low organic matter (an index of BOD), organic N and reactive P. Effluents showed the presence of Zn and Fe but toxic metals like Ni, Pb and Cd were below 0.1ppm. *Azolla microphylla* was not able to grow on sewage effluents and showed poor growth even on effluents diluted with tap water. This may be due to low reactive P (~ 1ppm in the effluents). The dried biomass samples harvested from sewage showed high concentration of Zn and Fe as compared to those harvested from controls showing that they have accumulated Zn and Fe metals from effluents though growth was poor. Toxic metals like Ni, Cd and Pb were below detectable limits in biomass samples. Thus, *Azolla microphylla* biomass removed Zn and Fe from sewage effluents.

3.10.20 Studies on Treatment of Cr-Contaminated Tannery Effluents Collected from Kanpur

Studies on tannery effluents were carried out to assess the potential of *Azolla* to remove Cr from effluents. Cr containing tannery effluents were collected from two tannery sites at Kanpur. Their physicochemical characterization was done and the Cr levels (0.15-0.28ppm) were found to be little higher than the limits prescribed by the Bureau of Indian Standards for discharge of effluents on inland surface but they were lower than those described for discharge in public sewers. Since *Azolla microphylla* is able to concentrate Cr from environment, it was grown on these effluents. However, *A. microphylla* was unable to grow on effluents while it showed good growth on Espinase & Watanabe medium containing 1 ppm and 5 ppm Cr (which were used as controls). Inhibition of *Azolla* growth on effluents may be due to some inhibitory substances, dark colour or low available P in the effluents. Thus, *Azolla microphylla* was unable to grow on tannery effluents. Therefore, for removal of Cr from highly coloured effluents, a passive process using dried biomass should be used. *A. microphylla* was not suitable for treating tannery effluents by active process.

3.11 ORCHARD MANAGEMENT PRACTICES

3.11.1 Mango Malformation

A mixture prepared by gentle agitation of 100 g each of the leaf, stem and flower extracts of *Datura stramonium* L., *Calatropis gigantean* R. Br. and neem along with cowdung manure in 25 l of water for 30 days reduced mango malformation to a large extent and also gave slight improvement in fruit quality. The mixture was sprayed on Amrapali mango trees during the first week of April.

3.11.2 Rootstock Research in Guava, Mango and Citrus

Multiplication of released guava rootstock Pusa Srijan was done through stooling and air-layering. Four species and three varieties were collected to identify a dwarf and wilt tolerant rootstock for guava.

Similarly in mango, four polyembryonic genotypes, viz., Kurakkan, Kerala 1, Kerala 2 and Olour were studied to identify a salt tolerant rootstock. Olour and Kurakkan showed tolerance up to ≈4.0 dS/m, whereas, Kerala 1 and Kerala 2 died at ≈ 2.0 dS/m. Plant height, stem diameter, and number of leaves decreased in all the cultivars with the increase in salinity level. Higher salinity levels also caused leaf defoliation. Kurakkan seedlings survived up to ≈4.0 dS/m in chloride dominated salts and up to 6.0 dS/m in sulphate and carbonate dominated salts after three months. The chloride dominated salts at 4.0 dS/m were more injurious to reduce plant height and root length and they also caused more defoliation particularly in Kurakkan.

Cleopatra mandarin gave better quality fruits having more total soluble solids, higher ascorbic acid, lower acidity, less number of seeds and lowest granulation in Mosambi sweet orange. In contrast, Jambhiri and Karna Khatta produced more granulated fruits.

Fruit quality in Mosambi sweeet orange as affected by different rootstocks

Rootstock	No. of seeds	Fruit weight (g)	TSS (%)	Acidity (%)	Ascorbic acid (mg/100 ml)	Reducing sugars (%)
Soh Sarkar	18.3	178.10	10.01	1.01	46.28	3.13
Jambhiri	20.2	153.04	9.90	1.10	43.25	2.93
Mosambi	17.1	161.02	10.00	1.07	47.88	3.65
Karna Khatta	23.8	187.00	10.25	1.05	47.03	3.43
Cleopatra mandarin	16.3	160.25	10.30	0.98	49.07	3.76

3.12 POST-HARVEST TECHNOLOGY AND MANAGEMENT

3.12.1 Controlled Atmosphere (CA) Technology for Guava Fruits

Guava being a potential fruit crop of subtropical regions of India, occupies a distinct position among other fruits. Its fruit is extolled for delicious taste and high nutritional value. CA storage of unripened guava cv. Lucknow 49 reduced the weight loss of fruit, maintained its firmness and colour and alleviated its chilling injury (CI). The post CA storage ripening completed under controlled (20°C and 75% RH) and ambient (28-30°C and 40-50% RH) conditions, within 5 and 3 days, respectively, showed that the fruits ripened under controlled conditions were superior in nutritional and sensory qualities to the fruits ripened under ambient conditions.

3.12.2 Extending the Marketability of Ripe Mango

Mango being a climacteric fruit spoils fast after ripening. A huge proportion of fruits (25-50%) is lost at the stage of retail marketing. A study was initiated to evaluate the role of ascorbic acid, a natural antioxidant, on the post harvest physiology of ripe mango fruits. It was evident from the study that ascorbic acid infusion treatment resulted in lowering the respiratory activity of ripe mango cv. Chausa at ambient condition. Similarly, the climacteric peak of ethylene evolution was delayed by this treatment.

3.12.3 Effect of Grading on Quality of *Bael* Fruit

The *bael* fruits were graded into four grades depending on their size and colour for evaluation of their quality parameters for processing. *Bael* fruits of small size (400-500g) showed higher level of ethylene evolution and respiratory rate with high content of acidity compared to bigger fruits (750-1000 g). High percentage of pulp recovery was observed in smaller fruits as compared to big ones.

3.12.4 Maturity Studies in Mango

Ten-year old mango (cv. Amrapali) trees were sprayed with 15, 30 and 50 ppm Gibberellic acid (GA_3) in the last week of June. Fruits were harvested in the second week of July. Harvested fruits were stored at 10°C temperature and 90% relative humidity. GA_3 application delayed the ripening of the fruits during storage. GA_3 (30 ppm) application was to be found more effective than other treatments in respect of fruit quality parameters. Physiological loss in weight (PLW) was reduced (9.82%), and TSS and vitamin C remained higher (11.5% and 35.14 mg/100 g pulp) in GA_3 (30 ppm) treated fruits.

3.12.5 Studies on Tree Age and Canopy Height of Guava (cv. Allahabad Safeda)

In plant age and fruit quality studies on guava fruits, it was noted that nutrient uptake and chemical composition of fruits were affected with advancement in plant age. Fifteen years' old plants produced superior fruits in respect of higher TSS (11.85), lower seed content (0.81%) and higher vitamin C (235 mg/100 g pulp). Fruits of old age plants (20 years) were found comparatively poor in terms of Ca and K uptake.

3.12.6 Nutritional and Microbial Quality of Hurdle Processed Mango Slices (cv. Chausa)

The concept of hurdle technology has provided very successful method in achieving microbial stability and safety while stabilizing the sensory and nutritive properties of food. A method for the hurdle processing of mango slices was standardized. Mango (cv. Chausa) slices soaked in sucrose solution (70%) showed higher ascorbic acid and total carotenoids retention while the best soaking ratio was 1: 4. The slices soaked at 40°C for 2 h were adjudged the best treatment with respect to yield of the product and quality parameters during storage under different environmental conditions.

3.12.7 Quality Evaluation of Minimally Processed Bittergourd Rings (cv. Pusa Do-Mousmi)

Minimally processed food incorporates the concept of preparation of lightly processed new value added products using hurdle technology to prepare fresh, convenient and high quality products by combining a set of mild hurdles (factors) to prevent post harvest losses. The bittergourd rings soaked

in 10% salt solution in a 1:5 ratio at 30°C for 12 h gave the best results with respect to yield of the product and retention of chlorophyll as well as organoleptic quality. Microbial quality was also observed.

3.12.8 Packaging Study of Hurdle Processed Mango Slices and Minimally Processed Bittergourd Rings

Quality of mango slices (hurdle processed) and bittergourd rings (minimally processed) packed in different packaging materials was evaluated during storage at ambient (20.5-33°C) and low temperatures (4 ± 2°C). Both the products could be stored safely up to a period of 4 months at ambient temperature and for 6 months at low temperature. The best packaging material for both the products was found to be aluminum co-extruded film pouches followed by glass bottles and polyethylene pouches for retention of various quality parameters.

3.12.9 Osmo-processing of *Aonla* Segments

Osmotic dehydration of *aonla* at five levels each of temperature, rpm, solution to sample ratio and solution concentration was studied over a period of 5 h using a centrally rotatable block design of response surface methodology. The optimum condition for osmotic dehydration considering maximum moisture loss and minimum solids gain was found to be at solution to sample ratio 3.4:1; solute conc. 60° Brix; 250 rpm at 39°C for 4 h. The moisture loss at optimum condition was 44% of the initial moisture content (d.b.) and the solids gain was 3% of the initial weight.

3.12.10 Evaluation of Carrot Cultivars for Dehydration

Thirteen genotypes of carrot, namely, Nantes Scarlet, SHA-U-C-108, 95 x N x 1061, MS 505, SH, MS 16, No.501, 240607 x N x 1060, Nantes, PY, 28 x Py, CR 59, and New Kuronda obtained from the Division of Vegetable Science, IARI, were screened for the preparation of dehydrated carrot shreds. On the basis of yield of the finished product, dehydration characteristics, â-carotene, lycopene, ascorbic acid, etc. as well as sensory score, the cultivar MS 16 was found to be the best for the preparation of dehydrated carrot shreds.

3.12.11 Packaging and Storage Study of Dehydrated *Methi* Leaves

To study the effect of packaging on the quality of dehydrated *methi* leaves, three different types of packaging material, namely, 200 and 400 gauge LDPE, HDPE and 150 gauge polypropylene were used to pack the samples and stored at ambient temperature (15-33.5°C) for 3 months. HDPE pouches of 200 gauge were found to be the best with respect to chlorophyll, â- carotene, ascorbic acid and rehydration ratio as well as sensory score.

3.12.12 Storage Study of Dehydrated Bittergourd Rings

The dehydrated bittergourd rings were packed in 200 gauge LDPE, 150 gauge polypropylene and 200 gauge HDPE pouches for storage up to six months at room temperature and low temperature. During storage, 200 gauge HDPE pouches were found to be better for packaging of dehydrated bittergourd rings as they retained better chlorophyll, ascorbic acid, rehydration ratio and sensory score in the samples.

3.12.13 Osmotic Dehydration of Guava Slices

Ready-to-use dehydrated guava product was prepared by osmotic dehydration in 60°B sugar syrup containing 0.05% KMS and 0.1% citric acid for 6 h with the use of guava fruit slices (cv. Allahabad Safeda). The water loss and solid gain were found to be increased with the increase in sugar concentration and temperature of solution during osmotic process. The optimum solid gain (13.1%), water loss (34. 2%) and mass reduction (21.1%) were recorded. Osmotic drying considerably increased the sugar content and reduced the acidity without any significant changes in colour, texture and original flavour of the slices.

3.12.14 Effect of Blanching Methods on the Beta-Carotene Content of Frozen Carrots

High temperature short time (HTST) blanching followed by low temperature high time (LTHT) blanching is a viable technology for obtaining high quality frozen carrots with high antioxidant properties and sensory quality.

3.12.15 Retention of Total Flavonoids in Onions (cv. Pusa Red) as Affected by Processing Methods

Processing methods affected the antioxidant properties of processed onion paste differentially. Microwave processing resulted in higher flavonoid retention in comparison to that retained by pressure and steam methods.

3.12.16 Physical Characteristics of Maize Genotypes

Fifteen (15) genotypes of maize from among the field (flint), sweet, and popcorn were evaluated for their physical characteristics at 9.78% moisture content (wb), to relate these properties with the known features of different types of corn

and their specific usage. Results indicated that the sweet corn genotypes were distinct from the other two types of corn in lower hardness, test weight, bulk density and terminal velocity and higher porosity.

3.12.17 Physical Properties of Composite Maize Varieties

Physical properties, namely, bulk density, true density, porosity, angle of repose, coefficient of friction, terminal velocity and hardness of Pusa composite varieties of Maize (PC 2 and PC 3) were determined at 9 different moisture contents. Equilibrium moisture contents of PC 2 and PC 3 varieties of maize were determined at different temperatures (20, 30 and 40°C) and relative humidity between 10 and 80%.

3.12.18 Effect of Chemical Treatments on Cooking Time of Three Pigeonpea Varieties

Three pigeonpea pulse (dehulled) samples were dipped for 4 h in various solutions of sodium chloride, sodium carbonate, sodium bicarbonate and sodium tripolyphosphate (0.5 to 1.5% each) at ambient temperature and dried at 60°C for 16 h with respect to low compression strength (N), i.e., less cooking time and yellow appearance of the pigeonpea. The response for chemical treatments varied with different varieties used.

3.12.19 Irradiation Study in Mango Pulp

A preliminary study was carried out for preserving mango pulp (cv. Chausa) by irradiation for its storage at ambient and low temperatures up to 6 months in glass bottles and zip pouches. Control samples were non-irradiated, and heated pulp was preserved with 700 ppm KMS along with 0.3% citric acid. In irradiated samples, two doses (0.1 K Gray and 0.25 K Gray) of irradiation were given. It was observed that with respect to colour and viscosity of pulp, non-irradiated samples performed better than irradiated samples.

3.12.20 Disinfestation of Whole Pigeonpea Pulse by Irradiation

Three varieties of pigeonpea, namely, Pusa 2001-7, Pusa 2008 and Pusa 33, were irradiated with 0.25, 0.50 and 0.75 K Gray doses of irradiation. A storage study was carried out in LDPE pouches for 3 months at ambient temperature. Preliminary results showed that increasing the dose of irradiation from 0.25 to 0.75 K Gray, resulted in reduced beta carotene content and slight increase in protein content and cooking time.

4. CROP PROTECTION

4.1 PLANT PATHOLOGY

4.1.1 Fungal Diseases

4.1.1.1 Wheat

Inheritance of resistance in bread wheat cultivars to stem rusts. Four bread wheat cultivars, namely, DL 788-2, GW 322, HUW 533 and HW 2004 were analysed against three pathotypes of *Puccinia graminis* f. sp. *tritici*, i.e., 122(7G11), 40-1(62G29-1) and 117A(36G2). The segregation pattern of seedlings in F_2 derived from crosses with Agra Local as susceptible parent showed the presence of 2 dominant resistance genes in HUW 533 to pathotype122(7G11) and 117A(36G2) and one recessive gene to pathotype 40-1(62G29-1). In HW 2004, 3 dominant resistance genes to pathotype122(7G11) and 2 dominant resistance genes to 40-1(62G29-1) and 117A (36G2) were identified. Variety GW 322 showed single dominant gene when analysed with pathotype 122(7G11) and 117A(36G2) and one recessive gene to 40-1(62G29-1). In DL 788-2 variety 3,2 and 1 dominant resistance gene(s) governed resistance to pathotypes 117A(36G2), 122(7G11) and 40-1(62G29-1), respectively. Reciprocal crosses of the cultivars also supported the above findings. Analysis of BC_1 and BC_2 with pathotype 40-1(62G29) confirmed the presence of 2 dominant independent genes for resistance in HW 2004 and 1 gene each in HUW 533, GW 322 and DL 788-2 confirming the above findings.

Mode of segregation of seedlings of different crosses in F_2 to three pathotypes of *Puccinia graminis* f. sp. *tritici*

Cross	Segregation of F_2 seedlings			x^2	P value
	R	S	Ratio		
HUW 533 x AL					
122 (7G11)	324	23	15R:1S	0.090	0.80-0.70
40-1 (62G29-1)	87	270	1R:3S	0.020	0.90-0.75
117A (36G2)	244	12	15R:1S	0.660	0.50-0.25
HW 2004 x AL					
122 (7G11)	335	6	63R:1S	0.080	0.80-0.70
40-1 (62G29-1)	246	13	15R:1S	0.660	0.50-0.25
117A (36G2)	340	26	15R:1S	0.305	0.75-0.50
GW 322 x AL					
122 (7G11)	299	101	3R:1S	0.013	0.95-0.90
40-1 (62G29-1)	76	209	1R:3S	0.150	0.75-0.50
117A (36G2)	322	104	3R:1S	0.090	0.95-0.75
DL 788-2 x AL					
122 (7G11)	332	25	15R:1S	0.305	0.75-0.50
40-1 (62G29-1)	294	100	3R:1S	0.013	0.95-0.90
117A (36G2)	331	7	63R:1S	0.080	0.80-0.70

Confirmation of leaf rust resistance genes (Lr) in bread wheat. The genetic studies of allelic crosses among HUW 510, HW 2044, K 9644 and PBW 433, and near isogenic lines were made for the confirmation of leaf rust resistance genes. F_2 seedlings of crosses HUW 510 x *Lr13*, HW2044 x *Lr1*, HW 2044 x *Lr13*, K 9644 x *Lr1*, K 9644 x *Lr13* and PBW 443 x *Lr13* did not show segregation for susceptibility confirming the presence of *Lr13* in HUW 510, *Lr1* and *Lr13* in HW 2044 and K 9644 and *Lr13* in PBW 443.

Mode of segregation of seedlings of different crosses in F_2 to pathotype 106 (0R9) of *Puccinia recondita tritici*

Cross	Segregation of F_2 seedlings	
	R	S
HUW 510 x *Lr13*	285	0
HW 2044 x *Lr1*	290	0
HW 2044 x *Lr13*	289	0
K 9644 x *Lr1*	295	0
K 9644 x *Lr13*	260	0
PBW 443 x *Lr13*	302	0

Identification of sources of combined resistance to stem and leaf rusts in durum wheat. A total of 109 *durum* wheat genotypes (selected on the basis of rust resistance from over 1100 lines field evaluated at Indore during 2002-03) including released varieties, land races and indigenous as well as exotic genetic stocks, have maintained their resistance to both stem and leaf rusts (terminal rust severity up to 10S) at Indore, Mahabaleshwar and Wellington during 2003 to 2005. Hence, these genotypes hold promise as stable sources of combined resistance to stem and leaf rusts in *durum* wheat.

Identification of diverse genes for resistance to stem rust in durum wheat. Genetic studies revealed the presence of four different genes for seedling resistance to 40A, the most prevalent stem rust pathotype, and at least eight diverse genes for adult-plant resistance to 117-6, the most virulent stem rust pathotype on *durum* wheats, among five *durum* wheat genetic stocks, B 662, ED 2398A, HG 110, IWP 5019 and Line 1172. These genes are different from *Sr2*, *Sr7b*, Sr9*e* and *Sr11*, the stem rust resistance genes commonly postulated among Indian *durum* wheat genotypes. Except *Sr2*, the other three genes are ineffective against the

pathotypes 40A and 117-6, and *Sr2* is expressed only in adult plants and is inherited recessively, compared to seedling-expression of the recessive gene effective against 40A, and dominant inheritance of the genes for adult-plant resistance identified in the present study.

Gene postulation for rust resistance. Gene postulation of 65 advance lines was done at IARI Regional Station, Tutikandi, Shimla, with the aim to select high yielding wheat genotypes with diverse resistant genes for leaf and stripe rusts. *Lr 34* was the most frequent leaf rust resistance gene occurring in 45% genotypes either single or in combination of other genes. Other leaf rust resistance genes postulated were *Lr 26* (37%), *Lr 1* (31%), *Lr 23* (20%), *Lr 13* (13.8%) and *Lr 10* (6.2%). Similarly, three stripe rust resistance genes were postulated in above genotypes. *Yr18* was the most frequent gene (45%), followed by *Yr 9* (37%) and *Yr 2* (7.6%).

Developing species specific primer for detection of Karnal bunt (Tilletia indica). Specific primers were developed for the first time from rDNA- ITS region for the detection of Karnal bunt teliospores by polymerase chain reaction (PCR). The forward ITS KB1, 5' ACGGAGCTCTTCTTCGGA 3' and reverse ITS KB2, 5' TCGATGATTCCGAAGAAT 3' primers could amplify uniformly all the isolates of *T. indica* only, but not other *Tilletia* species like, *T. caries* and *T. horrida*.

Resistance against Karnal bunt pathogen. Eighty-seven entries were tested by artificial inoculation against *T. indica* and thirteen, viz., VL 822, PDW 283, PDW 289, NIDW 295, PDW 291, HPW 233, HS 459, VL 869, K 9107, HI 8638, HD 4672, HI 8627, and DDK 1025 were found resistant.

Pathogenic and molecular variability in Ustilago segetum tritici. Pathogenic variability in 23 isolates of *Ustilago segetum tritici* causing loose smut, recorded on 19 international differentials, demonstrated the existence of four races, viz., T1, T4, T7 and T11 in northern India. Genetic variability through RAPD analysis exhibited high level of genetic polymorphism among the isolates, where 36 primers gave 100% polymorphism. The genetic variability among the isolates ranged from 10 to 48%.

RAPD amplification pattern of 23 isolates of *Ustilago segetum* f. sp. *tritici* with OPA8

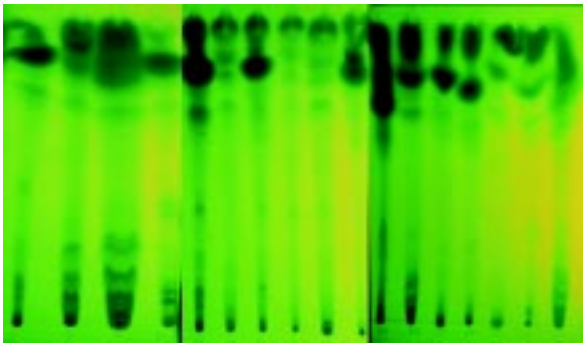
Resistance against loose smut. One hundred fifty-one advanced wheat lines developed by IARI wheat breeders were artificially inoculated with *Ustilago segetum tritici*. Among these, 138 showed resistance for the last 2 years. Some of the resistant entries are: P 121-3, P 425-11, P 464-3, WBM 1502, WBM 1553, WBM 1568, WBM 1603, WBM 1614; IB 99-71; IB 99-79; IB 99-80; DL 25; DL 32; DL 36; WR 959; WR 1010; and WR 1019.

Role of toxin in pathogenesis of spot blotch pathogen (Bipolaris sorokiniana). The interaction between the toxic culture filtrate of *B. sorokiniana* and wheat cultivars through histochemical staining indicated the role of H_2O_2 in host – pathogen interaction. The early accumulation of H_2O_2 in susceptible cultivars induced host cell necrosis whereas delayed accumulation in resistant ones was attributed to play a role in host defense.

Histochemical staining of wheat cultivar infiltrated with toxic culture filtrate for H_2O_2 detection

Cultivars	No. of cells with DAB staining/microscopic field					
	Epidermal cells			Mesophyll cells		
	24 h	36 h	48 h	24 h	36 h	48 h
Arnez	7.3	9.1	9.2	9.1	10.3	10.9
Chiriya-3	1.8	2.1	2.6	2.7	3.3	3.4
HD 2329	6.9	7.9	8.7	8.7	9.6	10.1
Ning 8319	4.8	5.3	5.3	5.0	6.6	6.7
Suzhoe	1.9	3.3	3.8	3.5	3.9	4.6
VL 616	6.4	8.3	8.7	10.2	10.5	11.1
SED:0.17	CD (0.05):0.33 CV : 7.62%					

Variability in toxin production of B. sorokiniana. Variability in 35 isolates of *B. sorokiniana* with respect to toxin production indicated qualitative and quantitative differences. All the isolates except BS-52 and BS-53 produced a common dark black band of R_f 0.81. One more major band of R_f 0.91 was produced by all the isolates but with low intensity. Isolate BS-102 from barley showed a bright blue band of R_f 0.23 not shown by any other isolates,



Rf values of various compounds produced by *Bipolaris sorokiniana* isolates

indicating production of a different toxic molecule by this isolate.

Molecular variability in B. sorokiniana. Variability in 50 isolates of *B. sorokiniana* was studied using 40 random primers belonging to OPA, OPN and OPM series. The amplification products with 15 primers gave reproducible and scorable bands; and the analysis showed 25% similarity among all the isolates. Isolate BS-54 from Almorah (Uttaranchal) and BS-68 from Pune showed 95% similarity, while isolates BS-32 and BS-28, both from Faizabad, showed 100% similarity.

4.1.1.2 Rice

Identification of resistant sources to sheath blight. A total of 368 entries received from IARI breeders, and the Directorate of Rice Research (DRR), Hyderabad were evaluated against sheath blight under artificial epiphytotic conditions in field. Entries RR 270-56, AS 99035 (NSN-1), IHRT-ME-14 (NHSN), HPR 2373, HPR 2188, VL 7174, VL 2000-30018, VL 2000-30032, VL 2000-30061, VL 2000-30118, VL 97-6747, VL 88-971, VL 88-1190, VL 89-5038, VL 93-6052, VL 97-3747, and VL 96-3680 (DSN) were found resistant.

Management of sheath blight. Seven fungicides, namely, Armure 30EC, Difenconazole + Propiconazole, RIL-FA 200SC, Antracol 75WP, Dhanteam 75WP, Saaf 75WP,and Sheathmar 3L were tested against sheath blight on the variety Pusa Basmati 1. Inoculations with *Rhizoctonia solani* were carried out at maximum tillering stage with colonized hypha leaf bits. Armure 30EC was found most effective @ 1.0 ml/l showing least disease incidence of 46.3% followed by Saaf (49%) and RIL- FA200SC (49.7% @ 1.5ml/l and @2.5ml/l, respectively, as against 93.4% in control). Recommended fungicide Sheathmar 3 L showed a disease incidence of 24.3% only.

4.1.1.3 Maize

Resistance to diseases. Of 208 lines materials evaluated against maydis leaf blight (*Bipolaris maydis)* and banded leaf and sheath blight (*Rhizoctonia solani* f.sp. *sasakii)*, six lines, viz., J H 10704, J H 11044, MCH 29, MCH 23, Prabhat and DEH 111 showed resistant reaction against both the diseases. Ten QPM lines, viz., J H (QPM) 159, MHQPM 05-2, HQPM 5, HQPM 6, HQPM 7, SHAKTIMAN 4, BQPMH 43, HQPM 4, HQPM 5, HQPM 1 and an elite inbred line (CM 136-9-1) developed at Delhi also showed resistant/ tolerant reaction against both the diseases.

Management of banded leaf and sheath blight. Sheathmar 3L (Validamycin) @ 2.7 ml/l was found effective in minimizing the BLSB incidence for the second subsequent year.

Data indicate that both single spray (1 day after inoculation) and two sprays (1 DAI + 15 DAI) of Sheathmar controlled disease up to 90% in both the maize cultivars, Surya and Pro311. However, there was no significant difference in these treatments in reducing disease incidence. It is, therefore, recommended that one spray of Sheathmar (2.7ml/l) may be applied immediately after the appearance of BLSB to minimize the losses in the grain yield.

Effect of Sheathmar 3L (2.7 ml/l) on banded leaf and sheath blight of maize

Treatment	Surya		Pro 311	
	Length of disease development		Length of disease development	
	(in cm)	% inhibition	(in cm)	% inhibition
Single spray at 1 DAI	3.80	90.25	5.07	87.07
Single spray at 3 DAI	20.43	47.58	24.6	37.30
Single spray at 7 DAI	22.93	43.12	31.7	19.21
Single spray at 14 DAI	31.83	18.34	33.72	14.06
Double spray at 1 & 15 DAI	3.13	91.97	6.32	83.89
Double spray at 3 & 17 DAI	18.18	53.36	20.83	46.91
Unsprayed control	38.98	0.0	39.24	0.0

More than 80 diseased samples were collected not only from maize but from crops like, sorghum, *bajra*, sugarcane and rice as well. Out of these, only 63 samples could be purified, and single hyphal tip isolates established. These isolates were studied for cultural variability, colony characters and sclerotial characters. The data generated reveal that there exists a great deal of cultural variability with regard to colony characters as also sclerotial morphology. The fastest growth of the mycelium was noticed in isolate RS 32 (full plate in 72 h) while, slowest growth occurred in culture RS 35 which took as long as 240 h to cover the whole petri plate. Regarding sclerotial characters variations were found in colour (whitish brown to dark brown), number of sclerotia per plate (5 to 418) and formation pattern (peripheral, central and scattered) on the plate.

Pathogenic variability was studied under the field conditions in two maize lines, viz., CM 206 (susceptible) and POP-145 (resistant). Disease rating on CM 206 ranged from 2.5 to 5.0. Isolates RS-6, RS-7, RS-8, RS-13 and RS-42 were highly virulent, while isolates RS-1, RS-31, RS-32 and RS-40 were least virulent. Disease rating on POP-145 ranged from 1.5 to 3.0. In this case, even highly virulent isolates gave rating of 3.0 as compared to the susceptible cultivar where it was 5.0. No correlation between pathogenecity and morphological characters could be established.

4.1.1.4 Chickpea

Evaluation of chickpea genotypes against wilt and Ascochyta blight. Of 146 chickpea genotypes evaluated against Fusarium wilt and Ascochyta blight, 10 genotypes, namely, H 00-216, IPC 2001-04, H 01-74, GNG 1599, H 0 1-36, IPC 2001-22, PG 9426-2, HK 94-134, Phule G 9425-9 and H 01-08 were resistant against wilt, and one genotype IPCK 401 was moderately resistant to Ascochyta blight. Of 25 genotypes of IARI evaluated against *Ascochyta rabiei*, FLIP 97020-1785, FLIP 94-509C and FLIP 94-510C were resistant.

Integrated management of wilt of chickpea. Chickpea seeds treated with a combination of *Trichoderma harzianum* and vitavax supported maximum seed germination (96.1%), minimum wilt incidence (39.7%) and the highest grain yield (1.73 t/ha) under wilt sick field.

Molecular characterization of Trichoderma isolates. Based on PCR-RAPD and UPGMA clustering analysis of 10 isolates of *Trichoderma* spp. using 40 primers, the isolates were separated into two clusters at 0.20 genetic similarities. Two isolates of *T. virens* (TR-9 and TR-10) were grouped into one cluster and rest of the isolates into another group. All *T. viride* isolates (TR-2) were grouped into a distinct cluster with 55% similarity, and both *T. harzianum* isolates were grouped separately with 70% similarity. Primer OPA 13 efficiently differentiated all the isolates of *T. viride* with cent percent similarity coefficient (TR-2) from the rest of the isolates. Primer OPB 05 distinguished the isolates of *T. virens* from others with 76% similarity. Ranchi (TR-1) and Delhi (TD-4) isolates of *T. viride* grouped separately by OPA 01 showed 70% similarity. These two isolates were most effective both *in vitro* and *in vivo* conditions.

4.1.1.5 Urdbean

Reaction of genotypes against major diseases. Of eight urdbean genotypes evaluated, only two genotypes, namely, P 2052 and P 2057 showed resistant to moderately resistant reactions against major diseases like Cercospora leaf spots, Macrophomina blight and yellow mosaic.

4.1.1.6 Mungbean

Integrated management of diseases. Amongst the treatments evaluated, the integration of seed treatment with Bavistin + Thiram (1:1-2g/kg) + Gaucho (2g/kg) with foliar spray of Confidor 0.02% at 30 days after sowing and Bavistin 0.05% at 45 days after sowing gave maximum grain yield (1.23 t/ha) along with minimum intensity of Cercospora leaf spots (4.4%) and mungbean yellow mosaic virus (MYMV) incidence (12.8%) and intensity (16.4%). The germination percentage recorded in this treatment was also significantly superior to control.

4.1.1.7 Pigeonpea

Growth pattern of biocontrol agent Trichoderma viride. The activity of *T. viride* in relation to temperature, pH, and water was quantified. At low (5 - 10°C) and high (38°C) temperatures, growth occurred at a constant rate (0.05-0.07 cm/day), indicating that high or low temperatures are not effective as far as activity is concerned. At a temperature of 15 – 20°C, the growth rate increased to 0.14 – 0.2 cm/day and attained maximum rate (0.33 cm/day) at 25 – 32°C and continued to grow unless subjected to constraints like nutrients exhaustion and or inhibition by external factors. Growth rate started declining at 35°C. Optimum pH was 7.5 and growth declined afterwards.

IARI soil samples were evaluated for *T. viride* population dynamics and none of the samples showed *T. viride* population count (plate count taken for MPN) due to high pH (8.6).

In vivo biocontrol response of Trichoderma viride in relation to soil moisture and temperature. Wilt (pathogen) suppression by *T. viride* (as seed a treatment) at temperature of 18-26°C was 5.5-10.6%. However, at a temperature of 32°C and moisture deficit conditions, there was no inhibitory effect against wilt infection. Biocontrol effect of *T. viride* against wilt may be attributed to induction of resistance in plants as antibiosis and lysis may not be operative without the growth in soil.

4.1.1.8 Soybean

Major soybean diseases recorded in Delhi region were yellow mosaic virus (YMV) and bud blight while anthracnose was also recorded in traces. DS 9712, DS 9814, SL 688 and PS 1042 were identified as resistant or tolerant to YMV and bud blight.

Pathogenic variability in Fusarium udum. Ten differential lines, viz., resistant (ICP 87119, ICP 12797, BSMR 175, ICP 8863, ICP 8859), tolerant (C11 and BDN2) and susceptible lines (ICP 2376, Pusa 9001 and Pusa 2006) were identified, and six isolates of *F. udum* viz., AF2, AF3, AF4, AF7, AF21 (Rajasthan) and D3 (Delhi) were tested which differentiated three major groups of the pathogen.

4.1.1.9 Rapeseed and mustard

Evaluation of Brassica spp. against different diseases. One hundred and seventy five entries belonging to different *Brassica* spp., were evaluated and multiple disease resistance to white rust (WR), downy mildew, Alternaria blight and Sclerotinia rot was exhibited by EC 338997, PBC 9221, PBN 2001, and PBN 2002.

Evaluation of single and double Brassica lines. Of seventeen entries screened, Bio-Q-108-2000, GSL 1, BCN 14, PT 303, CAN 39, 78, TERI (oo) R 9903 and TERI (OE) R 03 were free from white rust both under natural and artificial conditions. All entries were highly susceptible to Sclerotinia rot.

4.1.1.10 Vegetables

Alternaria blight of Brassica juncea and vegetable crops. A total of 115 isolates of *Alternaria* spp. (43 from tomato, 46 from cauliflower and 26 from onion samples) collected from four states, viz., Uttar Pradesh, Haryana, Rajasthan and Delhi were grouped based on cultural and morphological characters.

Wilt of cucumber and muskmelon. Fifty isolates of *Fusarium oxysporum* f. sp. *cucumerinum* and *Fusarium oxysporum* f. sp. *meloni* were collected from wilt affected cucumber and muskmelon plants from seven districts of Uttar Pradesh (Aligarh, Bijnor, Bulandshahar, Ghaziabad, Meerut, Muzaffarnagar and Saharanpur), Alipur block of Delhi; two districts of Haryana (Gurgaon, and Jhajhar) and seven districts of Rajasthan (Ajmer, Bundi, Bhilwara, Churu, Jaipur, Sikar, and Tonk) for cultural, and pathogenic variability and molecular characterization studies.

Biocontrol of petal infection by Sclerotinia sclerotiorum. In an exploratory investigation four different saprophytic bacterial isolates were found associated with blossoms of seed crop of cauliflower and one of the isolate showed antagonistic activity against ascospore germination and mycelial growth of the fungus *in vitro* and preliminary tests in growth chamber.

In vitro screening of cabbage seed against downy mildew (Peronospora parasitica). The seed lots of 2004 cabbage variety Golden Acre and MR-1 were screened applying alkaline maceration technique for the presence of the downy mildew pathogen. The presence of mycelia was detected in the variety Golden Acre only. A multi-resistant line MR-I did not reveal the mycelial presence. The technique may be helpful in screening the germplasm at seed stage against the pathogen.

Field observation has revealed that occurrence of downy mildew disease in cabbage seed crop markedly pre-dispose plants towards increased attack of black rot pathogen (*Xanthomonas campestris*).

4.1.1.11 Large cardamom

Characterization and management of leaf and sheath blight epiphytotic in large cardamom. A new disease has been reported to occur in large cardamom plantations of Sikkim and Darjeeling hills since 1999. The disease first appeared sporadically at higher altitudes (at more than 5000 ft above msl) and subsequently it spread out everywhere to attain epiphytotic proportions. The disease appears generally with the advent of the pre-monsoon showers and progresses rapidly during the rainy season (June to August). In the affected large cardamom clumps, water-soaked lesions appear either at margins or tips or any other point on leaves which rapidly enlarge, coalesce and cover the entire lamina. The affected areas become necrotic and dry out. Blighting starts at the upper leaves and gradually spreads to the lower leaves and leaf sheaths. Leaf sheaths covering the pseudo-stem show blackish-brown discolouration which extends up to the rhizomes and subsequently turn into greyish patches with brown margins. Gradually the pseudo-stems become brittle and break at the middle or at the collar region. As a whole, the affected clump exhibits burnt-up appearance. The disease mostly affects the bearing tillers of the clump while the new tillers remain apparently healthy. Later in the season, the young, emerging leaves of the new tillers in the diseased clump show pale yellow discolouration in the interveinal areas. The spikes from the diseased clump exhibit elongated appearance in comparison to the spikes from the healthy clump. Water-soaked, brownish spots appear on the spike. Spike, as a whole, remains greenish brown. Flowering and seed setting take place but the seed pulp does not mature out.

Preliminary investigation revealed the association of *Glomerella cingulata* with the disease. To contain this dreaded disease, on-farm demonstrations were taken up 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.

4.1.2 Viral Diseases

4.1.2.1 Rice tungro disease

Transmission of tungro viruses through mealy bugs. Tungro associated rice tungro spherical (RTSV) and bacilliform (RTBV) viruses were transmitted using viruliferous mealy bugs (*Brevennia rehi*) as vector and the percentage of infection was 38%. Back inoculations and immunosorbent electron microscopy (ISEM) from the inoculated plants also confirmed the results.

In vitro acquisition of tungro viruses by two vectors in membrane feeding system. Viruliferous mealy bugs were allowed to feed on one side of the membrane sachet containing 10% sucrose solution, and from the opposite side

of the same sachet, non-viruliferous *Nephotettix virescens* were allowed an acquisition access of 18 hours. After the expiry of acquisition feeding access, the leafhoppers were removed and young TN 1 seedlings were inoculated @ 3 hoppers/plant. Some of these inoculated plants developed symptoms of tungro disease. The percentage of infection was 40%. Back inoculations and ISEM from such plants also proved the virus transmission.

In another experiment, non-viruliferous mealy bugs (*B. rehi*) were kept on one side of the membrane sachet and viruliferous *N. virescens* were allowed to feed from the opposite side. After the expiry of acquisition feeding access, young TN 1 seedlings were inoculated @ 3 bugs/plant. RTSV and RTBV were transmitted in this case also as symptoms appeared in some of the inoculated plants and back inoculations from such plants were also positive and the percentage of infection was 33.3%. These results constitute the first report of successful *in vitro* acquisition of tungro viruses in membrane feeding system by employing two different vectors.

New host for multiplication of GLH (Nephotettix virescens). Wheat Variety (Agra Local) was identified as a suitable host for the leafhopper, *N. virescens* under glasshouse conditions. When leafhoppers were encaged, they thrived well and eggs were laid and nymphs were also hatched. This is the first record of survival and multiplication of GLH on wheat.

Varietal screening for resistance. Rice cultivars Pankhari 203 and Bindli Mutant 66 and Bindli Mutant 68 were identified as immune to tungro. These cultivars were neither infected even when inoculated with six different tungro isolates nor tungro viruses could be recovered in back inoculation and ISEM tests from the inoculated plants.

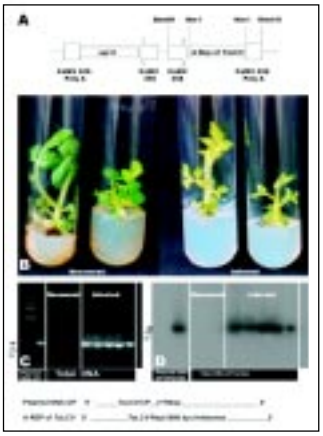
4.1.2.2 Mungbean yellow mosaic virus (MYMV)

Functional genomic and promoter evaluation of DNA viruses. The role of ORF AV2 in DNA A of MYMIV in viral pathogenesis was investigated by site directed mutagenesis. Site directed mutagenesis was performed following overlapping PCR method and around 25% of the transformants had desired mutation as verified by sequencing. Five mutations were done for blackgram isolate (bg) of MYMIV, namely, BgM_1, Bgdel-A, BgW_2, $BgH_{14}G_{15}$ and BgY_{32}. Similarly, seven mutations for cowpea (Cp) isolate. viz., CpM_1, CpW_2, $CpH_{14}G_{15}$, CpK_{73}, CpG_{44}, CpC_{86} and $CpC_{84\text{-}86}$ were done. Agroinoculation of legume hosts with mutants W_2, $H_{14}G_{15}$ and Y_{32} resulted in attenuation of symptoms and reduced single stranded and super coiled DNA levels. Severe and altered symptoms localized to vascular tissue and increased DNA levels were seen with CpK_{73} and $CpC_{84\text{-}86}$ suggesting that ORF AV2 may be affecting the replication of the viral genome, by interacting with replication initiator protein.

4.1.2.3 Tomato leaf curl New Delhi virus (ToLCNDV)

Diversity and distribution of DNA ß associated with tomato leaf curl disease. Leaf curl affected tomato samples collected from Aurangabad (4), Bangalore (1), Gujarat (3), Nasik (1) and Sonepat (4), were made to clone the genomic components from Aurangabad and Bangalore isolates in pUC 18. In Aur1, Aur2 and Bangalore isolates, totally six clones of *Bam* HI, *Kpn*I and *Xba*I having 2.7 kb insert were confirmed, representing full-length DNA A or B genome. In Bangalore isolate, all *Kpn*I clones restricted with *Kpn*I enzyme released 1.3 kb band representing satellite DNA ß components. The clones are being sequenced for further authentication. Transmission studies revealed that Aur1 isolate was highly sap transmissible.

Polyclonal antisenses production to ToLCNDV. *In vitro* expression strategy was used for the production of polyclonal antiserum against coat protein of *Tomato leaf curl New Delhi virus- Potato* (ToLCNDV-Pot). The viral coat protein gene was cloned in an expression vector pMAL - C2X , in which the coat protein will be expressed as a fusion protein with maltose binding protein (70.5kDa). The fusion protein was detected in insoluble fractions. The protein was solubilised



Transgene (antisense-Rep)-induced silencing of Tomato leaf curl virus: (A) antisense-Rep gene construct of ToLCV; (B) phenotypic alterations caused by transgene-induced silencing of virus and recovery of plant from viral infection; (C) Southern analysis of DNA extracted from post-transcriptionally silenced (transformed-recovered) and non-silenced (non-transformed-regenerated) plants; PCR amplicons using specific primers for ToLCV-CP amplification (~750 bp) in transformed-recovered, non-transformed-regenerated and infected positive control plants (D) to determine the presence of virions, Southern and Northern blot analyses to demonstrate the presence of viral genome in non-silenced and positive control infected plant and 21–25 nt long siRNA in silenced plants using different probes indicated in the left.

by using bacterial protein extraction reagent (B-PER) (Pierce) and will be purified prior to immunization.

Transgenic resistance to tomato leaf curl virus. Studies have shown that transforming leaf curl virus infected tomato plants with the homologous antisense replicase gene resulted in recovery of infected plants, suggesting that antisense suppression in the virus infected plants, provides a threshold level of dsRNA needed to induce gene silencing.

Transgenic resistance - Viral gene suppression in transgenic plants expressing chimeric transgene from tomato leaf curl New Delhi virus and cucumber mosaic virus. Chimeric construct with CMV-CP (cucumber mosaic virus) and ToLCNDV-rep gene transcriptionally fused under the control of CaMV-35S promoter was used to transform tobacco and tomato using *Agrobacterium*. Transforming ToLCNDV and CMV infected plants with the homologous chimeric gene construct produces RNAs capable of duplex formation and confers gene silencing. This suggests that the antisense suppression in ToLCNDV infected plants provides a threshold level of dsRNA needed to induce gene silencing, whereas sense suppression in CMV infected plants may be operating through co-suppression, leading to delayed and attenuated symptoms.

4.1.2.4 Groundnut bud necrosis virus (GBNV)

The movement protein (NSm) gene from GBNV affected tomato samples, exhibiting bronzing and necrotic spots on leaves, extensive necrosis of the buds, petioles and concentric rings on fruits, collected from Coimbatore (Tamil Nadu), Kanpur (Uttar Pradesh) and Pune (Maharashtra) was cloned using virus specific primers RKJ5 5' ATGTCTCGCTT (A/G/T)TCTAA (A/C/T)GT(C/G/T)3' and RKJ6 5' TTATATTTCAAGAA GATTATC3'. Sequence analysis showed that the NSm gene from GBNV isolates from tomato shared maximum identity with GBNV type isolate from groundnut both at nucleotide (92-96%) and amino acid (97-99%) levels. Further, the NSm gene among GBNV isolates from tomato originating from three different locations (Pune-AY817495, Coimbatore-AY817496 and Kanpur-AY817497) was highly conserved (97-99%).

In-vitro gene expression strategy was followed for the production of polyclonal antiserum to nucleocapsid protein (NP) of groundnut bud necrosis virus (GBNV). The polyclonal antiserum efficiently detected the natural infection of GBNV and watermelon bud necrosis virus (WBNV) in leguminous and solanaceous hosts collected from different locations in DAC-ELISA test. GBNV infection was detected from cowpea, mungbean, soybean, tomato and urdbean. WBNV, antigenically related to GBNV, was detected from cucumber, muskmelon, ridge gourd and watermelon. Antiserum was also successfully used to detect tospovirus infection antigenically related to GBNV from chilli and weed hosts such as *Acanthospermum*, *Physalis*, *Portulaca* and *Cassia* spp. The antiserum showed low degree of non-specific reaction (A405 nm: 0.20-0.45), suggesting the presence of antibodies against the bacterial proteins having homology with healthy plant proteins. The non-specific reaction could be corrected by cross-absorption with healthy sap (A405 nm: 0.07-0.16).

Detection of tospoviruses in naturally infected plant species by direct antigen-coated enzyme-linked immunosorbent assay using polyclonal antiserum to recombinant nucleocapsid protein of groundnut bud necrosis virus

Virus Isolate*/ Source	Origin	A405nm
Groundnut bud necrosis virus **(GBNV)**		
Arachis hypogaea (groundnut)	Bangalore	1.75
Glycine max (soybean)	Bangalore	1.50
	Coimbatore	0.82
Lycopersicon esculentum (tomato)	Bangalore	1.96
	Coimbatore	2.61
Vigna mungo (urdbean)	Bangalore	1.50
Vigna radiata (mungbean)	Bangalore	1.90
Vigna unguiculata (cowpea)	Bangalore	1.60
Watermelon bud necrosis virus **(WBNV)**		
Citrullus lanatus (watermelon)	Bangalore	1.40
	Varanasi	1.28
Cucumis melo (muskmelon)	Bangalore	1.20
Cucumis sativus (cucumber)	Bangalore	1.83
	Varanasi	0.72
Luffa acutangula (ridge gourd)	Coimbatore	0.99
Unidentified Tospovirus		
Acanthospermum sp.	Bangalore	1.98
Capsicum annuum (chilli)	Bangalore	1.64
	Faizabad	0.62
	Raichur	1.05
Cassia tora	Bangalore	1.27
Physalis minima	Bangalore	1.40
Portulaca sp.	Bangalore	1.64

* Tospovirus infection identified as GBNV and WBNV on the basis of nucleocapsid protein gene sequence

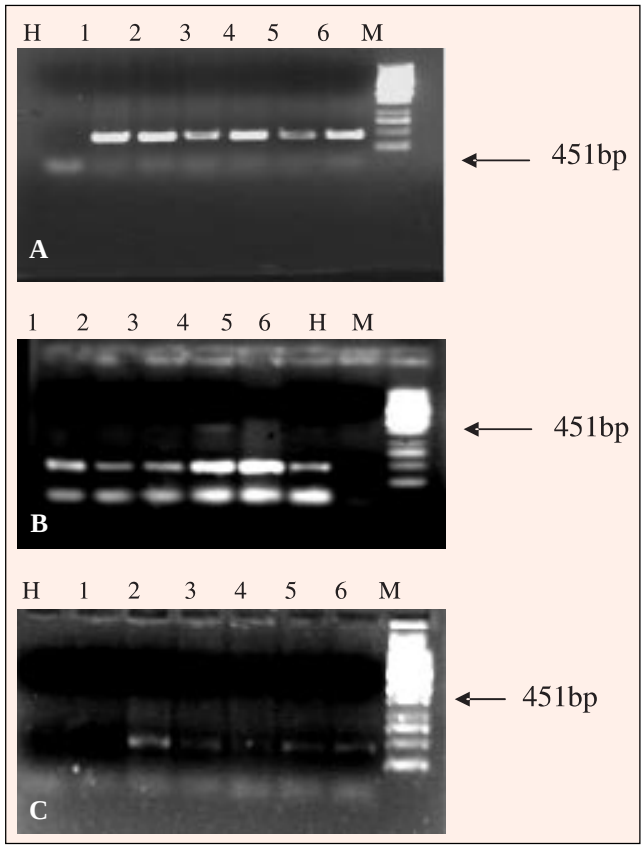
4.1.2.5 Virus and viroid diseases of citrus and their management

Citrus tristeza virus (CTV). Mandarin orchards in Darjeeling district of West Bengal were surveyed for incidence and distribution of CTV. The orchards surveyed were found infected with CTV by using biological indexing, electron microscopy, ELISA and RT-PCR. Further, CTV free mandarin mother trees were identified, maintained and healthy bud wood were grafted on healthy root stocks of Darjeeling mandarin, Rangpur lime and rough lemon for the production of healthy propagative materials.

The 5-terminal regions (C. 400 bp) comprising a part of ORF-1a, of eight CTV isolates were cloned and squenced. Four groups of CTV isolates were identified and the nucleotide sequence identity was 89-97% within the groups. The group I included CTV2 which is distinct and nearer to group IV. The group II included CTV3 which is also a distinct and new isolate, and the group III included isolates, K2C19 and K4C15 which are related to exotic Florida mild CTV strain, T30, and T385. The group IV included isolates, K3C9, K323, K1C10 and CTV7, which are similar to exotic Israel CTV strain, VT and California CTV strain, SY568. Still no isolate related to Florida severe CTV strain T36 was identified.

Collection and maintenance of citrus tristeza virus isolates. During 2005-06, one citrus *tristeza* virus (CTV) isolate was collected, indexed and maintained on *kagzi* lime (*Citrus aurantifolia*). To obtain healthy bud wood for grafting, 64 mother plants were indexed in DAS-ELISA using polyclonal antibodies to CTV. Only one mother-plant was found to be free from CTV.

Citrus greening bacterium. The reliability of PCR based detection of citrus greening bacterium, three primer sets and two polymerase enzymes were evaluated. Primer combination yielding an amplicon of 451 bp proved better for amplification compared to the primer pairs producing amplicons of 703 bp and 1160 bp. Furthermore, the primer combination yielding amplicon of 451 bp was amplified at a DNA template concentration of 100 pg with Taq polymerase and at 0.1 pg with the Klen Taq polymerase. To reduce the cost of PCR based detection method, a simple non-phenol chloroform method of DNA extraction was evaluated and found comparable with a commercial DNA extraction kit (Quagen) and better than a CTAB based DNA extraction method. The final PCR protocol combining sodium-sulphite extraction of DNA, primer pair producing an amplicon of 451 bp and the Klen Taq polymerase enzyme was found very effective in detecting greening bacterium in citrus trees at one-hundredth cost of the DNA extraction compared to the commercial kit. The sequence of cloned amplicon from 16S ribosomal RNA gene of Delhi isolate shared 89 - 100 % sequence identity with corresponding sequence of *Candidatus* Liberibacter asiaticus from China, Brazil, Japan, and Pune isolate of India, *C.* Liberibacter americanus from Brazil and *C.* Liberibacter africanus from Africa.



DNA extraction by different methods and its amplification with a primer set from 16S ribosomal RNA (451bp) and Klen Taq. A:DNeasy kit, B:Non-phenol chloroform method and C:CTAB. Lane 1 to 6, greening bacterium infected samples, H:Healthy-Mosambi sweet orange, and M: 1 kb DNA ladder

Per cent nucleotide sequence identity of a part of 16S ribosomal RNA gene from isolates of different greening bacterium

	% Nucleotide sequence identity								
	CLAs-D	CLAs-P	CLAs-CH	CLAs-BR	CLAs-BR	CLAs-JP	CLAm-BR	CLAf-AF	CLAf-Nel
CLAs-D	100.00	98.00	100.00	96.00	89.30	96.40	92.60	93.70	96.20
CLAs-P		100	98.0	94.00	87.50	94.40	90.90	93.10	96.40
CLAs-CH			100	96.00	89.30	96.40	92.60	93.70	96.20
CLAs-BR				100	93.30	99.50	89.30	89.80	92.20
CLAs-BR					100	92.60	95.80	85.50	88.00
CLAs-JP						100	89.30	90.20	92.60
CLAm-BR							100	88.80	91.30
CLAf- AF								100	96.00
CLAf-Nel									100.00

CLAs-D = *Candidatus* Liberibacter asiaticus, Delhi (India) (present study); CLAs-P= *C.* Liberibacter asiaticus, Pune (India);CLAs-BR= *C.* Liberibacter asiaticus, Brazil; CLAm-BR= *C.* Liberibacter americanus, Brazil; CLAs-JP= *C.* Liberibacter asiaticus, Japan; CLAs-CH= *C.* Liberibacter asiaticus, China; CLAf-AF= *C.* Liberibacter africanus sub spp. capensis Africa and CLAf-Nel= *C.* Liberibacter strain Nelspruit Africa

Citrus yellow mosaic virus (CYMV). The genome sequencing of CYMV associated with mosaic disease of Rangpurlime (*Citrus limonia* Osb) rootstock of citrus was completed. Primers with restriction sites were designed to isolate the promoter gene from CYMV from *Citrus grandis* L. (Osb) (Pummelo) . Amplified fragment of about 1 kb using primer 6542 F Sal I and 20 R Bam H1 was cloned in a cloning vector (pDrive vector) and then recloned in a binary vector pBI 101 (a promoter less vector). Cloning in vector pBI 101 was confirmed using restriction enzyme Bam H1 and Sal I. The pBI101 vector containing CYMV 1 kb fragment was renamed CYMVpBI 101. The construct was then mobilized into an *Agrobacterium* strain EHA 105 using helper pRK2013 by triparental mating method. Positive clones of *Agrobacterium* were confirmed by colony PCR.

Survey and identification of aphids. Survey of citrus plantations in Pune and Parbhani districts revealed 70 and 40-50 per cent incidences of citrus die-back, respectively. The aphids colonizing citrus plants in Parbhani district were identified as *Aphis craccivora, A. citricola* and *Uroleucon orientalis;* the last found on weed *Ecinus echnatus*, was recorded first time on citrus.

Monitoring of aphid vector population in Kagzilime plantation. Monitoring of aphid vector population in Kagzilime plantation by yellow coloured traps placed at different heights of 1', 2', 3', 4', 5' and 6' recorded maximum of 1772.5 aphids/trap in the first week of January. The trap placed at 1' height recorded more aphid catches compared those caught on traps placed at other heights.

The five and 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.

4.1.2.6 Papaya

Survey of papaya plantations showed 50-60 per cent incidence of papaya ring spot virus (PRSV) in Pune and cent per cent incidence of PRSV in Satara districts.

PRSV incidences were 25, 50, and 46.14 per cent in inoculated and 45, 0.09 and 0.0 per cent in uninoculated plants of papaya transplanted in April, May and June, respectively.

In a screening trial, all the eight papaya cultivars showed PRSV incidence (80.77-100%) by flowering stage with, var. Pusa Nanha showing 11.53 per cent mild PRSV symptoms.

1600 papaya plants (var. Red Lady) were pre-immunized with mild isolate of PRSV and planted in farmer's field as demonstration trial.

Plant growth. Among cross-protected plants, maximum plant height was recorded with seedlings transplanted on 15th February (P2)(1.33 m), and among different doses of insecticide with those receiving 25% recommended doses (RD) of imidacloprid (i.e., 0.005% a.i.) (1.32 m). Among non cross-protected plants, maximum plant height was recorded with seedlings transplanted on 5th February (P1) (1.37 m), and among different doses of insecticide with those receiving full RD of imidacloprid (i.e., 0.02% a.i.) (1.34 m). Among cross-protected plants, maximum collar diameter was recorded with seedlings transplanted on 5th February (P1) (6.03 cm), and among different doses of insecticide with those receiving 25% recommended doses (RD) of imidacloprid (i.e., 0.005% a.i.) (6.03 cm). Among non cross-protected plants, maximum collar diameter was recoded with seedlings transplanted on 5th February (P1) (6.31 cm), and among different doses of insecticide with those receiving half RD of imidacloprid, (i.e. 0.01% a.i.) (6.16 cm).

Aphid population. On an average year basis, the border crop of banana reduced the aphid population (weekly total/ trap) from 32.77, outside the border crop to 19.90, in side the border crop.

Cross-protection. Out of 324 cross-protected seedlings transplanted in field, only 1.85% plants showed severe symptoms of PRSV as compared to 3.47% among non-treated plants two months after transplanting. At the time of fruit set, only 18.83% cross-protected seedlings showed severe symptoms as compared to 38.04% control seedlings. The supremacy of cross-protected plants continued during late fruits setting stage where cross-protected plants showing severe symptoms were 56.17% compared to 93.09% of non-treated seedlings.

Fruit yield and quality. The highest fruit yield (30.02 kg/tree) in the first year was observed in seedlings transplanted on 5th February, as compared to those transplanted on 15th and 25th February. The TSS and flesh thickness varied from 11-13^{o} Brix and 2.0-3.4 cm, respectively, under various treatment combinations. There was no pattern of TSS and flesh thickness among various treatment combinations, except that PRSV infected fruits showed TSS as low as 7^{o} Brix.

4.1.2.7 Peri-urban vegetables

Survey. Survey of the fields of cucurbits around Pune revealed the occurrence of papaya ringspot - watermelon strain on spongegourd, ridgegourd and pumpkin (10-35%).

Potato virus Y on sponge gourd. Natural occurrence of potato virus Y on sponge gourd was detected by ELISA and the virus particles were observed under ISEM. The virus isolate is being maintained on differential host for molecular characterization.

Molecular characterization of ZYMV bottle gourd isolate. The nucleotide sequencing of the cloned PCR product showed that it was 497 bp long. Sequence analysis indicated that it contained N - terminal part of coat protein gene and 211 bp long 3' un-translated region (UTR). The sequence was 98-99% identical to other isolates of ZYMV.

polyclonal antibodies to bean common mosaic *potyvirus* and pepper veinal mottle *potyvirus* in DAS-ELISA.

Characterization of the virus causing Foorkey disease. Insect-transmission of *Foorkey* disease of large cardamom was attempted using 3 aphid species, viz., *M. kalimpongensis*, *R. maidis* and *M. persicae*. Only *M. kalimpongensis* transmitted the virus to healthy large cardamom plants. It transmitted the virus at least up to 9 days after acquisition from the infected host. Polyclonal antibodies to banana bunchy top *babuvirus* (BBTV) reacted mildly with the virus causing *Foorkey* disease of large cardamom.

4.1.2. 8 Large cardamom

Production of polyclonal antiserum to chirke virus. The purification protocol of chirke virus was standardised, which yielded virus preparation of about 1 mg/100 g of infected large cardamom leaf materials. The purified virus preparation was used for the production of polyclonal antibodies by immunizing rabbit. The decoration test showed binding of the polyclonal antibodies with the chirke virus particles indicating serological specificity.

Characterization of the virus causing Chirke disease. Insect-transmission of *Chirke* disease of large cardamom was attempted using 5 different aphid species, viz., *Rhopalosiphum maidis*, *Myzus persicae*, *Micromyzus kalimpongensis*, *Toxoptera citricidus* and *Toxoptera aurantii*. Only *R. maidis* and *M. persicae* transmitted the disease to healthy large cardamom plants. The virus causing *Chirke* disease of large cardamom could not be detected by using

Transmission of *Foorkey* disease of large cardamom using different aphid species

Aphid species used	Pre-AFP	AAFP	IAFP	No. of insects used per plant	Per cent trans-mission	Incubation period
Micromyzus kalimpongensis	2 h	24h	24h	20	9.24(11/119)	252 d (111d to 417d)
Rhopalosiphum maidis	2h	24h	24h	20	0 (0/20)	——
Myzus persicae	2h	24h	24h	20	0 (0/20)	——

Detection of *Foorkey* virus using polyclonal antibodies to Banana bunchy top *babuvirus* (BBTV) in DAS-ELISA

Plant sample	A_{405} Value
Healthy banana leaf	1.083
BBTV-infected banana leaf	2.283
Banana inoculated with *Foorkey* virus	1.679
Healthy large cardamom leaf	0.774
Foorkey-infected large cardamom leaf	1.100

Transmission of *Chirke* disease of large cardamom using different aphids species

*Aphid species used	Pre-AFP	AAFP	IAFP	No. of plants per treatment	Per cent trans-mission	Incubation period
Rhopalosiphum maidis	2 h	5 min	24 h	20	30	139 days
		1 h	24 h	20	30	205 days
		24 h	24 h	20	40	174 days
Myzus persicae	2 h	5 min	24 h	20	20	173 days
		1 h	24 h	20	10	170 days
		24 h	24 h	20	10	170 days
Micromyzus kalimpongensis	2 h	5 min	24 h	20	0	——
		1 h	24 h	20	0	——
		24 h	24 h	20	0	——
Toxoptera citricidus	2h	5 min	24 h	20	0	——
		1 h	24 h	20	0	——
Toxoptera aurantii	2 h	5 min	24 h	20	0	——
		1 h	24 h	20	0	——

*Number of viruliferous insects used per treatment – 20

Characterization of the virus causing large cardamom mosaic. Insect-transmission of large cardamom mosaic was attempted using 3 aphid species, viz., *M. persicae*, *R. maidis* and *M. kalimpongensis*. All the three aphid species transmitted the disease to healthy large cardamom plants. The virus causing large cardamom mosaic could not be detected in DAS-ELISA by using polyclonal antibodies to cucumber mosaic *cucumovirus*.

Transmission of large cardamom mosaic using different aphid species

Aphid species used	Pre-AFP	AAFP	IAFP	No. of insects used per plant	Per cent trans-mission	Incubation period
Myzus persicae	2 h	5 min	24 h	20	30	167
		1 h	24 h	20	30	166
		24 h	24 h	20	20	241
Rhopalosiphum maidis	2 h	5 min	24 h	20	30	165
		24 h	24 h	20	30	120
Micromyzus kalimpongensis	2 h	5 min	24 h	20	40	180

4.1.3 Bacterial Diseases

4.1.3.1 Screening for disease resistance

A total of 120 entries obtained from the Directorate of Rice Research (DRR), Hyderabad were screened in glasshouse condition against the highly virulent Kaul isolate of *Xanthomonas oryzae* pv**.** *oryzae (Xoo*). Entries CR 874-24-2-2, WR 3-2-1, OR 1898-32-69, R 1250-1557-895-1, NDR 2063, RP-Bio 197 and 2 checks (IR64 and Ajaya) were found resistant.

4.1.3.2 Effect of RRb (Rice Rhizobacteria) isolates on bacterial leaf blight of rice in microplot

Two plant growth promoting rhizobacteria (PGPR), viz. RRb-103 and RRb-11 were able to reduce bacterial leaf blight disease intensity in Pusa Basmati 1 when co/challenge inoculated with *Xoo.* RRb-11 reduced disease intensity to 15.84 % while in RRb-103 reduction was 29.74 % as compared to 65.30 % observed in control (Pusa Basmati 1, treated with sterile distilled water (SDW) and challenge inoculated with *Xoo*). Disease intensity in the case of co-inoculation was 28.94% for RRb-103 and 17.21% for RRb-11. Thus RRb-11 was able to reduce disease intensity significantly more both in the case of co & challenge inoculation with *Xoo* as compared to disease intensity in Pusa Basmati 1 treated with RRb-103 followed by co/challenge inoculation with *Xoo*.

Both PGPRs were able to improve plant growth parameters, viz,., plant height (cm), dry matter plant (g) and yield g m^{-2}. Pusa Basmati 1 plants treated with RRb isolates followed by co/challenge inoculation with *Xoo* showed significant increase in plant height both in the cases of co-inoculation (94.10 cm for RRb-103 and 97.68 cm for RRb-11) and challenge inoculation (94.30 cm for RRb-103 and 98.93 cm for RRb-11) as compared to plant height (85.00 cm) in control (PB-1 treated with SDW and inoculated with *Xoo*).

PB 1 plants treated with RRb isolates followed by co/challenge inoculation with *Xoo* showed significant increase in dry matter both in the cases of co-inoculation (59.50 g $plant^{-1}$ for RRb-103 and 67.50 g $plant^{-1}$ for RRb-11) and challenge inoculation (63.75 g $plant^{-1}$ for RRb-103 and 68.25 g $plant^{-1}$ for RRb-11) as compared to dry matter (44.25 g $plant^{-1}$) in control (PB-1 treated with SDW and inoculated with *Xoo*).

Interaction between biotic elicitors (RRb-11 and RRb-103), PB 1 plants and *Xoo*, resulted in 2.2-fold increase in PAL activity as compared to PAL activity (1410.00 n mol t-CA g^{-1} f wt min^{-1} at 144 h after inoculation) in control (PB-1 treated and inoculated with SDW).

Effect of RRb* isolates on bacterial leaf blight of rice and plant growth promotion

Treatment	Disease intensity (%)** At 21 DAI	Plant growth parameters**		
		Plant height (cm)	Dry matter g $plant^{-1}$	Yield g m^{-2}
Pusa Basmati 1(PB1) + Water•	0.00	96.50	59.05	333.16
PB 1+ *Xoo*£	65.30	85.00	44.25	271.36
PB 1+ RRb-103***	0.00	101.25	61.50	375.96
PB 1+ RRb-103 + *Xoo* Co	28.94	94.10	59.50	357.25
PB 1+ RRb-103 + *Xoo* Ch	29.74	94.30	63.75	368.46
PB 1+ RRb-11***	0.00	103.38	72.00	398.00
PB 1+ RRb-11+ *Xoo* Co	17.21	97.68	67.50	390.90
PB 1+ RRb-11+ *Xoo* Ch	15.84	98.93	68.25	392.55
CD ± 0.05	1.56	3.36	4.58	49.71

* 10^7 cfu of bacteria used

** Average of 3 replications

*** Treatment was applied as seed bacterisation, root dip and foliar spray

Co = Co inoculation on (0 hrs); Ch = Challenge inoculation (8 hrs); DAI =Day after inoculation of *Xoo;* • = (Control =PB 1 treated and inoculated with sterile distilled water); £ =(Control =PB 1 treated with sterile distilled water and inoculated with *Xoo*)

4.1.4 Mushroom Cultivation

4.1.4.1 Biology and strain improvement in mushroom

Button mushroom. Gamma radiation treatment dose of 0.8 to 1.0 kGy enhanced the growth of *Agaricus bisporus* mycelium during spawn formation and reduced the spawn formulation period to 15 days from 17 days in untreated control. While treatment dose of 1.2 kGy and 1.4 kGy was found to retard its growth and spawn completion, the period was enhanced to 20 days.

However, when button mushroom spawn was treated with gamma radiation doses, no spawn run stage was observed in the case of 1.2 and 1.4 kGy treatment doses, while delayed spawn run and pinning was observed in the case of 0.8 and 1.0 kGy treatment dose of gamma radiation.

In these treatments, first pinning was observed after 70 days of spawning in comparison to 34 days in control.

4.2 ENTOMOLOGY

4.2.1 Insect Pest Management

4.2.1.1 Cereals

An experimental trial was undertaken to assess the efficacy of insecticides against rice pests. A foliar application of different insecticides, viz., endosulfan EC 33%, lambda cyhalothrin EC 5%, acetamiprid 0.4% + chlorpyriphos EC 20%, indoxacarb EC 15%, and monocrotophos EC 36% first 11 days after transplanting proved effective to control the incidence of leaf folder *Cnaphalocrosis medinalis*. A second spray 47 days after transplanting was also essential to control *C. medinalis* damage in all treatments. Indoxacarb treatment led to over 7% increase in yield over control.

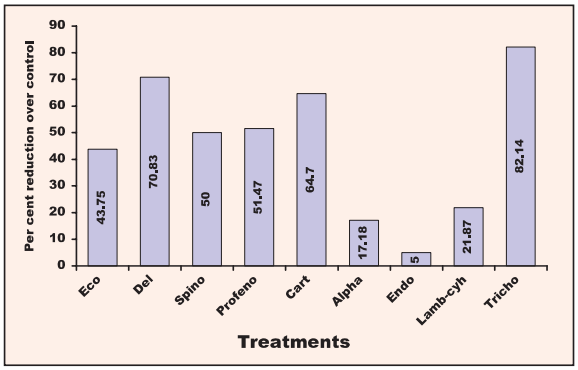
Sorghum lines, viz., AVHT 328, ICSV 705, ASSVT 14, SBRIL 66188 showed multiple resistance to shootfly, stem borer and *Pyrilla*, and P 44, P 63 and P 61 showed resistance to shootfly and stem borer. Studies on the identification of mechanisms of resistance in 3 lines of sorghum, *viz*., PGN 62, PGN 75 and PGN 86 resistant to shootfly and stem borer indicated the presence of non-preference for oviposition and the antibiosis for the two pests. Studies on the preference for oviposition by *Pyrilla* found that plant type affects egg laying. Non-tan type plants were more resistant as compared to tan type plants. IPM technology in sorghum based on seed treatment with neem oil @ 5 ml/kg seed followed by a spray of 5% neem seed kernel extract (NSKE) at 30 days after germination and 50% at flowering was found effective in controlling shootfly and stem borer. In *bajra*, three lines, *viz*., EAT 215, IPT 403 and IPT 413 were found resistant to stem borer and grey weevil.

4.2.1.2 Oilseeds

A total of 205 lines of germplasm /cultivars of mustard under three different trials were screened against *Lipaphis erysimi* during *rabi* 2004-2005. Aphid infestation index varied from 0.1 to 1.8 at flowering and 0.7 to 3.5 at pod formation stage. Peak population of aphids was observed during the ninth standard week. An insecticidal trial on two varieties of Indian mustard, Pusa Kalyani (*Brassica rapa* var. brown *sarson*) and Pusa Jaikisan (*B. juncea*) against *L. erysimi* indicated that although all the treatments with oxydemeton methyl, thiomethoxam and imidacloprid were effective on both the varieties, yet the benefit/cost ratio due to oxydemeton methyl treatment was higher being 15.6 in Pusa Kalyani and 17.0 in Pusa Jaikisan as against 5.3 to 9.3 obtained for other treatments. Pollination due to honeybees and other insect pollinators increased the seed yield by 25%, in mustard variety Pusa Gold.

4.2.1.3 Vegetables

In a field trial with cauliflower variety Pusa Snowball K-1, the release of *Trichogramma chilonis* HF- strain @ 50,000/ha followed by a foliar spray of Delfin™ @ 1 g/l gave maximum reduction of the diamond back moth *Plutella xylostella* population.



Efficacy of various treatments on larval populations of *P. xylostella* in cauliflower [Econeem™ (1ml/l), Delfin ™ (1g/l), Spinosad (17.5 g a.i./ha), Profenophos (500 g a.i./ha), Cartap ™ (500 g a.i./ha), Alphamethrin (25 g a.i./ha), Endosulfan (700 g a.i./ha), Lambda-cyhalothrin (25 g a.i./ha), and *Trichogramma chilonis* HF- strain @ 50,000/ha]

In another study with brinjal variety Pusa Kranti, three different crops, *viz*., maize, cowpea and radish, were used as border crops around brinjal. Two foliar sprays of either Econeem™ (1 ml/l) or Delfin™ (1g/l) were given. Per cent infestation by the shoot and fruit borer *Leucinodes*

Influence of habitat management and insecticides on the shoot and fruit borer *Leucinodes orbonalis*

Insecticide schedule	% Damage (on count basis)	% Damage (on weight basis)	Yield kg/25 m²
Maize (border crop) Delfin – Delfin Maize (border crop)	7.78 (16.03)	7.88 (15.37)	20.98
Econeem – Econeem	6.77 (14.18)	8.00 (15.22)	20.12
Cowpea (border crop) Delfin – Delfin	11.06 (19.25)	13.09 (21.04)	29.45
Cowpea (border crop) Econeem – Econeem	8.25 (16.49)	12.49 (20.34)	31.87
Radish (border crop) Delfin – Delfin	11.95 (19.93)	12.03 (22.74)	31.93
Radish (border crop) Econeem – Econeem	10.05 (18.27)	11.11 (19.14)	29.42
Control	12.45 (20.63)	15.12 (22.80)	22.92
S. Em ± CD (P =0.05)	1.94 5.99	2.56 7.898	4.65 14.32

orbonalis was minimum in treatment having maize as border crop followed by two foliar sprays of Econeem™ (6.77%).

Habitat management trial for insect pests of *okra* with maize as an intercrop showed higher yield of *okra* during *kharif* with minimum infestation (8 - 21%) of *Earias vitella*, compared to that of control with 80-100% infestation. *Okra* sown in summer season was almost free of fruit borer infestation.

Sex pheromone based modules for the management of brinjal fruit and shoot borer (BFSB) were evaluated. Use of sex pheromone trap, shoot clipping and 4 alternate sprays of neem seed kernel extract (4.0 %) and prophenphos @ 800 g a.i. /ha was found most effective in decreasing the infestation.

Incidence of insect-pests in vegetable crops sown/ transplanted during summer in hills was recorded. All the crops were damaged by cabbage cut worm in June. Potato aphid was recorded in okra in June, Diamond back moth (DBM) in cabbage from June-July, Frenchbean bug in July, cucurbits fly in squash and cucumber and BFSB in brinjal from August-September.

Cypermethrin (0.05 %) was found the most effective followed by carbosulfan (0.05 %) and prophenphos (0.05%) for the control of Frenchbean bug in main crop of Frenchbean cv. Contender.

Maximum infestation of different insect pests was observed in cabbage transplanted in June and infestation of DBM was recorded in all 4 planting but was maximum (66.82 per cent of plants) in July transplanted cabbage.

4.2.1.4 Soybean

Based on the yellow mosaic virus rating, DS 9814 and DS 9712 varieties of soybean could be identified as promising sources of resistance to whitefly attack. Results obtained on the efficacy of different insecticides revealed that seed treatment with thiamethoxam 70 WS @ 1 g/kg seed effectively controlled both stem fly infestation and yellow mosaic incidence transmitted by whitefly *Bemisia tabaci*.

4.2.1.5 Pulses

Seven biopesticide formulations, including three fungal ones (viz., *Metarrhizium anisopliae* @ 1 g/l, *Verticillium lecanii* @ 1 g/l, *Beauveria bassiana* @ 1 g/l), three *Bacillus thuringiensis* var. *kurstaki* wettable powder formulations (viz., Pusa golden (PG Bt), a laboratory prepared dry formulation @ 1 g/l, Biolep ™ @ 1 g/l and Lipel™ @ 1 g/l), and neem emulsion @ 8 ml/l, chlorpyrifos @ 2.5 ml/l and untreated control were used for the management of gram pod borer *Helicoverpa armigera* in chickpea during *rabi* 2004-2005. All the treatments proved to be significantly superior to control and reduced pod damage from 51.23% in untreated control to 8.82% in plots treated with PG (Bt) and chlorpyrifos followed by 13.21% in plots treated by Lipel™ and chlorpyrifos and 14.21% in plots treated with *B. bassiana* and chlorpyrifos. Among the treatments PG (Bt) and chlorpyrifos gave the highest yield (1200 kg/ha) as against 493.75 kg/ha in control followed by Lipel™ and chlorpyrifos (1025 kg/ha) and *B. bassiana* and chlorpyrifos (1006 kg/ ha). The treatments, viz., PG (Bt), *M. anisopliae* and chlorpyrifos, and chlorpyrifos provided substantial control of *H. armigera*, and reduced pod borer damage to 16.44, 16.89 and 17.41%, respectively, and were on a par.

4.2.1.6 Cotton

Field trials showed that *desi* types of cotton were tolerant to bollworms with minimum incidence compared to the hirsutum type. Insecticidal treatments with Spinosad @ 100 g a.i., /ha was effective in protecting the crop from the attack of bollworms and significantly increased the yield of seed cotton to 2985.5 kg/ha compared to 1039.5 kg/ha in untreated control. No phytotoxic effect could be seen.

Indoxacarb and abamectin tested against 5-day-old larvae of *H. armigera* and *Spodoptera litura* were more toxic to *H. armigera* (LC_{50} 0.0023% and 0.0026 %, respectively) than to *S. litura* (LC_{50} of 0.0064% and 0.0113%, respectively).

4.2.1.7 Storage entomology

Microwave heat disinfestations studies revealed that exposure for 40 seconds at a power of 320 Watt resulted in cent per cent mortality of adults of *Callosobruchus chinensis*, *Rhizopertha dominica* and *Sitophilus oryzae*, whereas the same mortality in the case of *Tribolium castaneum* could be achieved in 30 seconds. *R. dominica* adults exposed to citronella oil for 24 hours at a dose of 0.8697 µl/l resulted in 96.9% mortality but a higher dose of 7 µl/l caused 90.9% mortality of *Sitotroga cerealella* adults.

Toxicity of dichlorvos was studied against *T. castaneum* collected from two NSP centres at Coimbatore, Tamil Nadu and Kalyanpur, Uttar Pradesh. The respective LC_{50} values of 0.04 and 0.071% were slightly higher than the LC_{50} of 0.034% for the susceptible laboratory strain.

4.2.2 Biological Control

Field studies on the effect of mixed cropping ecosystem involving eight different crops, *viz.*, gram, lentil, tomato, maize, potato, pea, vegetable pea and French bean on the foraging capacity of three species of *Trichogramma*, viz., *T. brasiliensis*, *T. chilonis* and *T. exiguum*, indicated that irrespective of the *Trichogramma* species, the maize crop (63.67) showed the highest response followed by pea (32.56). Among the three trichogrammatids, *T. exiguum* (34.79)

Mean parasitism of different species of *Trichogramma* in mixed cropping ecosystem

Crop	No. of eggs parasitized over 48 h period (Mean of 30 observations)			
	T. chilonis	*T. exiguum*	*T. brasiliensis*	Mean
Gram	5.00	6.00	10.00	7.00[a]
Lentil	11.67	5.67	11.00	9.44[a]
Tomato	4.33	29.00	0.00	11.11[a]
Maize	27.00	132.00	32.00	63.67[b]
Potato	3.33	31.00	39.00	24.44[a]
Pea	11.00	14.00	72.67	32.56[a]
Veg. pea	11.67	32.33	16.67	20.22[a]
French bean	52.67	28.33	9.67	30.22[a]
Mean	15.83[a]	34.79[a]	23.87[a]	

Figures with the same letter in column or row do not show statistically significant differences

showed maximum response in the mixed cropping system.

T. castaneum and *Drosophila melanogaster* larvae were identified as better alternate hosts for mass multiplication of the predator *Chrysoperla carnea* as against eggs of *C. cephalonica*. Standardization of host rearing techniques showed an optimum population of 100 pairs of adults of *T. castaneum* to produce more biomass in terms of both number (2265.00) and weight (244.30 mg) in 150 g of wheat flour over a period of 20-24 days.

A zero energy economically viable cooling chamber technology named as Entocool, was developed for rearing of insects including the predator *C. carnea* at farm level.

Field observations at various north Indian locations, viz., Jammu, Jabalpur, Dehradun, Haridwar and Delhi, showed adaptation of *Zygogramma bicolorata* released for the control of pernicious weed *Parthenium*. The various types of soils at these places did not have any impact on their pupation / survival. The Delhi population of *Z. bicolorata* survived better compared to other populations while fecundity was the highest in the case of Jammu population.

4. 2. 3 Insect Physiology

Investigations on baseline susceptibility of neonates of *H. armigera* collected during winter season of 2005 from Hyderabad, Satna, Delhi, Rahuri, Hisar, Karnal, Faridkot, and Panchkula to *B. thuring*iensis Cry1Ac toxin indicated a 14-fold range of susceptibility.

Susceptibility of *H. armigera* neonates to *Bacillus thuringiensis* toxin Cry1Ac

Place of insect collection	Date of bioassay	LC_{50} µg/gm of diet	Fiducial limits at 95%	Resistance ratio
Hyderabad	Mar. 1, 2005	1.30	0.8-2.0	4.1
Satna	Mar. 29, 2005	3.58	2.0-8.4	11.2
Delhi	Mar.25, 2005	4.50	2.8-8.7	14.1
Rahuri	Mar.31, 2005	0.68	0.4-1.1	2.2
Hisar	May 28, 2005	1.13	0.7-2.2	3.5
Karnal	June 13, 2005	1.06	0.5-3.7	3.3
Faridkot	June 20, 2005	0.32	0.1-0.6	1.0
Panchkula	June 20, 2005	3.09	1.2-21.1	9.7
Hyderabad	May 19, 2005	0.310.	2-0.7	1.0

An allelochemic, solasodine hydrochloride was found to be adversely affecting the growth and development of *L. orbonalis* at the lowest concentration of 2 mg/100 ml of diet. The adult emergence was also drastically reduced at 25 mg/ 100 ml of solasodine hydrochloride incorporated in the diet.

Effect of solasodine hydrochloride on growth and development of brinjal fruit borer *Leucinodes orbonalis*

Treatment mg/100ml	% pupation	Larval period (days)	Growth index	Per cent adult emergence
Control	66.67	22.50	2.96	66.67
2	33.33	27.80	1.19	26.67
5	40.00	22.16	1.81	30.00
10	43.33	24.46	1.77	33.33
25	13.33	34.50	0.39	13.33
50	23.33	29.14	0.8	20.00
75	23.33	28.29	0.82	16.66
CD (P=0.05)	12.57	2.8		15.41
CD(P=0.01)	16.86	3.7		20.68

An improved semisynthetic diet formulated for *Chilo partellus* with 3% maize leaf powder and 6% of casein supported its growth and development with 7% increase in pupation and 13.9 per cent increase in fecundity.

4.2.4 Insect Toxicology

The relative susceptibility of *S. litura* and *H. armigera* to various insecticide mixtures, viz., Virat™, Bulldockstar™, Anaconda™, Polytrin C™, Ducord™, Nurelle D™, Spark™, Nagata™, Spectrum™, Super D™ and Koranda™ was evaluated. *H. armigera* was relatively less susceptible to all the combination products except Virat™, Polytrin C™, Spectrum™ and Koranda™. *S. litura* was least susceptible to Virat ™, Polyrin C™, Spectrum™ and Koranda™.

Antifeedant and growth inhibitory activities of five neem based formulations, viz., Aza 20%, Econeem™ 0.3%, Achook™ 0.15%, Vijayneem™ 0.15% and neem oil were studied against cabbage butterfly *Pieris brassicae*. It was observed that Aza showed consistently high efficacy both in antifeedancy and growth inhibition. The EC_{50} (%) for antifeedant activity after 48 h was least in Aza (0.001392) followed by Econeem™ (0.002711), Achook™ (0.003821), Vijayneem™ (0.004188) and neem oil (0.007001), respectively. The same trend was also observed in growth inhibitory activity.

Toxicity of chlorpyrifos-methyl was evaluated against three species of pulse beetles, viz., *Callosobruchus maculatus*, *C. analis*, *C. chinensis* and three strains of rust

red flour beetle *T. castaneum*, viz., susceptible laboratory strain, malathion resistant strain and deltamethrin resistant strain. Pulse beetles were more susceptible than all the strains of *T. castaneum* to chlorpyrifos-methyl.

4.3 NEMATOLOGY

4.3.1 Biodiversity

4.3.1.1 Plant parasitic nematodes

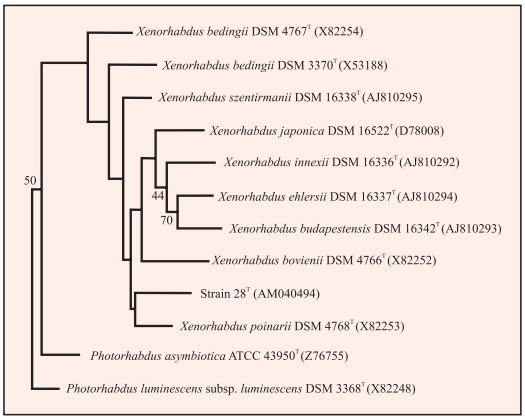
During an extensive survey undertaken in Almora, Bageshwar and Pithoragarh districts of Uttaranchal state for monitoring the nematode diversity in different cropping systems being followed in the region, more than one hundred soil samples were drawn from various fields under different cropping systems. In Almora, both rice and maize were the main crops with the scattered presence of some pulse crops. The analysis of the soil samples taken from rice revealed the dominating occurrence of *Helicotylenchus dihystera* followed by *Tylenchorhynchus mashhoodi* and *Pratylenchus zeae*. The presence of the cyst nematode *Cactodera* sp. in high population in fields having maize crop in Shaher Phatak village was another revelation of nematode diversity in this district. The root-knot nematode *Meloidogyne* sp. was also found infesting turmeric crop. The presence of *Paratylenchus* sp. was also detected in rice fields in Almora district.

The cereal cyst nematode infestation caused by *Heterodera avenae* was found in wheat for the first time in Narela village in northern Delhi. Earlier, this infestation was found restricted to two villages- Pandwala Khurd and Pandwala Kalan of Najafgarh block.

The root-knot nematode *M. incognita* was identified as a serious nematode problem (with nematode population @ 15 J2/cc soil) in vegetable cultivation (okra, tomato, cucurbits) in Rohtak, Bahadurgarh, Panipat and Karnal areas while gladiolus was found to be highly infected with *M. incognita* in Ghaziabad and Bulandshahr districts of Uttar Pradesh.

In Darjeeling district of West Bengal, two important plant parasitic nematodes, *Atlantodorus porosus* and *Xiphinema elongatum*, were found associated with tea as well as ginger and cardamom, respectively.

In continuous soil sampling at a regular interval in polyhouses of Indo-Israel Project at IARI for the last few years, it was observed that pepper (cv. NUN 3020) was least damaged by root-knot nematode infestation while tomato (cv. R 144) and cucumber were the most severely affected. About 20% damage in tomato/cucumber crop was observed because of *M. incognita*.



Phylogenetic dendrogram obtained by distance matrix analysis of 16S rDNA sequences showing the position of *Xenorhabdus indica* sp. nov. strain 28T among phylogenetic neighbours

4.3.1.2 Entomopathogenic nematodes

Baiting of the collected soil samples with greater wax moth larvae (*Galleria mellonella*) revealed the presence of saprophagous nematodes *(Rhabditis terricola* and *Diplogasteritis lineatus)* in 6 samples from Darjeeling; and two populations of entomopathogenic nematodes, one each of *Steinernema* sp., and *Heterorhabditis* sp. from Meghalaya and Darjeeling, respectively.

The symbiotic bacterium associated with entomopathogenic nematode species *Steinernema thermophilum* was found to be a new species based upon its morphological, cultural, biochemical and molecular characteristics, and the new species is named *Xenorhabdus indica*. Distance matrix analysis of 16S rDNA of all other species in the genus revealed its closest phylogentic relationship with *X. poinarii* and *X. szentirmaii*, each having 97.7% similarity in 16S rDNA. The new species of *Xenorhabdus* is the tenth species of this genus in the world, but first species from this country.

4.3.2 Mechanism of Resistance

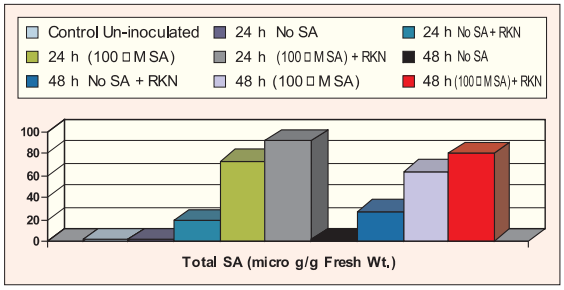
4.3.2.1 Role of salicylic acid

Eleven promising genotypes of chickpea were screened against root-knot (*Meloidogyne incognita*) nematode for resistance and were characterized as resistant, moderately resistant, and susceptible. Out of 11 genotypes, all were moderately resistant except Pusa 362, which was susceptible. Estimation of salicylic acid (SA) was done by spectrophotometer. The results showed that the moderately resistant varieties Pusa 267 and Pusa 391 had higher content of SA, 16.61 and 15.63 ppm/g sample, respectively, compared to the susceptible variety Pusa 362 (12.55 ppm). Moreover, the SA content in roots (12.55 – 16.61 ppm/g sample) was

more as compared in the shoots which ranged between 10.21 and 11.38 ppm. Therefore, the SA may have a positive role in resistant mechanism in chickpea.

4.3.2.2 Increase in salicylic acid at the onset of systemic acquired resistance in cowpea and tomato

Spectrophotometric analysis showed higher accumulation of salicylic acid (SA) in cowpea shoots and roots irrespective of application method (spray or drench). However, when applied along with carbofuran (@ 1kg a.i./ha), there was a sharp increase in the SA accumulation in shoots but when the concentration of both increased (SA @ 100 ppm and carbofuran (@ 1.5 kg a.i./ha) the accumulation decreased. In the case of tomato, the total SA increased with the inoculation of *M. incognita*.



Effect of systemic acquired resistance on total SA in tomato

4.3.2.3 New quantification method of amino acid and salicylic acid

A gas chromatographic (GC) method for quantification of 16 amino acids following derivation to vaporizable and stable derivatives under aqueous alkaline conditions was developed. The method is simple, fast, sensitive, rapid, cost-effective and a precise method for routine analysis of amino acids as against the common liquid chromatography with fluorescent or UV detection after derivation. The technique satisfactorily measures the typical amino acids (aspartate-aspargine, glutamate-glutamine, alanine, leucine, phenylalanine and lysine) generally employed for identification and quantification of a protein and compromises as in the case of other techniques for poor sensitivity/recoveries due to partial (serine and threonine) or complete (tryptophan) destruction and incomplete bond cleavage (val-val), unreactive guanidino group (arganine) or low extractability (tyrosine) because of its polarity.

The method was extended for quantitation of salicylic acid, the signal transduction molecule in SAR without any interference due to other plant growth regulators and at a sensitivity many fold higher than HPLC. However, tryptophan and tyrosine could be satisfactorily analysed by LC-UV (Liquid chromatography with UV detection) without any derivation. The method is being exploited to quantify free and bound amino acids from tomato plant matrices.

α-Tomatine, a steroidal glycoalkaloid in tomato is synthesized from its aglycon tomatidiene (a cholosterol derivative) by glycosylation to impart resistance against phytopathogens. Very little information is available regarding its effect on nematode resistance. The studies using liquid chromatography could well correlate high levels of α-tomatine in tomatoes with resistance to root-knot nematode *Meloidogyne incognita* in field.

4.3.3 Nematode Management

Out of 6 fungal bio-agents (*Aspergillus fumigatus*, A. *terreus*, *Trichoderma harzianum*, *Sepodonium mashewarium*, *Pacelomyces lilacinus*, *Aspergillus nidulans)* tested, *A. fumigatus* was found to be more effective in suppressing the nematode population, thereby increasing the plant weight of mungbean in field, followed by carbofuran 3 G applied in rows. Among *Aspergillus* spp. tested, *A. fumigatus* was most active followed by *A. nidulans* and *A. terreus* and enhanced the plant biomass as compared to control.

Evaluation of fungal bioagents against root-knot nematode

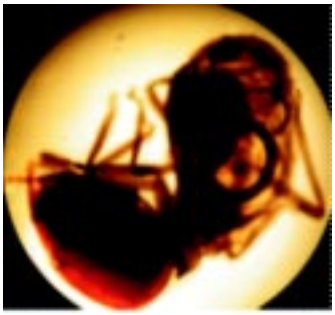
Fungal bio-agents	Nematode population (100 ml)			Total plant weight (kg)
	Initial	30 days	At harvest	
Trichoderma harzianum	396.6	190.0	163.0	1.60
Aspergillus fumigatus	350.0	60.0	116.0	2.25
A. terreus	413.3	180.0	143.0	1.31
A. nidulans	366.6	180.0	126.0	1.67
Sepodonium mahewharium	430.0	50.0	263.0	1.35
Pacelomyces lilacinus	363.3	120.0	213.0	1.67
Carbofuran	430.0	100	110.0	2.21
Control	390.0	360	396.0	1.10

Kalisena and *T. harzianum*, as seed dresser, were more effective in combined application with carbofuran as it reduced root knot galling by 20-50% in comparison to their lone application (10-20%). Comparatively, *T. harzianum* was better than Kalisena in reducing the root knot damage in combined application and *vice versa* was true in lone treatments. Increase in dose of bioagents apparently did not show better effect in reducing root knot damage.

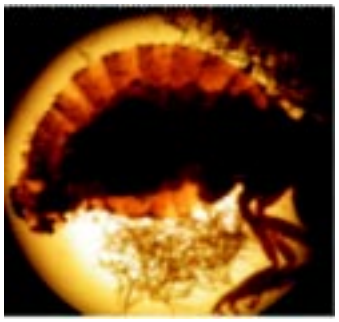
Calotropis sp. and neem oil alone mitigated root-knot galls by 62%. In combined application, reduction in nematode multiplication was not enhanced as against that achieved in lone treatments. Neem oil, *T. harzianum* and *Dhatura* in combined application decreased root-knot galling to a maximum by over 70%. Application of neem based formulations, viz., neemark, neemgold and nimbecidine @ 5% and 10% v/w and neem seed powder @ 5% and 10% w/w as seed coating proved nematicidal against *Heterodera cajani* in pigeonpea.

4.3.4 Entomopathogenic Nematodes for Termites Management

Pathogenicity of entomopathogenic nematodes was demonstrated against subterranean termites *Odontotermes* sp., which is a serious threat to agriculture and wooden materials. Baiting stubs prepared from bamboo sticks and newspapers were exposed to termite infestation by placing them on the termatarium. The stubs were transferred in jars and treated with three indigenous isolates of EPN, viz., *Steinernema* A, *Steinernema* B and *Hetrorhabditis indica*. *Steinernema* A was most virulent imparting 16.6% mortality as early as 8 h after inoculation, which gradually increased to 33.3% (12h) and 66.6% (16h). Complete mortality (100%) was observed within 20 h in all the treatments. The median time revealed the virulence potential of the three isolates as *Steinernema* A (13.1 h) > *H. indica* (14.9 h) > *Steinernema* B (15.7 h). The cadavers showed the presence of nematode developmental stages. The nematode life cycle completed within 7-10 days in different isolates.



Developmental stages of *Steinernema* A inside the cadaver



Emergence of *H. indica* infective juveniles

4.3.5 Toxicity of Biological Control Agents

Three isolated fractions of toxins from *Trichoderma harzianum* were tested for their toxicity against second stage juvenile of root-knot nematode (*Meloidogyne incognita)*. Only two fractions of toxins were toxic.

Effect of fractions of toxins from *Trichoderma harzianum* on mortality of root-knot nematode

Toxin fraction	Observations
PD7	No toxicity/ immobility till 96 h
6 pentyl α pyrono	Instant mortality
6 pentyl α pyrovo (analogue of 6 pentyl α pyrono)	Instant mortality
Control (Tergitol)	No toxicity/ immobility till 96 h

4.4 AGRICULTURAL CHEMICALS

4.4.1 Development of Natural and Synthetic Agrochemicals and their Adjuvants

4.4.1.1 Botanical pesticides

Nematicidal activity of Tinospora cordifolia. Hexane, chloroform, methanol and water extracts of stems of *Tinospora cordifolia* were evaluated for their nematicidal activity against root-knot nematode *Meloidogyne incognita*. The chloroform extract exhibited 98.7% mortality after 72 h. The fractionation of chloroform extract yielded two alkoloids, palmatine and tetrahydropalmatine which gave 100% mortality at 500 ppm as compared to 78.5% mortality in cultural filtrate of *Aspergillus niger*.

Antifugal activity of essential oil of Piper longum. The fruits of *Piper longum* belonging to family piperaceae were subjected to hydro-distillation to yield essential oil and dihydrocarveol, which were assayed against three phytopathogenic fungi, namely, *Sclerotium rolfsii*, *Pythium debaryanum* and *Alternaria alternata*. The essential oil exhibited more activity against *S. rolfsii* and *A. alternata* with ED_{50} of 189 and 187 mg ml^{-1}, respectively. However, dihydrocarveol exhibited minimum activity.

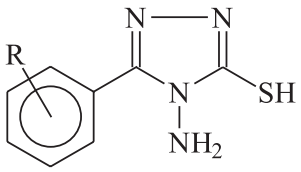
Neem oil ingredients as nitrification inhibitors. Twenty-five samples of neem oils with different background (source, method of preparation, age of sample, etc.) showed significant nitrification inhibitory activity. Neem formulations procured from the market were the best followed by expeller grade neem oils.

Azadirachtin, salannin, nimbin, desacetyl salannin, desacetyl nimbin, etc., isolated from neem oil were screened for their effect on nitrification. All of them at 5000 ppm of urea concentration inhibited nitrification up to 10 days of incubation.

Neem leaf volatiles as insecticides. The GC-MS spectra of the leaf volatiles revealed the presence of more than 20 compounds, out of which major constituents were identified as trithiacyclodecanone; trithiacyclohexane; propyl propenyl di-, tri-, and tetrasulfides; tetrathiacyclodecane, longifolene, and 2,3-butanediol, 2-propanone and 3-hydroxy-2-butanone. The volatiles were evaluated for their fumigant activity against the pulse beetle *Callosobruchus maculates* and the red flour beetle *Tribolium castaneum*. Complete adult mortality (100 %) of *C. maculates* was observed at a concentration of 200 µl/l whereas in the case of *T. castaneum* it was 600 µl/l after one-hour exposure period.

4.4.1.2 New synthetic products

Aminomercaptotriazoles as fungicides and nitrification inhibitors. Twenty-eight 5-aryl-4-amino-3-mercapto-1,2,4-triazoles were synthesized. Besides their fungicidal potential,



these compounds showed remarkable nitrification inhibitory activity. Three of these, viz., BGT 2, BGT 26 and BGT 28 exhibited excellent nitrification inhibitory activity over a long period of time and were comparable to N-Serve®, a commercial nitrification inhibitor. Six new pyrazole derivatives were synthesized. Their fungicidal activity is being evaluated.

Schiff bases as fungicides and nematicides. Seven Schiff bases were synthesized and evaluated for their fungicidal (against *Rhizoctonia bataticola* and *Sclerotium rolfsii*) and nematicidal (against reniform nematode *Rotylenchulus reniformis* Linford and Oliveira) activity. *N*-propyl-2-hydroxyacetophenonimine was found to be most active against both *R. bataticola* (EC_{50} 12.99 ppm) and *S. rolfsii* (ED_{50} 28.87 ppm) followed by *N*-hexyl-2-hydroxyacetophenonimine (ED_{50} 180.01 and 64.27 ppm, respectively). However, the nematicidal effect of these Schiff bases was not as pronounced as fungicide. Of the seven the compounds tested against *R. reniformis*, the compound *N*-propyl-2-hydroxyacetophenonimine was again found to be most active (LC_{50} 130.4 ppm) followed by *N*-hexyl-2-hydroxyacetophenonimine (LC_{50} 192.3 ppm).

Furyl oxadiazoles as nitrification inhibitors. The effects of temperature and source of nitrogen on the potency of nitrification inhibitor furyl oxadiazoles were studied. The nitrification inhibitory activity of the oxadiazoles decreases with the increase in the temperature from 25 to 35° C but it remains comparable with the reference inhibitor, nitrapyrin.

Chemical hybridizing agents (CHA). Microwave assisted synthesis of ethyl 4-fluoro oxanilate (EFOA), the CHA, was achieved without the use of any organic solvent. All the three promising CHAs were found not to affect female fertility of wheat lines tested. Eleven salts of 1, 4-diazabicyclo (2, 2, 2)-octane (DABCO) were prepared by monoalkylation with alkyl, allyl, propargyl and benzyl bromides and the salts as seed treatment were found to be safe to wheat seeds in terms of germination and seed vigour. However, the seed treatment even up to 3000 ppm did not induce male sterility. None of them was found ineffective as CHA on wheat. Three promising CHAs did not affect female fertility of wheat when tested up to 1500 ppm spray concentration.

Hydrogels. Swelling studies of two series of synthesized hydrogels based on acrylonitrile (CH_2 = CG – CN) and acrylomido methyle propane sulfonic acid were completed and the reaction parameters optimized. It was observed that acrylonitrile based hydrogels showed better swelling in water at pH 7 (9750%) and temp. 4°C, time 24 h as compared to the hydrogel based on acrylamidomethyl propane sulfonic acid (9000% pH 7, temp. 40°C, time 24 h).

4.4.2 Pesticides: Risk Assessment, Environmental Fate and Remedies

4.4.2.1 Supervised field trials for pesticide risk assessment

Persistence of propargite in tomato. Propargite, a miticide was applied to tomato crop at the recommended rate of application at the time of flowering and 50% fruit formation stage. Residues in fruits were monitored till 15 days after second application. Residues dissipated with a half-life of 5 days on tomato fruits.

Persistence of sulfosulfuron in wheat field soil. Sulfosulfuron, a herbicide was applied to wheat crop at recommended rate (25 g ha^{-1}) and double the recommended rate (50 g ha^{-1}) of application. The terminal residues in harvest soil were found below detectable limits (0.001µg/g) when analyzed by HPLC. Therefore, bioassay of harvest soil was carried in pots with bottle gourd as indicator plants to find out the carry over effect of this herbicide. On the basis of fresh weight, root and shoot length, no phyto-toxicity was observed to bottle gourd plants till 20 days after germination.

Persistence of imidacloprid in paddy, cotton and mustard. Field experiments were conducted to study the residues of imidacloprid at harvest time in grains, paddy straw, cottonseed and lint and soil samples when applied @ 24.5 and 49.0 g a.i. ha^{-1} from WG formulation. Residues of imidacloprid were nondetectable in grains, paddy straw, cottonseed, lint and soil samples while in the case of mustard, residues were nondetectable after 75 days of sowing from seed treatments (4.9 and 9.8 g a.i. kg^{-1}seed) with 70 WS formulation. The TMDI values for cottonseed oil, rice and mustard were found lower than the maximum allowable intake.

Persistence of deltamethrin in okra. The initial residues of 0.58 mg kg^{-1} of deltamethrin in okra fruits reduced to nondetectable level on the 7th day after application while in the case of tomato fruits, the residues were not detected on the 10th day. The insecticidal schedules appeared safe and consumption of okra and tomato fruits was safe after 5 and 7 days of treatment, respectively.

Persistence of thiamethoxam and acetamiprid in gram. Following seed treatment, though the residues of both thiamethoxam and acetamiprid translocated to plant parts but no residues were detected in grains and fodder at harvest.

Persistence of imidacloprid and thiamethoxam in rice. Following root dipping treatment, the residues of both imidacloprid and thiamethoxam translocated to aerial part of plant and persisted up to 15 days. However, no residues were detected in grains at harvest.

Persistence of carbosulfan, carbofuran and thiamethoxam in sorghum. No residues of carbosulfan,

carbofuran and thiamethoxam were detected in sorghum grains and fodder at harvest.

Persistence of thiacloprid in tomato. Thiacloprid (Calypso 240SC) applied on tomato (var. DT-39) persisted up to 15 days after application. The half-life recorded was 3.6-5.4 days at both the application rates respectively. Thiacloprid (Calypso 240 SC) applied on cabbage (var. Golden acre) persisted up to 10 days. The half- life recorded was 5.68-6.15 days.

Persistence of thiamethoxam and acetamiprid in mustard. Thiamethoxam (Actara 25W) and acetamiprid (Pride 20SP) applied as foliar application on mustard (var. Pusa Bold) persisted beyond 15 days in leaves. The residues were below the detectable limit (0.05 mg/kg) in harvest grains. The half-lives of thiamethoxam and acetamiprid in mustard leaves and pods were 3-4 and 8.36-9.56 days, respectively.

4.4.2.2 Environmental fate of pesticides

Persistence and leaching of NNI in soil. NNI dissipated very slowly under laboratory condition with 30.3-57.8% dissipation on the 60th day. There was no significant effect of different moisture regimes and the dissipation was faster at 1 ppm level of fortification than at 10 ppm level. NNI showed low leaching potential. Even after infiltration of 2.5 litre water (equivalent to ~65 cm rainfall), the major amount (>90%) of the applied pesticide remained in top soil (15 cm depth).

Persistence of acetamiprid in soil. The studies on dissipation of acetamiprid in soil under different moisture regimes revealed that the dissipation was faster under field capacity ($T_{1/2}$-3-5 days) than under submerged condition ($T_{1/2}$ -19-30 days). No appreciable degradation occurred under dry condition.

4.4.2.3 Analytical methods

Improved method for residue analysis of beta cyfluthrin in cole crops and soils. A simple GLC method for the analysis of beta cyfluthrin in cauliflower, cabbage and soil was improvised and standardized. Recoveries were quantitative in the case of cauliflower curd and its leaves, cabbage head and soil involving different solvents for extraction and clean up by liquid-liquid partitioning followed by column chromatography.

HPLC method for estimation of thiamethoxam from four soils and five vegetables. A simple method using acetone as extraction solvent followed by hexane partitioning for clean up was developed for thiamethoxam. Residues were analysed by gradient elution on RP-18 column using PDA detector. The recoveries were quantitative when validated for five vegetables and four soils.

Water based microwave assisted extraction of thiamethoxam and metsulfuron methyl from soil. A new organic solvent free extraction method was developed for thiamethoxam and metsulfuron methyl using water as extraction solvent and microwave energy and SPE. The recoveries were more than 90%. The method was time saving, environment friendly and cost-effective.

4.4.3 Improvement in Safety and Efficacy of Pesticide Formulations

4.4.3.1Controlled release formulations of carbofuran and their bioefficacy evaluation

Controlled release formulations of carbofuran (3 % a.i.) in the matrix of a polymer polyvinyl chloride (PVC-3), carboxy methyl cellulose (CMC-3) and carboxy methyl cellulose-kaolinite (CMC-Kaolinite-3) were developed and their bioefficacy against the rice leaf folder *Cnaphalocrocis medinalis* was evaluated in comparison with commercial formulation 3G in fields. The controlled release formulations at half the doses provided significantly superior control of *Cnaphalocrocis medinalis* and yielded higher grain yields as compared to their commercial formulation. The residues were estimated in straw and rice grains at harvest. The mean residue values of carbofuran CMC granules were higher than those of both commercial formulation and PVC formulations but below the MRL level.

4.4.3.2 Development of seed coats

Polymer based seed coating formulations with or without azadirachtin was developed and compared with commercial formulation of thiram and azadirachtin concentrate for seed quality enhancement of soybean seed under storage. The polymer coats have acted as moisture barriers and checked the degradation of azadirachtin. Apart from this, the polymer coatings have also prevented the proliferation of storage fungi over the period of storage. Among all the polymers tested PEM, PVAc and PVP were found to be significantly superior (P = 0.01) in maintaining the soybean seed quality during storage.

4.4.3.3 Tablet formulations of imidacloprid

A tablet formulation PUSAIMIDA 5 TB was developed for the systemic neo-nicotinoid insecticide - imidacloprid - for use in soil application. This is a novel type of formulation developed for occupational safety to farmers replacing the granules. The tablets were tested for their attrition qualities, active ingredient content, accelerated storage, etc. The tablets could stand a crushing pressure of 15 kg/cm^2 and met the requirements for stability of active ingredient content on accelerated storage. The size, shape and attrition quality of the tablet are designed to make it suitable for application at the time of sowing along with seeds using IARI-seed-drill in cash crops like cotton, one-time plucking crops, like maize, sorghum, etc., and other crops, like tomato provided

imidacloprid dissipates in the soil before the plucking starts. The bio-efficacy and release in the soil are under evaluation.

4.5 WEED MANAGEMENT

4.5.1 Weed Management in Conventional as well as Zero Tilled Wheat

Considering the results of last year, chemical treatment with lower doses of metribuzin and sulfosulfuron was dropped this year. Out of the seven different treatments compared, it was observed that application of Isoguard plus after first irrigation for control of weeds in conventional as well as zero tilled wheat was better option than other chemicals tested. Treatment with this chemical resulted in almost 60% increase in yield compared to that of weedy check.

4.5.2 Weed Management in Soybean through Use of Low Dose Herbicides

An investigation was undertaken to evaluate the efficacy of low dose herbicides in controlling weeds in soybean. The dominant weed flora were: *Trianthema portulacastrum, Digera arvensis, Commelina benghalensis, Cyperus rotundus, Dactyloctenium aegyptium, Echinochloa colonum, Echinochloa crusgalli* and *Cynodon dactylon*. All weed control treatments markedly reduced the population and dry matter accumulation of weeds. The maximum reduction in weed growth was observed in repeatedly weeded plot. Among

Effect of low dose herbicides on weeds and seed yield of soybean

Treatment	Dose (g a.i./ha)	Weed population (no./m^2)	Weed dry weight (g/m^2)	Seed yield (t/ha)
Weedy check	-	322	936.3	0.63
Repeated weeding	-	25	48.5	2.00
Pendimethalin (pre-em)	1000	93	183.7	1.50
Pendimethalin (pre-em)	1500	65	151.2	1.62
Quizalofop (at 20 DAS)	50	105	500.8	0.85
Quizalofop (at 20 DAS)	75	92	483.3	0.89
Chlorimuron (at 20 DAS)	6	98	212.4	1.35
Chlorimuron (at 20 DAS)	9	68	131.0	1.60
Chlorimuron (at 20 DAS)	12	58	125.4	1.79
Imazethapyr (at 20 DAS)	50	96	215.5	1.50
Imazethapyr (at 20 DAS)	75	81	119.3	1.77
Imazethapyr (at 20 DAS)	100	66	116.2	1.89
SEm ±		5	13.9	0.09
CD (P=0.05)		16	40.9	0.28

the herbicides tested, chlorimuron ethyl @ 12 g/ha and imazethapyr @ 100 g/ha caused the highest reduction in weed population and weed dry matter accumulation, respectively. However, post-emergence application of chlorimuron-ethyl @ 9-12 g/ha and imazethapyr @ 75-100 g/ha, and pre-emergence application of pendimethalin @ 1500 g/ha was statistically on a par in reducing weeds growth. Significantly higher seed yield was recorded under repeated hand weeding, closely followed by imazethapyr application @ 100 g/ha. Higher doses of imazethapyr (75-100 g/ha), chlorimuron ethyl (9-12 g/ha) and pendimethalin (1500 g/ha) resulted in higher seed yield of soybean compared to those of other treatments.

4.5.3 Integrated Weed Management in Onion Seed Crop

Pendimethalin + hand weeding and oxyfluorfen + hand weeding were the best treatments to control broad leaf weeds compared to all other herbicide treatments and weedy check. All the herbicidal treatments alone or in combination with hand weeding and straw mulch recorded significantly higher seed yield compared to weedy check. Germination percentage of progeny seed was not affected. The weed management treatments produced bolder seeds resulting in increased seedling length and dry weight.

Effect of integrated weed management on seed yield of onion

Treatment	Weed density	Weed dry weight (mg)	Seed yield (kg/ha)
Mulching (Paddy straw)	16.8	39.825	124.9
Fluchloralin @ 1.0 kg/ha +HW	18.5	35.824	160.5
Fluchloralin @ 1.5 kg/ha	29.5	62.458	116.8
Alachlor @ 1.0 kg/ha +HW	19.5	40.018	134.4
Alachlor @ 2.0 kg/ha	36.0	79.366	81.42
Pendimethalin @ 1.0 kg/ha +HW	13.3	19.609	165.2
Pendimethalin @ 1.5 kg/ha	16.8	26.813	118.5
Oxyfluorfen @ 0.15 l/ha +HW	16.5	18.789	171.5
Oxyfluorfen @ 0.30 l/ha	21.3	44.173	125.4
Hand weeding at 30 and 60 DAP	20.0	25.023	130.9
Weedy check	96.0	105.380	56.10
CD (P=0.05)	20.60	26.27	19.01

4.5.4 Integrated Weed Management in Muskmelon

Cyperus rotundus, the most dominant weed (60% of the total weeds) was effectively controlled with glyphosate (1.0% and 0.5%) and polythene mulch (700 microns). The treatments resulted in significantly higher seed yields compared to those of hand weeding and weedy check. Seed quality under the weed control treatments was significantly superior in terms of germination and low electrical conductivity of seed leachate. Seedlings from polythene mulch and glyphosate treatments showed higher vigour.

Effect of integrated weed management on seed yield and quality of muskmelon

Treatment	Weed dry weight (g/0.25 m^2)	Seed yield (kg/ha)	Germination (%)	Seedling dry weight (mg)
Glyphosate 1%+ hoeing	3.88	107.9	84.0	11.22
Glyphosate 0.5%+ hoeing	6.15	82.05	87.0	11.05
Polythene mulch 700µ	2.67	105.9	91.5	11.07
One HW	26.75	40.3	88.0	8.84
Two HW	8.15	72.2	91.5	10.25
Weedy check	64.03	9.15	62.0	7.33
CD (P= 0.05)	37.08	35.5	8.67	1.97

5. BASIC AND STRATEGIC RESEARCH
(Covers partly NRCPB)

5.1 PLANT BIOTECHNOLOGY

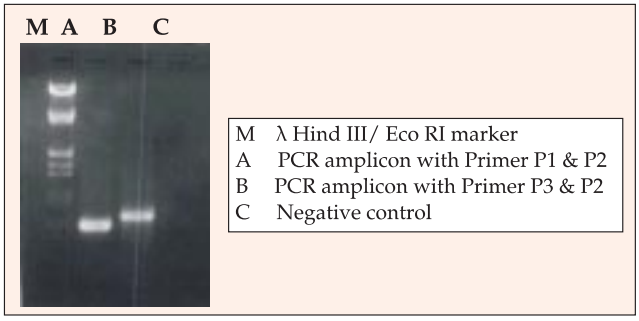
5.1.1 Isolation of Genes and Promoters for Development of Transgenics

5.1.1.1 Characterization of protease inhibitor (PI) protein from mungbean and chickpea

Protease inhibitor at different stages of germination and seed development was monitored in mungbean and chickpea. The PI proteins were isolated from mungbean and chickpea at different stages of germination. These were found to be active during dormant and germination stages. It suggested that PIs play an important role in preventing the seeds being attacked by pests and pathogens. The PI proteins accumulated at different stages of development. In mungbean, they were active 24 days after flowering (DAF) and the maximum accumulation was 30 µg of seed while in chickpea they were active 18 DAF and the maximum accumulation was 40 µg of seed.

5.1.1.2 Generation of lentil lectin gene

A set of primers was designed from known sequence of chickpea lectin cDNA clone (Accession No. AY221982). These primers were used for amplifying the lectin gene using genomic DNA of lentil (*Lens esculanta*, variety L 4076). Primer combination P1 and P2 amplified a fragment of size 600bp while primer combination P3 and P2 amplified a fragment of size 700bp. PCR amplicon B was purified and checked on 1% agarose gel. Nucleotide sequence of this PCR amplicon (670 bp) showed 88% homology with other legume lectin gene.



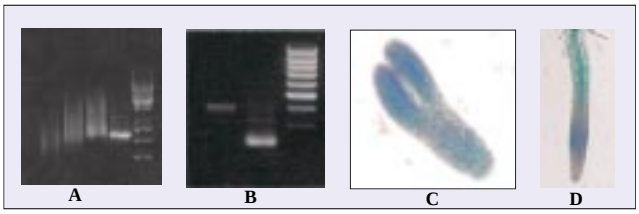
Agarose gel electrophoresis of PCR of lentil lectin

TGGCTACACCACAAAAGGGAAGTTGACACTGACCAAGGCAGTAAAGAGCACTGTTGGCAGAGCTC
TCTATTCCACACCTATCCATATATGGGATAGAGATACAGGTAACGTTGCTAATTTTGTAACTTCC
TTCACTTTTGTCATAGATGCGCCCAGCAGTTACAACGTTGCCGATGAGTTTACGTTCTTCATCGC
ACCGGTGGATACTAAGCCGCAGACTGGCGGGGGATACCTCGGAGTTTTCAATAGCAAAGAATATG
ATAAAACTAGTCAAACTGTTGCTGTGGAGTTTGACACTTTCTATAACGCTGCTTGGGATCCAAGC
AATAAAGAAAGACATATTGGGATTGATGTTAACAGTATCAAATCCGTAAATACTAAGTCGTGGAA
TTTGCAGAATGGTGAACGGGCTAATGTTGTGATAGCTTTTAATGCTGCCACTAATGTGTTAACTG
TTACTTTAACTTATCCTAATTCACTTGAGGAAGAGAATGTAACTAGTTATACTCTTAATGAAGTT
GTGCCTTTGAAAGATGTTGTTCCTGAGTGGGTGAGGATTGGTTTCTCAGCTACCACTGGAGCAGA
ATTTGCAGCACATGAAGTTCATTCATGGTCTTTTCATTCTGAGTTGGGCGGAACTTCGAGTTCTA
AGCAAGCTGCAGATGCATAG

Nucleotide sequence of lentil lectin gene (Accession No. AY 547295)

5.1.1.3 Isolation and characterization of protease inhibitor promoter

The cowpea trypsin inhibitor promoter was isolated by adopter-PCR technique, cloned and sequenced (Accession No. AY 573237). The transcription start site of the promoter was identified by 5' RACE. Reporter vector was constructed by replacing the CaMV35S promoter with trypsin inhibitor promoter. Reporter analysis experiment showed that the promoter is specific to cellular maturation phase of development. The expression in seeds starts at the torpedo stage of embryogenesis and continues till the last stage of seed maturation. Similarly, the expression in leaves was seen in the expanding leaves. Further, the expression was also seen in elongation zone of the root tips. The ABA induction analysis confirmed that the promoter is specific to growth arrest.



Cloning 5' flanking sequence (A), determination of transcription start site (B), expression of reporter in embryo (C), and root tip tissues (D).

5.1.2 Enhancement of Productivity through Exploitation of Heterosis

5.1.2.1 Improvement of productivity of mustard (*Brassica juncea*) by the production of hybrids

In crops, where pollination control system is workable, quantum improvement of productivity is possible by production of hybrids. To make use of this technology, the availability of a three-line system, namely, cytoplasmic-

genetic male sterility, sterility maintainers, and fertility restorers, is a pre-requisite. In mustard crop, all the above said lines (systems) were developed. The best heterotic parents (BIO 322-93 and Pusa Jai Kisan as female parent and RLM 198, JMG 401, CSR 499, BIO-YSR and BIO 467-95 as male parents) were identified using line x tester crossing design. The *Moricandia arvensis* based male sterile line was diversified by 4 back crossings with BIO-322-93 and Pusa Jai Kisan. Similarly, the fertility restorer line was diversified by back crossing with heterotic parents, RLM 198, JMG 401, CSR 499, BIO-YSR and BIO 467-95. Using these diversified CMS and fertility restorers, 5 experimental mustard hybrids were produced. These hybrids were then tested for yield potentiality in replicated experimental field trials on IARI farm. The results on seed yield indicated 24 to 25% seed yield superiority of three hybrids (BIO-HY 19-04, BIO-HY 20-04 and BIO-HY 22-04) over the best check (Pusa Jai Kisan). These hybrids were entered in the all India co-ordinated trials for 2005-2006 crop season.

5.1.2.2 Generation and molecular characterization of genetic stocks for development of hybrids

Molecular characterization of CMS (*Moricandia arvensis*) *Brassica juncea* was continued. Earlier studies had shown that CMS is associated with longer *atpa* transcript in the lower buds. In order to find the exact differences in the *atpa* transcript between male sterile and fertile plants, primer extension method was adopted. In male sterile flowers, *atpa* transcript was longer by 1000 nucleotides and contained a novel *orf* of 108 aminoacids. Thus a bicistronic transcript containing *atpa* gene was found in the male sterile. In fertility restorer line, the *atpa* transcript was shorter and contained only a part of the novel *orf* 108 sequences. Thus *atpa* transcript was monocistronic.

A new CMS line was derived from somatic hybridization between *B. juncea* and *Diplotaxis catholica*. In this system also, *atpa* gene was implicated in CMS. To understand the exact differences between the CMS and euplasmic *B. juncea*, *atpa* gene of new CMS line was cloned and sequenced. It was found that the 5' region of *atpa* gene shares similarity with *M. arvensis*. The *orf* 108 found in *Moricandia* CMS is also present in the new CMS line. The complete significance of this study will be known only after cloning the *atpa* transcripts from the male sterile and fertile lines.

5.1.3 Development of Transgenic Crops for Biotic Stress Resistance

5.1.3.1 Commercialization and IPR activities

Brinjal is a widely cultivated and consumed vegetable in India. Brinjal is highly susceptible to a lepidopteran pest

Fruits of transgenic (left) and non-transgenic brinjal lines

called brinjal shoot and fruit borer (BSFB), which damages the shoot tips during vegetative phase, and fruits during the reproductive phase. Chemical control of BSFB is not only expensive but also ineffective. Safe and effective alternative for the management of BSFB is to express insecticidal proteins of *Bacillus thuringiensis* (Bt) by genetic engineering. A codon-modified gene encoding a chimeric delta-endotoxin of Bt was constructed and tested for its expression *in planta*. Brinjal (cv. Pusa Purple Long) was transformed with the synthetic gene under the control of a powerful constitutive promoter (CaMV 35S). Transgenic lines with very high-level protection from BSFB were identified. The fruit damage in transgenic lines varied from 4 to7% in contrast to 35 to 43% in normal fruits. The Institute has signed a memorandum of understanding (MOU) with Bejo Sheetal Company for field-testing, bio-safety testing and commercialization of Bt-brinjal.

Two applications for patent rights dealing with codon-modified Bt (*Bacillus thuringiensis*) genes were filed.

5.1.3.2 Bt-rice

Yellow stem borer (YSB) is an important pest of rice which considerably affects its yield. Management of YSB by genetic manipulation of rice (IR 64) by expressing

Limited field trial of Bt rice (IR 64)

insecticidal proteins (ICP) of *Bacillus thuringiensis* was undertaken. Two Bt ICPs, viz., Cry1Aa and Cry1B were expressed in Indica variety of rice (IR 64). The genes encoding these two proteins were translationally fused and cloned in a plant transformation vector. Several transgenic lines were developed and field tested. Eight promising transgenic lines were identified.

5.1.4 Development of Transgenic Crops for Abiotic Stress Tolerance

There is an urgent need to evolve crop cultivars that can withstand vagaries of weather and can resist harsh environmental conditions, such as drought, salt, cold and high temperature stresses. With an objective to develop transgenics tolerant to these abiotic stresses, the National Research Centre for Plant Biotechnology (NRCPB) of the Institute has developed transgenic mustard and tomato over-expressing the osmotin gene. The transgenics were evaluated for tolerance to drought and salt stress in the Phytotron. The selected tolerant lines were then planted in the field for

Natural selection in tomato under freezing stress

conducting the contained field trial as per the norms laid by the Department of Biotechnology (DBT), Govt. of India. The transgenic tomato is being evaluated for its response to both drought and salinity while mustard transgenics are being assessed with respect to their response to drought only. A few lines behaving significantly better as compared to the wild type were identified.

5.1.4.1 Cloning of abiotic stress and ABA inducible group *LEA* 1 cDNA and its promoter from *Brassica* species

Cloning and characterization of abiotic stress-induced LEA genes are necessary to understand the interaction of plant cells with different environmental stresses and to engineer stress tolerant crops. A novel class of *LEA1* cDNA was cloned from *Brassica* species. The predicted LEA1 proteins of *B. napus* and *B. carinata* showed about 90% similarity to *A. thaliana* LEA1. Under non-stress conditions, *LEA1* gene is not expressed in vegetative tissues. However, salt, cold and osmotic (PEG and mannitol) stresses and ABA induced the expression of *LEA1* gene in the leaves of *Brassica* species. Further, the *LEA1* promoter was cloned from *B. carinata*, *B. juncea*, *B. napus* and *A. thaliana*. *In silico* analysis identified abiotic stress- and ABA inducible *cis*-elements, such as dehydration responsive elements/C-repeat elements, ABA responsive element, MYB and MYC *cis*-elements. Since this *LEA1* gene is induced by various abiotic stresses and ABA, the *LEA1* promoter and its coding sequence appear to be useful in engineering stress tolerance in crop plants.

5.1.5 Development of Genetically Engineered Microbes for Effective Microbe-Plant Interaction

5.1.5.1 Development of novel strains of *Mesorhizobium ciceri* for chickpea cultivation

Chickpea rhizobia (*Mesorhizobium ciceri*) are important in several ways to chickpea production. *M. ciceri* with free living N_2 fixing ability were identified retaining their symbiotic property. Transposon Tn 5 mutants were induced in a free living N_2 fixing isolate MC 59 with a view to select those, which did not grow on nitrogen free medium (NF). Four mutants were identified which responded to ammonium sulphate supplementation of NF medium. These mutants are expected to carry mutation in nitrogenase gene and provide a handle to test the presence of ACC (1-aminocyclopropane 1 carboxylic acid) deaminase gene. The presence of ACC deaminase gene was also examined by PCR amplification using *acdS* gene specific primers. Results suggested the presence of *acdS* gene homologue in an isolate of *M. ciceri*, MC 408. Free living N_2 fixing property in association with ACC deaminase in a strain of *M. ciceri* is expected to bring discernible change in chickpea production.

5.1.5.2 Determination of rhizobial diversity

Successful management of symbiotic association between chickpea and their bacterial endosymbionts, i.e., *Mesorhizobium ciceri* requires characterization of field rhizobial populations. India has a large biodiversity of rhizobial resources. However, only a few of them have been explored. Therefore, 30 strains of *M. ciceri* were isolated from rhizosphere soils from different sites of Hissar and IARI and characterized.

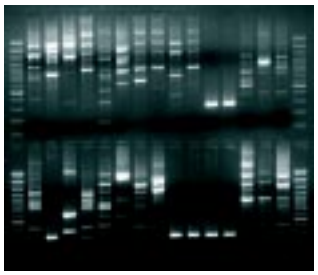
***Phenotypic characterization*.** All the 30 isolates were categorised on the basis of colony characteristics like colony colour, shape and texture. Majority strains had colonies with domed shape and watery translucent texture owing to the

exopolysaccharide secretion, a typical feature of *Rhizobium*. Exceptionally, two strains MC 8 and MC 15 grew with yellow coloured colonies, which is rare in *Rhizobium.*

Colony morphology

Biochemical characterization. Further characterization of all 30 strains was done by studying their growth pattern. Majority of them were found to be moderate growers (GT<3h) except five with fast growth (GT<50min) and one with slow growth (GT<8h). Intrinsic antibiotic resistance profile was also prepared. The growth of all isolates was inhibited by tetracycline (5µg/ml) but was insensitive to Naldixic acid (75-100µg/ml), and spectinomycin (300-400µg/ml).

RAPD analysis. Genomic DNA of all the 30 isolates was isolated after standardization of the protocol by lysozyme lysis followed by phenol: chloroform:isoamylalcohol extraction and ethanol precipitation. These genomic DNAs were amplified by twenty-two random decamer primers (Operon series). The amplification pattern revealed a high level of polymorphism in all the isolates.



RAPD profile obtained with 30 isolates of *M. ciceri* using K4 primer

5.1.5.3 Isolation and identification of soil bacteria effective against fungal pathogen (*Rhizoctonia solani*) of rice

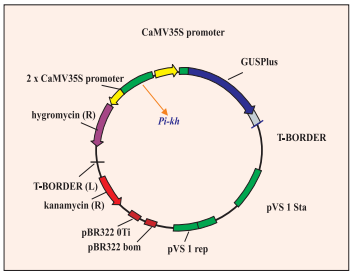
Soil microbes were isolated from three different locations (IARI rice field, Yamuna river bank and mid Sangam soil, Allahabad). Fourteen isolates showed antagonistic effect under culture conditions towards *Rhizoctonia solani*, a fungal pathogen of rice causing sheath blight disease of rice.

Characterization of microbes having inhibitory effect on the said pathogen for different physiological and biochemical parameters such as Gram staining, osmotolerance, temperature sensitivity, and antibiotic sensitivity and fluorescence on King A and King B media was carried out. Two most promising isolates JCP 2-15 and JCP 2-23 were sent to IMTECH, Chandigarh for identification. Transposon Tn5 mutants of microbial isolate JCP 2-15 with loss of antagonistic property towards *Rhizoctonia solani* were identified. Five more microbial isolates (pulse crop field, Bengal) and three microbial isolates (rice field, Shimla) were found to be antagonistic towards *Rhizoctonia solani.*

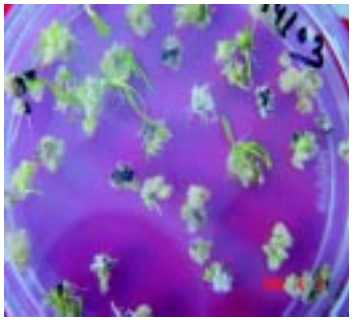
5.1.6 Genomics and Molecular Markers in Crop Plants

5.1.6.1 Preparation of the construct of a cloned blast resistance gene *Pi-k*^{h} and its transfer to rice

The NRCPB has recently cloned a blast resistance gene *Pi-k*^{h} from rice line Tetep. The Centre's objective is to study its function *in planta.* For this purpose, the cloned gene has to be introduced in a plant transformation vector along with its native promoter. Hence, complete candidate rice blast resistance gene was cloned in plant transformation vector pCAMBIA 1301.5 which contained CaMV35S Promoter, gene for hygromycin resistance (*hpt*), and Kanamycin resistance (*npt*II) as selectable marker. A japonica rice line TP 309 was used for the transformation analysis. Mature scutellum calli was used as explants for transformation using Biolistic approach. Transformed calli were allowed to regenerate for the development of transgenic rice plants.



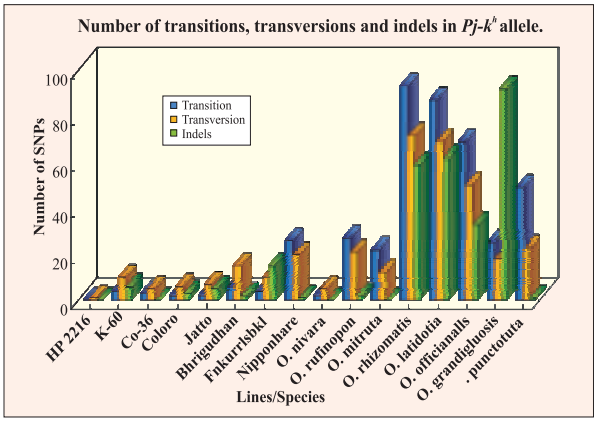
Plant transformation vector containing *Pi-k*^{h} gene



Transformed calli regenerating into plantlets

5.1.6.2 Allele mining of rice blast resistance gene *Pi-k*^{h}

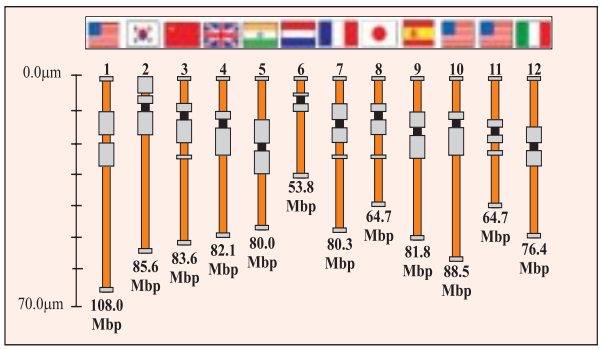
PCR-based allele mining approach was used as a tool for the cloning of various alleles of blast resistance gene *Pi-k*^{h} from different lines and wild species of rice to know molecular evolution of *Pi-k*^{h} gene. In present the investigation, 8 wild *Oryza* species and 9 lines of *O. sativa* were used for allele mining. The sequence analysis revealed maximum variation in the form of transition, transversion and indels among the alleles isolated from wild species.



Sequence variation in the *Pi-k*^{h} alleles isolated from different rice lines and wild species

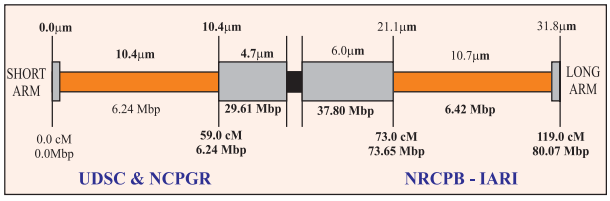
5.1.6.3 Tomato genome sequencing

The International Tomato Genome Sequencing Project has assigned the sequencing of chromosome 5 to India. The NRCPB of the Institute has to sequence the long arm of tomato chromosome 5 (~ 6.0MB) as per internal arrangements. Initially, the NRCPB received 72 seed BACs with 13 anchored markers on the long arm (73–119 cM) of tomato chromosome 5 from the Cornell University, USA. The solanaceae web site also has information for tomato Genetic map, FPC, seed BAC libraries and BAC end sequences. All these were available as resource for tomato genome sequencing.



The International Tomato Genome Sequencing Project Consortium. The karyotype of tomato chromosomes at pachytene. The blocks of grey represent condensed heterochromatin, the orange blocks represent euchromatin and the black blocks represent centromere

The Centre has identified 12 seed BACs anchored with 13 molecular markers on the long arm of tomato chromosome 5 and verified the presence of markers in the BAC clones by PCR amplification of known markers, and FPC data using Hind III digestion. Sequencing is in progress.



Tomato chromosome 5 showing the euchromatic region assigned to NRCPB-IARI for sequencing

5.1.6.4 Marker assisted selection for four bacterial blight resistance genes in rice

Earlier two genes (*xa13* and *Xa21*) for bacterial blight (BB) were combined by NRCPB with the *basmati* quality traits of Pusa Basmati 1 through molecular marker-assisted selection (MAS) in collaboration with the Division of Genetics of the Institute. One of the recombinant lines developed in this programme is being evaluated in the advanced varietal trials (AVTs). During the year under report, efforts were made to carry out MAS for four BB resistant genes, namely, *Xa4*, *xa5*, *xa13* and *Xa21* in the F_2/F_3 progeny of three different crosses involving *basmati*/aromatic rice lines. IRBB60 was used as the donor of the BB resistance genes. In the F_2 of the cross Pusa 1121 x IRBB60, nine segregants were identified to have desirable agronomic features and grain characteristics. Of these, three had all the four genes in either homozygous or heterozygous condition, two had three genes and the rest had only two genes for BB resistance. In the F_2 of the cross Pusa 2512 x IRBB60, out of 12 segregants identified to have desirable agronomic features and grain characteristics, four had all the four genes in either homozygous or heterozygous condition, five had three genes and the rest had only two genes for BB resistance. From the F_3 of the cross Pusa Basmati1/Pusa 1302//IRBB60, six segregants were selected for desirable agronomic characteristics, out of which only one plant had *Xa4* and *xa13* genes, while the rest had only *xa13*. The desirable segregants were selected for advancing the generation and further evaluation.

5.1.6.5 Development of 4045 genic microsatellite markers for use in cereals

In a massive effort to generate microsatellite markers for the genic regions that can be used across species and genera in cereal, the unigene sequences of five major cereals, namely, rice, wheat, maize, Sorghum and barly were mined for the presence of moicrosatellite repeat motifs. The nature, frequency and length of different microsatellites present in the unigene sequences were determined in all the five genera. Based on this information, a new class of markers called UGMS was designed. A total of 4045 UGMS markers were developed that included 2780 markers in rice, 429 in wheat,

273 in maize, 266 in Sorghum and 297 in barley. A high-density map of rice genome was constructed by physically anchoring 2622 UGMS markers onto the rice chromosomes. In wheat, 157 of the UGMS markers could be physically mapped to chromosome bins. Cross-transferability of these markers was evaluated *in silico* and validated experimentally, that suggested the use of many of these markers for mapping of genomes and genes across cereals. All the markers so developed were published for public use.

5.1.6.6 Development of new microsatellite and SNP markers for sugarcane genome

With the objective of generating sequence based microsatellite markers for mapping and tagging of genes in sugarcane, a partial genomic library of sugarcane variety Co 6304 enriched for six synthetic repeat motifs, namely, (GA)14, (CAC)9, (AGA)10, (ACA)10, (CAT)10 and (GATA)8 was constructed. A total of 2976 clones from this library were purified and 480 of these were sequenced in forward and reverse directions to generate 848.31 kb sequences of which 780.46 kb was of high quality. The DNA sequences so generated were searched for microsatellite repeat motifs that led to the identification of 91 clones (18.9%) carrying microsatellites. These included 53 class I microsatellites, eight with di, 38 with tri and seven with tetranucleotide repeat-motifs. The primer pairs flanking the repeat motifs were designed for each one of those identified. Thus a new set of 53 class I microsatellite markers for the sugarcane genome was developed. For developing Single Nucleotide Polymorphism (SNP) markers, 22 unigenes belonging to sugar pathway were identified and primers were designed for their amplification. These genes were amplified from a set of 19 sugarcane genotypes and sequenced in forward and reverse direction. By comparison of high quality DNA sequences, 96 SNPs were predicted, which were validated by CAPS analysis using 25 tetra-cutter and 10 hexa-cutter restriction enzymes. Twelve of these SNPs present in four of the selected genes, namely, sucrose synthase, sucrose phosphate synthase, soluble acid invertase and sucrose transporter were validated among the species by CAPS (9 tetra cutter and 3 hexa cutter). Three of these SNPs could be validated among 20 sugarcane varieties.

5.1.7 Molecular Characterization and Micropropagation in Fruit Crops

Forty-one accessions of *Ziziphus mauritiana* (Lam.) and its wild relative *Z. nummularia* (Burm. f.) were subjected to AFLP markers to know the extent of genetic diversity. The accessions were quite divergent and cluster analyses revealed two main groups. Thirty-three accessions of *Z. mauritiana* were clearly separated from the rest of eight accessions of *Z. nummularia*. However, 50 *ber* genotypes were grouped in nine clusters using RAPD analysis with maximum of nine genotypes in cluster 2 and two genotypes in cluster number 9. Seb and Chhuhara exhibited the maximum genetic distance from other genotypes.

Somatic embryogenesis in Amrapali

Forty-four accessions of *Vitis* species and six hybrids were examined thorugh RAPD and ISSR markers in grape. The dendrogram revealed 88 polymorphic ISSR and 266 polymorphic RAPD primers. ISSR and RAPD data gave approximately the same interpretation confirming sufficient polymorphism in grape germplasm. The seedless cultivars were grouped together.

Somatic embryogenesis in six mango genotypes, namely, Pusa Arunima, Amrapali, Dashehari and Lal Sundari (mono-embryonic) and Kurukkan and Olour (poly-embryonic) was achieved. The nucellus from 40 to 45-day-old fruitlets gave the maximum success for callus induction and somatic embryogenesis. Both the responses were earlier in poly-embryonic genotypes in comparison to mono-embryonic genotypes.

Somatic embryogenesis in mango genotypes

Genotype	*Callusing (%)*	*Somatic embryogenesis (%)*		
		Globular	*Torpedo*	*Cotyledonary*
Pusa Arunima	65.8	75.8	65.8	54.8
Amrapali	70.6	89.0	75.4	68.4
Dashehari	56.8	67.2	63.2	51.2
Olour	82.5	98.2	82.5	76.5
Kurukkan	88.5	96.4	87.4	83.5

The technique of *in vitro* multiplication using two-node repetitive micro-cutting technique was attempted to multiply the already released varieties, namely, Pusa Seedless, Pusa Urvashi and Pusa Navrang and two new genotypes, namely, Hybrid 76-1 and Centennial Seedless of grape. A large number of rooted plantlets in each genotype were transplanted in the field for their evaluation.

The embryo rescue technique was attempted in the crosses involving seedless and early maturing genotypes as

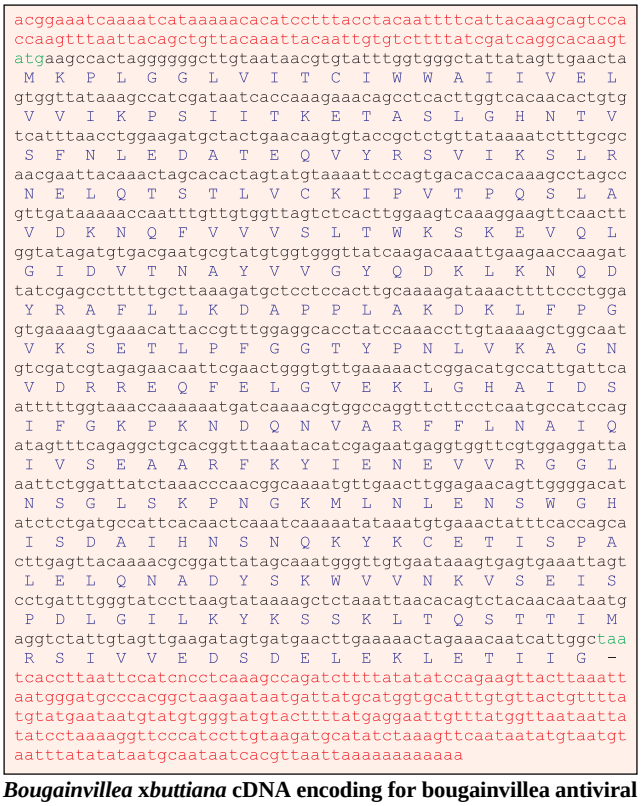
a seed parent. Sixty-nine rescued plantlets were hardened and transplanted in the field for their evaluation.

5.2 BIOCHEMISTRY

5.2.1 Cloning and Characterization of Gene Encoding Antiviral Protein of *Bougainvillea xbuttiana*

Earlier, in the Institute laboratory, antiviral proteins (AVPs) were isolated and purified from the leaves of *Bougainvillea* x*buttiana* c.v. Mahara., and their mechanism of action was studied. Now efforts are being made to isolate the gene(s) encoding AVPs for developing transgenic plants having virus resistance.

Through RT-PCR, a 261 bp cDNA sequence was amplified from mRNA isolated from the leaves of *Bougainvillea* x*buttiana* using forward and reverse primers, custom designed from conserved sequences of RIPs/AVPs available in GenBank. The deduced amino acid sequence of isolated cDNA fragment exhibited 62% homology with bouganin, an AVP of *B. spectabilis* leaves. This fragment lacked 5' and 3' regions. Therefore, 5' and 3' regions of the cDNA were obtained by 'rapid amplification of cDNA end' (RACE) using mRNA as template and gene-specific primers. A 456 bp cDNA sequence corresponding to 5' region, and their deduced amino acid sequence showed 76% homology with bouganin. Similarly, a 647 bp cDNA sequence corresponding to 3' region, and their deduced amino acid equence showed 76% homology with bouganin. A full-length cDNA of 1364 bp was amplified by PCR using forward and reverse primers, specific to the 5'UTR and 3'UTR isolated by RACE. This sequence submitted to the NCBI GenBank bears the Accession No. DQ013264. This cDNA encodes for 319 amino acid sequence having 72% homology with bouganin.



***Bougainvillea xbuttiana* cDNA encoding for bougainvillea antiviral protein (BAP1). Nucleotides: 1364 bp, Amino acids : 319**

Further studies are in progress to clone the coding region cDNA in order to see its expression initially in *E. coli.*

5.2.2 Cloning of Diacylglycerol Acyl Transferase (*DGAT)* Gene from *B. juncea*

Plants store energy in the form of triacylglycerols, which are synthesised in plants by the Kennedy pathway. The enzyme diacylglycerol acyl transferase is the terminal enzyme in the pathway and is specific to the triacylglycerol synthesis. Through RT-PCR using RNA isolated from developing seeds of *B. juncea*, two different transcripts of DGAT were obtained and the cDNA was cloned, sequenced and characterized. Both the cDNAs contain the complete ORF and start with the initiation codon and end with the first nucleotide of termination codon. The transcripts (named as *BJDGAT* 1 and *BJDGAT* 2) show homology to *DGAT* cDNA sequence from *B. napus* and other related species and are of 1510 base pair long. Both encode for a polypeptide of 503 amino acids. Restrictions mapping of the two clones show polymorphism with respect to *Eco*RI and *Sac*1 sites and 85% and 96% identity at nucleotide and amino acid levels, respectively. The substrate binding sites are conserved at the same position in both the sequences. They can further be used to manipulate triacylglycerol synthesis in plants. These sequences were submitted to GenBank with Accession Nos.: DQ016106 and DQ 016107, respectively.

5.2.3 Isolation and Characterization of *fad 2-1* Gene Encoding ()-6-desaturase from Soybean and Designing of Antisense Construct for Silencing *fad 2-1* Expression

Seed specific expression of *fad 2-1* gene encoding microsomal omega 6-desaturase plays a major role in the conversion of oleic to linoleic acid within storage lipids during seed development.

A *fad 2-1* specific probe of ~1.1 kb was generated by PCR using gene specific primers and its homology confirmed by sequencing. Screening of the sub-genomic library of

Glycine max with this probe resulted in a positive clone of 1852 bp (Acc. No. AY954300), which had a single continuous exon containing an ORF encoding a peptide of 379 amino acids, a single intronic region of 420 bp and a complete 3' untranslated region of 206 bp. Both the intron and exon showed 99% homology with *Glycine max fad 2-1* intron and exon sequences reported in the databank. Analysis of the deduced amino acid sequence showed the presence of metal ion binding conserved histidine boxes (HXXXH) in soybean microsomal w-6-desaturase as present in all the membrane desaturases. Southern hybridization studies revealed two copies of *fad 2-1* gene in the soybean genome which is consistent with its tetraploid nature. Five probable transmembrane segments could be predicted at the deduced amino acid level of the *fad 2-1* sequence. The sequence information obtained was used in designing of an antisense construct for silencing of *fad 2-1* gene expression.

A two-stage cloning strategy was adopted wherein the first stage PCR amplified conserved *fad 2-1* gene sequence was cloned in antisense orientation under the control of seed specific (vicilin) promoter derived from pCW 66 vector. In the second stage, this chimeric gene fragment was inserted in a plant transforming vector (pAKVS) carrying plant selection marker 'bar' gene and kanamycin resistance gene.

5.2.4 Isolation and Characterization of Differentially Regulated Genes under Moisture Stress in Rice

Complementary DNA was synthesized from mRNA obtained from the stressed leaf tissue of drought tolerant rice cultivar N 22. cDNA was ligated to pBlue script (SK^-) vector and transformed into *E. coli* DH 5α strain. Inserts from a few of these recombinant clones were amplified using T3 and T7 primers which were used further for Northern hybridization. One of these clones showed differential expression associated with water deficit stress. Sequence homology search analysis revealed that this 308 bp partial cDNA clone is located at the chromosome 1 of *Oryza sativa* and has a N-terminal domain of protein phosphase 2C, which has got an important role in ABA signaling pathway.

5.3 PLANT PHYSIOLOGY

5.3.1 Physiological Constraints Limiting Productivity

5.3.1.1 Analysis of physiological constraints limiting photosynthesis and grain growth

Starch synthase in relation to heat shock proteins (HSPs) in the grains of wheat varieties. Earlier studies showed that the decrease in grain growth under high temperature is associated with a decrease in soluble starch synthase. In the present study, an attempt was made to analyze whether HSPs provide thermo-tolerance to starch synthase, and consequently, grain growth in wheat.

Excised developing grains (20 DAA) of wheat varieties (DL 153-2, HD 2285, HD 2329 and WH 542) were incubated for two hours at 15^0, 25^0, 35^0 and 45^0C. Grains were also exposed for two hours at increasing temperature (15^0, 25^0, 35^0 and 45^0C) continuously, thus exposing grains to gradual rise in temperature. The above treated grains were then analysed for activities of soluble starch synthase (SSS), granule bound starch synthase (GBSS), kinetic constants of SSS and levels of HSP 100, HSP 90 and HSP 18.

The study further emphasized that SSS is more sensitive to elevated temperature than GBSS. Varietal differences in sensitivity of SSS to high temperature were observed. HD 2285, a relatively temperature tolerant variety in terms of grain growth maintained relatively higher activity of SSS compared to other varieties at higher temperature. HD 2329 appeared to have a better acclimation potential under gradual rise in temperature. High temperature increased Km (ADPG). Temperature tolerant HD 2285 had efficient SSS in terms of lower Km (ADPG) and higher V_{max}/K_m ratio in both control and high temperature exposure treatment. The present study showed the presence of both low (HSP 18) and high molecular weight (HSP 90 and HSP 100) heat shock proteins in the developing grains of wheat. HSP 100 appeared to be related with the high temperature stability of SSS and grain starch content.

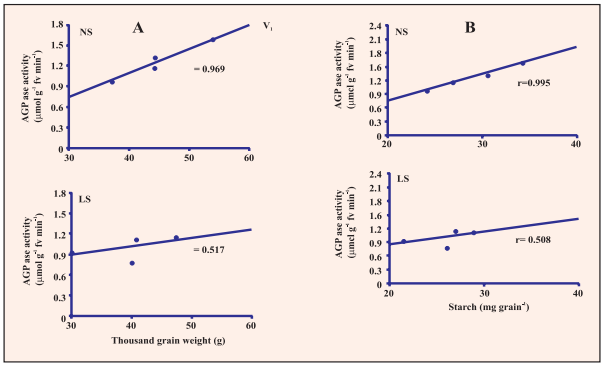
Kinetic constraints for soluble starch synthase in the grain exposed to two different temperatures in wheat cultivars

Cultivar	Temperature (^{0}C)	V_{max} (nmol mg^{-1} protein min^{-1})	Km ADPG (mM)	V_{max}/K_m
DL 153-2	25	16.67	0.67	24.88
	45	16.67	1.35	12.35
HD 2285	25	20.00	0.45	44.44
	45	20.00	0.71	28.17
HD 2329	25	20.00	0.46	43.48
	45	20.00	4.76	4.20
WH 542	25	25.00	1.89	13.22
	45	16.67	2.00	8.34

Grain growth, starch accumulation and AGPase activity in the grains of wheat varieties. Starch is deposited in amyloplast involving ADP glucose pyrophosphorylase (AGPase), starch synthase and branching enzyme. In the present study, an attempt was made to analyze whether grain growth in wheat is related with the activity of AGPase, a key regulatory and rate limiting enzyme in the pathway of starch synthesis and evaluate the sensitivity of AGPase from wheat grains to PGA and Pi and high temperature.

Four wheat varieties (DL 153-2, C 306, HD 2329 and WH 542) were grown under normal (27 November) and late (28 December) conditions. Mean maximum and minimum temperatures under late sown condition were 3.7^{0}C and 2.8^{0}C higher than the temperatures under normal sown conditions, respectively during grain growth period. Excised developing grains (20 DAA) were incubated for 1 h at 25, 35 and 45^{0}C. Grains were also exposed for 1 h to gradual rise in temperatures from 25 to 45^{0}C. AGPase activity was determined at different concentrations of PGA (0, 1, 2, 4, 6 and 8 mM) in the presence or absence of 2 mM Pi in the reaction mixture to analyze the sensitivity of AGPase to allosteric effectors.

A highly significant correlation of AGPase activity with starch accumulation and grain growth was observed in wheat under normal sowing but not under late sowing. AGPase from excised grains exposed to different temperatures showed little sensitivity to high temperature. Hence, the other enzyme in the pathway, viz., soluble starch synthase, because of its sensitivity to high temperature, might become more important in controlling starch synthesis under late sowing. Genotypic differences in sensitivity of AGPase from wheat grain to allosteric effectors were observed. Over expressing AGPase insensitive to PGA and Pi in wheat grain would, therefore, lead to faster starch accumulation and early filling of grains and may thus avoid extreme high temperature conditions experienced during later part of grain development.

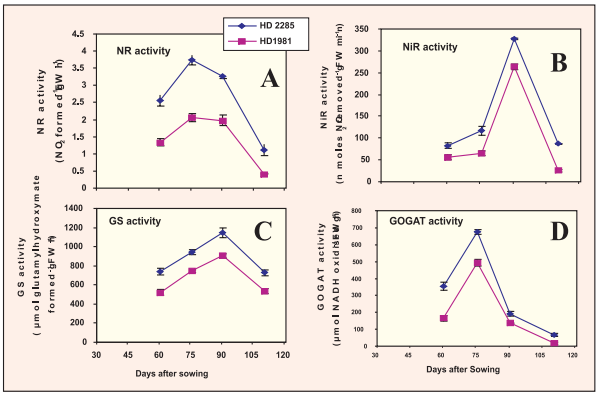


Relationship of mean AGPase activity (µmol min^{-1} g^{-1} f.w.) with thousand grain weight (A) and starch content (mg grain^{-1}) (B) in wheat cutlivars under normal sowing (NS) and late sowing (LS)

5.3.1.2 Investigations to improve nutrient use efficiency of crop

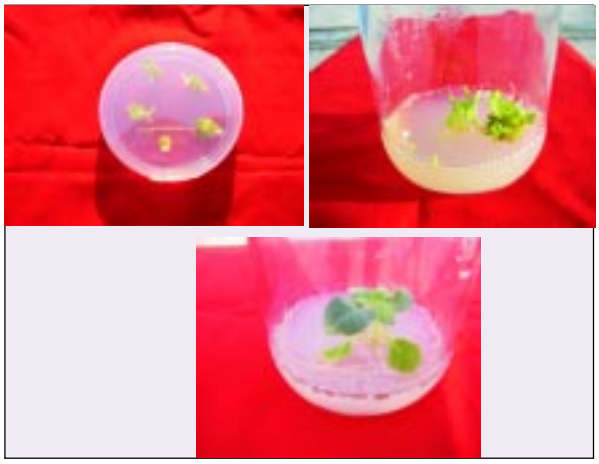
Activity of the enzymes of nitrate assimilation pathway in contrasting wheat genotypes. Two contrasting genotypes of wheat HD 2285 (high nitrate reductase, HNR) and HD 1981 (low nitrate reductase, LNR), which differed by two fold in the level of the nitrate reductase activity, were selected for the present study. The rate of nitrate uptake and the induction of the enzyme nitrate reductase were studied in these two genotypes earlier. The present experiment was conducted to examine whether NR activity has any bearing on the enzymes of ammonia assimilation pathway.

The plants of the two wheat genotypes were raised and NPK were applied at the rate of 120, 60 and 40 kg/ ha, respectively. The sampling was done at 40, 60 and 90 DAS, and all the enzymes, viz., nitrate reductase, nitrite reductase, glutamine synthetase and glutamate synthase were assayed. It was observed that NR activity was almost double in the HNR genotype as compared to that in the LNR genotype. Similarly, the activity of the other enzymes of the pathway, i.e., nitrite reductase (NiR), glutamine synthetase (GS), and glutamine oxoglutarate amino transferase (GOGAT), also known as glutamate synthase, was significantly high in the HNR genotype as compared to that in the LNR genotype. The difference in the level of the activity for the GS enzymes was less, but the activity of GOGAT was 3-fold higher at 90 DAS. The per cent N in grains was higher in the HNR genotype (25 % more), and retained less N in the leaf sheaths, leaves and chaff as compared to that in the LNR genotype. The LNR genotype accumulated significantly higher amounts of the nitrate in its tissues. The HNR genotypes also performed better in terms of growth, metabolic activity as well as grain N content. It is, therefore, important to select plants with desirable expression patterns/levels of the protein.



Activity of the enzymes of the nitrogen assimilation pathway in two contrasting wheat genotypes

Cloning high affinity nitrate transporter in tobacco. To examine whether high affinity transporters have any bearing on efficient nitrate uptake, the inducible high affinity nitrate transporter gene cloned from the genomic DNA of *Arabidopsis thaliana* and linked to 35S CaMV promoter was used to transform the *Nicotiana tobaccum* plants, and the transgenics were tested for the presence of the gene. In future, the kinetic studies will be performed.



Genetic transformation of tobacco by *Agrobacterium*

Evaluating the effect of direction of sowing on growth and yield of maize. Phosphorus (P) is one of the major limiting nutrients next to nitrogen in crop production. Identification of P efficient varieties can provide valuable genetic resources for improving yield under limited P supply. The objective of this experiment was to screen the wheat (exotic and indigenous) germplasms for P-use efficiency in the field under deficient and sufficient levels of P.

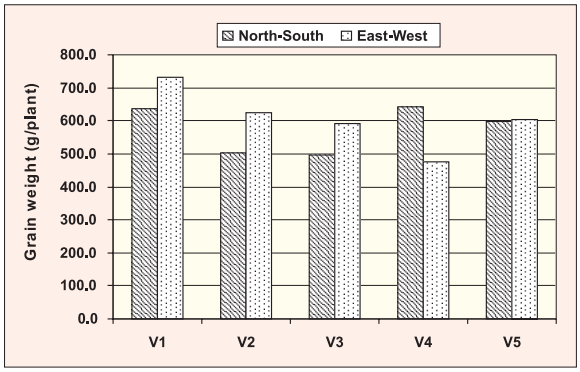
The seed material for this experiment was procured from CIMMYT, Mexico; AWCC, Australia; DWR, Karnal; DMR and Genetics Division of IARI, and multiplied at IARI Regional Station, Wellington.

Prior to wheat experiment for screening genotypes for P-use efficiency, a farm area at IARI, New Delhi was prepared by sowing maize, as it is an exhaustive crop. The experiment was designed using five maize hybrids (procured from DMR, IARI) viz., Bio 9681 (V_1), Seed Tech 2324 (V_2), Prabhat (V_3), Pro 311 (V_4), and Pioneer (V_5), to lower the content of available soil P. The objective of this experiment was to evaluate the effect of the direction of sowing, if any, on growth, partitioning of assimilates and yield in maize.

The field soil was sampled for P content before and after sowing. The recommended dose of urea and potash, i.e., 120 kg N and 40 kg K_2O/ha, was applied for maize. The sowing was done in two directions, viz., east-west and north south. Plant sampling for growth analysis was done at 15 days' interval starting from 30 days after sowing (DAS) up to harvest. The growth analysis parameters recorded were net assimilation rate (NAR), relative growth rate (RGR), and leaf area ratio (LAR).

Results of this experiment revealed significant difference among the maize hybrids in terms of NAR. But the direction of sowing had no significant effect on NAR. During initial stages of growth (30-45 DAS), the NAR was recorded maximum in all the hybrids whereas it decreased at 45-60 DAS. Thereafter, a slight increase was observed in NAR in all the hybrids, in both the directions of planting, except in the hybrid Pro 311 (V4). The hybrid Pro 311 (V4) exhibited a gradual decrease with plant age. Similarly, the LAR varied significantly among the hybrids but no effect of direction of planting was observed. The LAR was maximum during initial growing period after which it decreased with the age of the plant in all the hybrids. The LAR was higher in treatment V4 in both the directions of planting.

The RGR was significant among the hybrids as well as between the directions of planting. The RGR was higher in plants grown in east-west direction. Reduction in RGR was observed in all the hybrids during reproductive stage (i.e., 45-65 DAS) under both the directions of planting. An increase in RGR was noticed during grain development phase and continued till maturity. The average total of above ground plant dry weight was significantly higher in plants grown in the east-west direction. Marked increase in dry weight was recorded between 30 and 45 DAS in all the hybrids and a sharp increase was observed between 75 and 90 DAS. This increase in dry matter at grain development stage was due to high rate of RGR. In terms of grain weight per m^2, significantly higher weight was recorded among the hybrids as well as in the direction of planting. Except V_4 and V_5, all other hybrids possessed higher grain weight in the east-west direction over the north-south. The grain weight averaged over the direction of planting was found significantly in V_1 followed by V_5, while V_3 recorded the lowest.



Effect of direction of sowing on grain weight in maize hybrids

5.3.1.3 Analysis of constraints causing flower and fruit drops in pulses

Endogenous evaluation of jasmonic acid under water stress. Jasmonic acid (JA) is a naturally occurring plant growth regulator found in nearly 206 plant species representing 50 families. Several physiological roles have

been attributed to this compound. Leaf senescence promotion is one of the main effects of increased levels of JA. In the present study, the role of JA in leaf senescence was studied using mungbean (var. PS 16) plants. The plants were grown in the phytotron and changes in the endogenous levels of JA were quantified in both the control and water stressed plants. The changes in JA levels were compared with the changes in the relative water content (RWC) and chlorophyll content in the leaves. The JA levels were quantified at 25, 35, 45, and 55 days after sowing. An increase in the JA levels with the age of the plant was observed. After 30 days, the plants were subjected to water stress by withholding water application. The RWC, JA, and chlorophyll were measured at 0, 3, 6 and 9 days after treatment and plants were again watered on the 9th day.

Within 3 days after the treatment there was a two-fold increase in the JA levels that gradually decreased on the 6th and 9th days though remained higher than the unstressed levels. The highest reduction in chlorophyll content was observed on the 6th day though it started to decline corresponding to the treatment. It was clearly evident that the rise in JA levels preceded the reduction in chlorophyll and the rise in JA levels was in response to the water stress.

5.3.2 Improvements in Abiotic Stress Tolerance in Crop Plants

5.3.2.1 Identification of morpho-physiological traits associated with stress tolerance

Understanding of mechanism of high temperature tolerance in wheat. In the present experiment, two wheat genotypes C 306 (tolerant) and PBW 343 (susceptible) were grown under two different temperatures, 25/18 ^{o}C (normal) and 35/25^{O}C (high) in phytotron. Observations were recorded on chlorophyll a/b ratio, rate of photosynthesis and expression of Rubisco genes at three different stages, i.e., vegetative, anthesis and 15 days after anthesis.

There was a significant increase in chlorophyll a/b ratio under heat stress compared to that under normal temperature, and maximum ratio was recorded in PBW 343 at all stages of growth. This indicates that there is significant reductions in chlorophyll b content under high temperature and more reduction in susceptible type.

Significant reduction in photosynthetic rate was recorded in both genotypes grown under heat stress treatment. The genotype C 306 showed 16.0, 15.4 and 24.3% reduction under heat stress compared to that under normal temperature, while PBW 343 showed 36.7, 35.9 and 37% at vegetative stage, anthesis and 15 days after anthesis, respectively.

A single 480 bp RT-PCR product of Rubisco small subunit was obtained in all the treatments. Heat susceptible genotype PBW 343 showed significant reduction in the expression of Rubisco small (rbcS) under heat stress treatment at all the stages of growth. In heat-tolerant genotype C 306, reduction in the expression of small subunit of Rubisco was recorded only at 15 days after anthesis. A single RT-PCR product of Rubisco large subunit of size 811 bp was obtained under heat stress and normal temperature treatment at all the stages of growth. Expression of Rubisco large (rbcL) was not influenced by heat stress treatment in heat tolerant genotype C 306 at any of the growth stages, whereas rbcL transcripts were less abundant in PBW 343 subjected to heat stress at anthesis and at 15 days after anthesis. The data collected on Rubisco small and large subunits showed more reduction in small subunits under heat stress treatment particularly in susceptible genotype PBW 343 especially at reproductive stages. The sensitivity of SSU mRNA to heat shock suggests that decreased synthesis of chloroplast proteins produced in the cytoplasm may be an important causal factor of heat damage to plants.

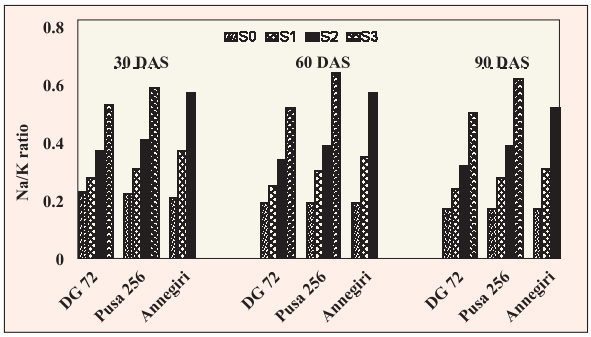
Studies on mechanism of high temperature tolerance in chickpea. In the present experiment, two chickpea genotypes (Pusa 1103 and Pusa 261) were grown at normal (25 ^{o}C) and high (35^{o}C) temperatures for four hours in BOD incubator. Observations were taken on antioxidant enzymes, i.e., superoxide dismutase (SOD), ascorbate peroxidase (APX) and glutathione reductase (GR) at the end of a four-hour period.

The biomass weight was recorded from the plants grown at normal temperature and high temperature (4.5 to 8.5 ^{o}C higher in Solar Energy Trap). It is clear from the results that activities of all three enzymes were relatively increased because of high temperature exposures and the intensity of increase was significantly greater in Pusa 1103, which showed better adaptability to rise in temperature as compared to Pusa 261. The data on biomass production also showed similar trend. The improved genotypes like Pusa 1103 and others could be used for increasing productivity potential of chickpea particularly under late planting in north-west India.

Mechanism of salinity tolerance in chickpea. In order to study the response of chickpea to salinity, the relationship among Na/K ratio and expression of ascorbate peroxidase and tubulin genes, and their ultimate reflection in terms of biomass production were studied in two physiologically different chickpea genotypes, i.e., DG 72 developed at IARI and Annegiri, a successful genotype profusely grown in peninsular condition.

Na/K ratio was lower in DG 72 (0.35, 0.33 and 0.30) compared to that in Annegiri (0.39, 0.37 and 0.33) at 30, 60

and 90 DAS, respectively. There was an increase in ratio with increasing levels of salinity in both the genotypes. The expression levels of ascorbate peroxidase (APX) increased up to 75 mM level. In advanced line DG 72, the expression was higher as compared to that in Annegiri at all the levels of salinity. The expression at the gene level under salinity condition showed a close association with biomass production. The reduction in biomass due to salinity was observed in both the genotypes. However, the reduction was relatively greater in Annegiri (susceptible) than in DG 72 (tolerant).



Effect of salinity stress on Na/K ratio of chickpea genotypes

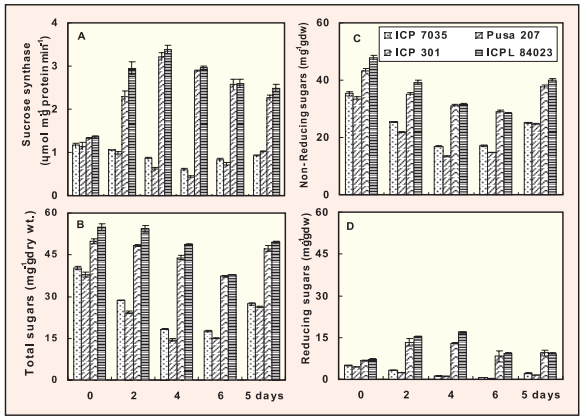
It is inferred that the restricted growth under saline condition was mainly due to Na content of the cell. K accumulation and dry matter production were relatively better in DG 72, which could be used as one of the tolerant parents in improvement of yield potential under salinity condition.

5.3.2.2 Understanding the mechanism of stress tolerance at cellular and biochemical levels

Physiological basis of differential waterlogging tolerance in pigeonpea genotypes. An experiment was conducted with 4 pigeonpea genotypes–2 comparatively tolerant (ICP 301 and ICPL 84023) and 2 susceptible (ICP 7035 and Pusa 207). Sowing was done in 30 x 30 cm pots filled with clay-loam soil and farm yard manure in 4:1 ratio. Pots were fertilized with fertilizers equivalent to 15 kg N, 60 kg P_2O_5 and 60 kg K_2O per ha. Six seeds were sown in each pot after inoculation with *Rhizobium*, and after 15 days of emergence, only 2 plants were maintained in each pot. One month old (about 25 days after germination) plants were subjected to 6 days water logging by putting them in double layered polythene bags filled with water up to soil surface in pots. Observations for all parameters were recorded after 2, 4 and 6 days of treatment, while recovery was studied in all genotypes after 4 days of waterlogging as ICP 7035 and Pusa 207 showed more than 90 % mortality during recovery from 6 days of waterlogging.

Waterlogging caused a gradual decrease in RWC in all the genotypes. However, comparatively tolerant genotypes ICP 301 and ICPL 84023 maintained greater levels of RWC than susceptible genotypes (ICP 7035 and Pusa 207). Similarly, MSI both in root and leaf tissues, and Chl content, though decreased under progressive waterlogging, were significantly more in ICP 301 and ICPL 84023 than in ICP 301 and ICPL 84023. After 4 days of waterlogging, tolerant genotypes showed almost complete recovery 5 days after termination of treatment, while susceptible genotypes could not recover fully even after 10 days of treatment termination. Chl a/b ratio increased during waterlogging, more in susceptible genotypes (ICP 7035 and Pusa 207) than in tolerant ones (ICP 301 and ICPL 84023) and decreased more rapidly to pre-stress level in tolerant than susceptible genotypes during recovery. The results suggest more damage to Chl b than Chl a under waterlogging, and this damage was higher in ICP 7035 and Pusa 207 than in ICP 301 and ICPL 84023.

Sucrose synthase activity increased very significantly in tolerant genotypes and decreased in susceptible ones under waterlogging. During recovery, tolerant genotypes exhibited a decline, while susceptible ones showed slight increase in SuSy activity. Total soluble sugars and non-reducing sugars also decreased under waterlogging, and more decrease was observed in susceptible genotype than in tolerant ones. Similar to the trend observed for SuSy activity, reducing sugars increased during waterlogging, and the increase was greater in tolerant genotypes (ICP 301 and ICPL 84023), while the susceptible genotypes (ICP 7035 and Pusa 207) recorded a decline. Since glycolytic substrate-dependent phosphorylation is the only source of energy (ATP) under hypoxic conditions of waterlogging, there is a greater demand



Effect of waterlogging on sucrose synthase activity (A), contents of total soluble sugars (B), non-reducing sugars (C), and reducing sugars (D) in pigeonpea genotypes. Recovery was studied only for 4 days' waterlogged plants. Vertical bars indicate ±SE of mean. Value is significant (P =0.05)

for reducing sugars, which is met by enhanced SuSy activity in tolerant genotypes.

ADH activity increased much higher in tolerant genotypes up to 6 days of treatment, while in susceptible genotypes the increase was less, and only up to 4 days of waterlogging. After recovery, ADH activity decreased to the levels of control plant. ADH is a key enzyme under anaerobic respiration, which helps in maintaining NADH/NAD ratio, as accumulation of NADH formed during glycolysis will inhibit glycolysis, and, therefore, glycolytic ATP synthesis.

Under waterlogging the rate of ethylene evolution increased only in tolerant genotypes (ICP 301 and ICPL 84023), while only marginal increase was observed in ICP 7035 on the 4th day of waterlogging. Ethylene levels came back to normal in recovered tolerant genotypes.

From the results, it is apparent that waterlogging tolerant pigeonpea genotype should have higher ADH and SuSy activity, higher total soluble sugars and reducing sugars, and ethylene levels. Ethylene is involved in the induction of various waterlogging induced genes, including ADH and those associated with aerenchyma formation.

5.3.2.3 Role of growth regulators in stress amelioration

Cuticle formation and its significance in wheat and sunflower under stress condition. The cuticle is very effective in limiting water loss from aerial parts of the plant. The thickness of the cuticle varies with environmental conditions. Plant species native to arid areas typically have thicker cuticles than plants from moist habitats. Plants from moist habitats often develop thick cuticles when grown under dry conditions. Keeping these in view, sunflower and wheat leaves were observed for the formation and significance of cuticle under nitrogen and temperature stresses. Sunflower plants were grown with 30 kg N and 120 kg N as urea in pot culture. Wheat cultivars C 306 (water stress tolerant), HD 2285 (heat tolerant) and HD 2428 (water stress susceptible) were planted at different dates of sowings (15 November, 15 December, 15 January and 25 March) from 1999 to 2004. Plants were raised in earthen pots of 30 x 30 cm size filled with sandy loam soil and farmyard manure in 3:1 under natural environment. Each pot was fertilized corresponding to 120, 90 and 60 kg/ha of N, P and K, respectively. Four plants were maintained in each pot. Plants were watered as per requirement. Flag leaf of mother shoot was used for all kinds of observations. Yield components were analysed at harvest in all treatments. ABA was analysed by HPLC (Waters, USA) at PDA 254 nm. Micro-adaptations were analysed by light and electron microscopy. Research findings are mentioned here for sunflower and wheat. The cuticle is composed of a top coating of wax, a thick middle layer containing cutin embedded in wax (the cuticle proper), and a lower layer formed of cutin and wax blended with the cell wall substances pectin, cellulose, and other carbohydrates. Cutin is formed from 16:0 and 18:1 fatty acids. These triacyl glycerides are synthesized in the epidermal cells. They leave the epidermal cells as droplets that pass through pores in the cell wall by an unknown mechanism. Channels in the cell wall connecting cytoplasm to cuticle in guard cell of sunflower were observed. The cuticle of wheat also has similar layers.

5.3.3 Post-harvest Physiology of Fruits, Vegetables and Flowers

5.3.3.1 Regulation of ripening in climacteric fruits

Evaluating the effect of ethanol 1-methylcyclopropene (1-MCP) and UV-C exposure treatments on the shelf life of tomato fruits. An Attempt was made to find out the optimum dose of ethanol required to delay the ripening in two contrasting varieties [slow ripening type (Pusa Ruby) and fast ripening type (Pusa Gaurav)] when fruits were harvested at green mature stage and stored at room temperatures after treatment. Further, a comparison was also made between the most effective dose of ethanol treatment and the most suitable dose of 1-MCP for delaying the ripening. Results indicated that the dose of ethanol required for optimum response (to delay ripening), without any adverse effect, on the tomato fruits differs in varieties tested. For variety Pusa Ruby, 8 ml of ethanol per kg of tomato fruits was the best. On the other hand, 6 ml of ethanol per kg of tomato fruits gave the most satisfactory results for the var. Pusa Gaurav. For both the varieties, lower doses could not delay the ripening substantially, while higher doses caused some adverse effects on fruits such as sunken appearance of scar tissue, unhealthy skin with shrinkage, off smell and flavour of fruits and blackish appearance of internal tissues especially seeds. Ethanol dose of 8 ml/kg and beyond caused scar tissue damage for Pusa Gaurav, while 16 ml/kg and beyond caused similar affect on Pusa Ruby. In comparison with ethanol, 1-MCP treatment was on a par for Pusa Gaurav but it was inferior for Pusa Ruby.

In another experiment, an attempt was made to delay the process of ripening in tomato fruits with short time exposure of UV-C light (254nm), which is reported to trigger the antioxidative system along with plant defense mechanisms. Observation indicated that UV-C treatment could not show any positive effect in delaying the ripening of treated green mature fruits. But, with the increase in the

duration of exposure, alteration in the colour/pigmentation of tomato fruits was noticed. This may be of practical relevance as pigments, especially carotenoids, have nutritional quality with manifold health benefits in view of their strong oxidative property.

Study on respiration rate for attached and detached fruits of tomato varieties with contrasting ripening behaviour. The variety Pusa Gaurav showed slower ripening rate in comparison to Pusa Ruby. Total post-harvest life periods of tomato fruits of Pusa Gaurav and Pusa Ruby were found to be 18-22 and 10-14 days, respectively when fruits were harvested at green mature stage and stored at room conditions (temperature 28 ±2 ^{0}C; relative humidity 35.0 ±6 %).

Pusa Gaurav exhibited significantly lower rate of respiration throughout the storage period. Similar results were obtained when fruits of different ripening stages were harvested directly from the plant. The results, therefore, confirmed the differential behaviour of two varieties towards the rate of respiration. The lower respiratory activity in Pusa Gaurav could be one of the factors responsible for its slower ripening rate. In fact, respiration rate has been linked with the post-harvest life for a number of commodities and there is an inverse relationship between respiration rate and post-harvest life. Further, Pusa Gaurav showed lower PLW % throughout the storage duration. At 14 days after harvest (DAH), physiological loss of weight (PLW) was 30% less in Pusa Gaurav than in Pusa Ruby. As respiration and PLW/ water loss are known to be influenced by surface morphological/anatomical features, these features need to be investigated in future for climacteric fruits including tomato.

Respiration rate (µmole CO^2 h^{-1} g^{-1} fr. wt.) of tomato fruits harvested at green mature stage and stored under room conditions up to 14 days in two varieties.

Days after harvest (DAH)	Pusa Ruby	Pusa Gaurav	Mean (DAH)
1	10.56^{a}	5.64^{c}	8.09^{a}
5	9.93^{a}	3.58^{d}	6.75^{b}
8	7.35b^{c}	3.52^{d}	5.43^{c}
10	7.50^{b}	3.80^{d}	5.28b^{c}
14	6.21^{bc}	3.23^{d}	4.72^{c}
Mean (V)	8.31^{a}	3.95^{b}	
CD value at **P< 0.01 V = 0.760, DAH = 1.203, V x DAH = 1.701			

5.3.3.2 Physiological and molecular basis of regulation of flower senescence

Regulation of flower senescence by abscisic (ABA) acid in gladiolus. The senescence of gladiolus flower is not hastened by physiological levels of ethylene, nor is delayed by preventing ethylene synthesis or inhibiting its action. ABA may be a possible candidate for hormonal trigger for death of flowers (e.g., gladiolus) that do not respond to ethylene. Exogenous application of ABA accelerates senescence in leaves and certain flowers. Endogenous level of ABA also increases during senescence. But it is correlated with ethylene evolution in climacteric crops. If ABA has to be involved in gladiolus cell death, it will not be through an ethylene evolution.

It was observed that ABA advanced the senescence of gladiolus flowers by 2-3 days in a concentration dependent manner in the cultivars Snow Princess and Dhanwantari. Daily vase solution uptake by gladiolus spikes was also reduced by abscisic acid. Cumulative solution uptake was the highest in control (water) followed by 100 and 100 mmol ABA. Vase life and flower diameter were significantly reduced under the influence of ABA. There was a decline in protein content during flower senescence as expected as protein content is reduced because of little *de novo* synthesis and considerable protein degradation. The rate of protein decline was enhanced by the addition of ABA in holding solution.

Flowers start to show slow ion leakage even before opening and the leakage rate increases, as shown by decreasing membrane stability index, steeply until senescence. When ABA was added to the holding solution, ion leakage was stimulated in a concentration–dependent manner.

To examine if ABA accelerates the appearance of other senescence-associated parameters, the accumulation of peroxidized lipid was measured as thiobarbituric acid reactive substances (TBARS). Initially, TBARS increases slowly and then increases more rapidly. ABA caused a premature increase of TBARS in petals and the amount was significantly higher in the hormone-treated flowers. The differences were conspicuous at later stages. An increase in protease activity is another characteristic of senescing systems. The activity of protease remains low at early stages and then the activity increases steadily. When ABA is added to the holding solution, the protease activity increases. Initially, the differences were significant but at later stages the differences were huge.

Enhancement of banana nutritional quality by manipulating genetic variation for provitamin A carotenoids and antioxidants. Next to food security, nutritional security is an important national goal. Banana is one of the most important fruit crops of India, which contributes about 37 per cent of total fruit production and provides livelihood security to thousands of people. India is the largest producer of banana in the world contributing to about 22% to the global

production. Banana cultivars rich in provitamin-A, and carotenoids may offer a potential food source for alleviating vitamin-A deficiency, particularly in developing countries. Different cultivars of banana were analyzed for total carotenoids, antioxidants content, carbohydrate status and antioxidant enzymes. Physiological and biochemical evaluation of both the edible and non-edible portion of banana fruit was also carried out. The possibility of using the non-edible portion (peel) as potential source of carotenoids was also explored. The results showed remarkable differences in the carotenoids content of both the edible and non-edible portions. The banana cultivar Karpuravalli showed higher values for all the parameters studied in this experiment.

Plant regeneration through in vitro callus formation from gladiolus cormels. The cormels were aseptically cultured in half strength of MS media with 1.0 mg/l BAP. Before culture, the cormels were surface sterilized. MS containing standard salts and vitamins, 3 % (w/v) sucrose and 0.7 % (w/v) agar was used. The pH of the medium was adjusted to 5.8 before adding agar. Cultures were incubated at 10,000 lux with cool white fluorescent light and maintained at 24 ± 2°C. Callus was initiated from seven-day-old sprouts of cormels. Each cormel was sliced into 2 mm thick transverse sections and they were placed with a cut surface in contact with culture medium. The medium for callus initiation was MS basal salts, 3 % (w/v), sucrose, 0.7 % agar, glycine 2.0 mg/l, thiamine 1.0 mg/l, pyridoxine 0.5 mg/l, nicotinic acid 0.5 mg/l, mesoinositol 100 mg/l, 2,4-D, BAP and NAA, individually at different concentrations. Regenerating cultures were maintained under a 16-h light photoperiod at 24 ± 1°C.

Regenerable callus formed from the basal region of *in vitro* cultured cormel slices, approximately three weeks after the explants was placed on callus induction medium. The explants formed regenerable callus when cultured on either NAA (1, 2 or 4 mg/l), or 2, 4-D (0.5, 1 or 2 mg/l). Callus initiated on the various concentrations of these three hormones was friable and proliferated over the next subculture. Callus was maintained on callus inducing medium.

Extension of vase life of rose flowers using ethanol and sucrose. Cut flowers are highly perishable and vulnerable commodity with post-harvest losses estimated to be about 20-40 per cent. Efforts were made to regulate the senescence process using various chemical compounds. Since ethanol plays an important role in the inhibition of ethylene evolution, and sucrose, being a substrate for respiration, also maintains osmotic gradient for better water uptake, attempts were made to study their combined effect on the vase life of ethylene sensitive flowers like roses.

Stems of rose (*Rosa hybrida* L.) var. First Red were harvested at commercial stage (flowers with outer petal whorl just unfurled). Stems re-cut under water to a length of 60 cm bearing three leaves, were used in all the experiments. The cut flowers were subjected to 4 treatments, viz., (i) control (distilled water), (ii) 3% ethanol, (iii) 3% ethanol + 3% sucrose and (iv) 3% sucrose, and were kept in a temperature-controlled chamber at 20±2^{0}C and relative humidity of 65-70%. The room was illuminated with "cool white fluorescent tubes (light intensity =25 µmol m^{-2} s^{-1} at flower level on a 12 h on–off cycle). Nine flowers were used for each treatment.

Data pertaining to water potential, ethylene and ABA contents were taken using petals from different whorls of the flower, outermost to innermost (W_1 to W_7), at different stages of development.

Data clearly demonstrated that the treatment with 3% sucrose enhanced the vase life of flowers by two days in contrast to untreated control. Application of 3% ethanol also had a positive effect on the vase life. However, a combined treatment of 3% ethanol and 3% sucrose gave the best result in terms of vase life. An enhancement of 7.2 days was observed in the vase life. Higher water potential was measured in the treated flower heads in comparison to controls throughout the vase life period.

Effect of ethanol and sucrose on the vase life of the rose variety First Red

ABA accumulation was lower in the petals of treated flowers in contrast to untreated flowers. A significant decline in ABA accumulation was recorded during the first 3 days in both treated and untreated flowers. However, this decline was much more in petals of treated flowers. Similarly on the 9th day, the level of ABA was 1.2 fold higher in control flowers in comparison to treated ones.

A combined application of ethanol and sucrose in vase solution drastically reduced the triphasic evolution of ethylene from the petals. Characteristic rise of ethylene production was altogether eliminated from the vase life of treated flowers.

On the 3rd day in vase, ethylene formation was 6 times lower in treated petals as compared to control. Among the petal whorls, the evolution of ethylene was lesser in inner whorls than in outer whorls.

The lower level of ABA and ethylene might be responsible for the excellent vase longevity in ethylene sensitive rose flowers.

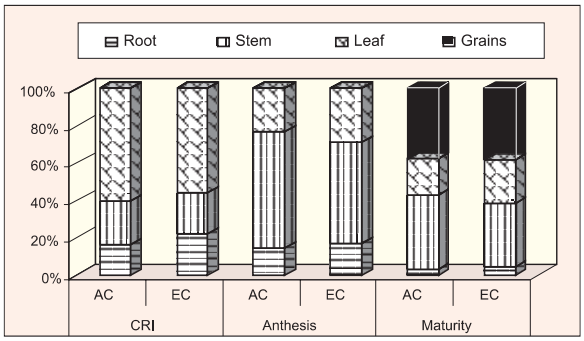
Effect of ethanol and sucrose on ethylene evolution (nL g^{-1} Fwt. h^{-1}) in petals of the rose variety First Red during vase life

Treatments		Days in vase						Mean
		0	3	6	9	12	16	
Control	W1	0.06	1.96	6.86	4.30	*	*	**2.19**
	W2	0.06	1.95	6.73	4.21	*	*	**2.16**
	W3	0.06	1.76	6.62	3.92	*	*	**2.06**
	W4	0.05	1.66	6.62	3.77	*	*	**2.02**
	W5	0.05	1.52	6.52	3.54	*	*	**1.94**
	W6	0.05	1.48	5.80	3.49	*	*	**1.80**
	W7	0.05	1.38	5.70	3.51	*	*	**1.77**
Mean		**0.05**	**1.67**	**6.41**	**3.82**	-	-	-
Treatment	W1	0.06	0.24	0.54	1.33	1.88	0.89	**0.82**
	W2	0.06	0.15	0.47	1.25	1.57	0.75	**0.71**
	W3	0.06	0.09	0.38	1.06	1.30	0.88	**0.63**
	W4	0.05	0.07	0.28	0.96	1.08	0.89	**0.55**
	W5	0.05	0.05	0.18	0.90	0.98	0.77	**0.48**
	W6	0.05	0.03	0.12	0.74	0.83	0.53	**0.38**
	W7	0.05	0.01	0.09	0.51	0.81	0.32	**0.30**
	Mean	**0.05**	**0.09**	**0.29**	**0.96**	**1.20**	**0.72**	-
Grand mean		0.05	0.88	3.35	2.39	0.60	0.36	-
CD at 5%								
Stage (S)		0.033						
Whorl (W)		0.047						
Stage x Whorl (S x W)		0.089						

5.3.4 Characterization of Crop Responses to Global Climate Change

5.3.4.1 Photosynthesis and partitioning of biomass and carbon in wheat under elevated atmospheric CO_2

Rising atmospheric carbon dioxide concentration and temperature in the global climate are likely to affect plant carbon assimilation, growth, biomass allocation and nutrient uptake. Most of the C_3 plants respond to increase in CO_2 in short term since the activity of Rubisco is limited by ambient/ atmospheric CO_2 concentration. The present investigation was conducted to study the effect of elevated CO_2 on growth, photosynthesis and biomass and carbon partitioning, and to determine the changes in root architecture and rhizospheric active carbon pools. Wheat crop plants (cv. HD 2687) were raised in plastic pots (diameter 8 inches) and grown inside open-top chambers. The plants were exposed to ambient (CA, 370±20 µl l^{-1}) and elevated CO_2 concentration (CE, 600±50 µl l^{-1}) from germination till maturity of the crop.



Biomass partitioning in different parts of wheat under elevated (CE) and ambient (CA) CO_2

Elevated CO_2 caused enhancement in the rate of photosynthesis and activation of Rubisco enzyme protein, while the Rubisco activity was not much affected because of elevated CO_2 treatment compared with ambient CO_2. Higher photosynthetic rate resulted in significant increase in leaf surface area and total plant biomass at all the growth stages but maximum enhancement in photosynthesis was observed at vegetative stage. Specific leaf mass of CO_2 enriched plants was marginally higher due to accumulation of non-structural carbohydrates. Partitioning of biomass and carbon was affected by elevated CO_2 and it was more towards roots at all the stages of growth compared to above ground plant parts. At maturity stage, the contribution of root biomass was less in total plant biomass compared to earlier growth stages but it increased in high CO_2 grown plants compared with ambient CO_2 grown plants. Enhanced partitioning of biomass and carbon to below ground resulted in more profuse and dense root growth. Root dry weight and volume were also higher under high CO_2 treatment, which increased the root shoot ratio marginally. Carbon concentration was higher in shoot and decreased marginally in grain due to dilution effect and no significant change occurred in roots. All active carbon pools in the rhizosphere increased due to partitioning of extra carbon towards below ground, and the increased microbial biomass carbon (MBC) was associated with high dehydrogenase

activity in soil, which reflects the changes in microbial activity under high CO_2 environment. The study concludes that the partitioning of more carbon in soil due to elevated CO_2 concentration may change the microbial activity which can influence the soil mineralization process.

Effect of elevated CO_2 on photosynthetic and growth characteristics of wheat at anthesis stage

Parameters	CO_2 concentration (µl l^{-1})	
	370±20 (CA)	600±50(CE)
Photosynthesis rate (µ mol CO_2 m^{-2} s^{-1})	15.10	23.78
Rubisco activity (µ mol CO_2 g^{-1} FW s^{-1})	18.78	20.07
Rubisco activation (%)	59.07	73.25
Leaf area (cm^2 $plant^{-1}$)	237.32	354.65
Specific leaf mass (dm^2 g^{-1})	2.82	3.17
Plant biomass (g $plant^{-1}$)	14.48	21.02
Root/shoot ratio	0.263	0.291
CA: ambient CO_2; CE: elevated CO_2		

5.3.4.2 Study on the response of rice cultivars to the interaction of elevated CO_2 and temperature

The response of rice varieties, PRH 10 and PS 2 to the interaction of elevated CO_2 and temperature was studied in controlled growth chambers at the National Phytotron Facility (NPF) of the Institute. Temperature and CO_2 concentrations were maintained in the chambers as follows: (i) ambient CO_2 concentration (370µmol mol^{-1}) with ambient temperature 31/24^{0}C, (ii) ambient CO_2 concentration (370 µmol mol^{-1}) with elevated temperature, 35/28^{0}C, (iii) elevated CO_2 concentration (550±15 µmol mol^{-1}) with ambient temperature 31/24^{0}C, and (iv) elevated CO_2 concentration (550±15 µmol mol^{-1}) with elevated temperature 35/28^{0}C. Observations were recorded at the vegetative, heading and ripening stages of the crop.

CO_2 enrichment brought about significant increase in photosynthesis, grain yield per plant, grain number per panicle, 1000-grain weight and harvest index. The increase was greater in PRH 10 compared to PS 2 for all these yield components. Higher temperature resulted in significant reduction in the photosynthesis and yield parameters. However, this reduction was significantly lesser under elevated CO_2 condition. Such an ameliorating response of elevated CO_2 to high temperature stress was more in PRH 10 compared to PS 2. However, the interaction of CO_2 x temperature was significant only for grain yield and grain number.

In the present study, elevated CO_2 brought about greater increase in the accumulation of whole plant biomass. The variety PS 2 was less responsive to elevated CO_2, whereas PRH 10 was able to express its full potential for growth at higher CO_2 concentration. Elevated temperature brought about reduction in biomass in both the varieties. At elevated CO_2, the temperature induced reduction was lessened to a greater extent in PRH 10 compared to PS 2. The enhancement in grain yield was due to the enhanced production of panicles per plant and increased grain mass. The fact that elevated CO_2 increased the spikelet number despite a reduction in plant N concentration suggests that elevated CO_2 promoted spikelet production efficiency per unit of plant N. Elevated CO_2 increased sink size by increasing the grain number and this generally leads to increased yield. Further, the increase in temperature from 31^{0}C to 35 ^{0}C brought about reduction in the grain number and grain mass, which was comparatively less in PRH 10. This reduction was ameliorated under elevated CO_2 by about 16% in the case of grain number in both the varieties. In the case of grain mass, it was 3% in PRH 10 and 2% in PS 2. These results thus point to the possibility of selecting or breeding rice cultivars with enhanced capability to take advantage of future global increase in CO_2.

The database generated on various morphological, physiological and biochemical parameters will contribute significantly in developing plant type and model for future climate condition. This study will help in tailoring suitable rice plants and identifying nutrient management and cultivation technologies for such cultivars in changed climatic condition.

5.3.5 Biophysical Characterization of Plant Responses and Post Harvest Quality Preservation of Agro-products

Grain samples were collected at every 15 days' intervals until 45 days and then at 120 days after treatment, and analyzed. Protein profile analysis of grains of both HD 2329 and PBW 343 indicated that gamma irradiation at dosage of 0.25 and 0.5 kGy, and temperatures, at 15 ºC (low temperature, LT) and 35ºC (room temperature, RT), had no adverse effect on the grain protein quality. An interesting observation was made for beta-carotene concentration of grains which declined, in general, upon irradiation in a dose dependent manner at zero time (S0) for both the genotypes. Over the storage period, the beta carotene levels did not change considerably both under un-irradiated and irradiated treatments for both the genotypes under low storage temperature. However, at room temperature, the beta carotene levels, in general, increased with storage time independent of genotype and radiation treatments. It will be interesting to ascertain the reasons for an increase in beta carotene, the precursor of vitamin A synthesis.

5.3.6 Application of Physical Approaches for Enhancing Crop Productivity and Post-harvest Storability

Studies were undertaken to explore the feasibility of gamma irradiation to increase the storability and its effect on the nutritional quality of mango. Results indicated that gamma irradiation of freshly plucked mangoes (var. Dashehari and Amrapali) with a dose of 0.5 kGy proved to be optimum for enhancement of the shelf-life for a week with practically no change in their appearance or weight loss in Dashehari, and about 2% less weight loss, 9 days after irradiation, in Amrapali mangoes. Further studies were undertaken to evaluate the effect of irradiation, by chemical analysis, on important anti-oxidants like beta carotene and ascorbic acid. Results exhibited the presence of comparatively more quantities of both the anti-oxidants in 0.25 and 0.5 kGy gamma irradiated mangoes compared to that in the control indicating the nutritional safety of the suggested doses of gamma irradiation for the preservation of mango.

Per cent weight loss in stored mangoes after irradiation

Dose (kGy)	IW (g)	Dashehari				Amrapali				
		Days after irradiation				IW (g)	Days after irradiation			
		2	4	7	9		2	4	7	9
0.00	1732	4.33	8.31	14.26	18.19	1500	4.66	9.20	12.90	17.40
0.25	1599	4.87	8.94	15.13	19.51	1554	4.69	8.79	12.48	16.92
0.50	1639	4.76	8.97	15.25	18.19	1653	4.59	8.34	11.85	15.60
0.75	1657	5.00	9.35	15.44	19.46	1494	4.75	8.70	12.35	16.13
1.00	1533	4.96	9.33	15.65	19.74	1548	3.91	8.09	11.84	15.82

IW: Initial weight at harvest/irradiation; (Average of 3 replications)

β-carotene and ascorbic acid (vitamin C) status in 100 g pulp of mangoes (12 days after harvest/irradiation)

Dose (kGy)	β-carotine (μg)		Ascorbic acid (mg)	
	Dashehari	Amrapali	Dashehari	Amrapali
0.00	15,092	15,093	14.82	14.25
0.25	13,499	16,374	13.68	14.66
0.50	16,477	16,897	13.40	15.31
0.75	14,077	14,342	11.85	12.45
1.00	12,856	13,363	12.47	13.91

Average of 3 replications

5.3.7 Genetic and Physiological Regulation of Phytosiderophore (PS) Production in Relation to Zinc Efficiency in Wheat

Variation in zinc efficiency among the wheat species and their relationship with the release/synthesis of PS has been determined and is positively correlated. Diurnal rhythm for variation in PS content of root and PS release in bread and *durum* wheat types investigated and is found to be similar. Effect of PS availability in root zone of Zn inefficient genotype on the Zn uptake has been investigated. The difference in the expression of key enzyme of PS biosynthesis nicotianamine amino transferase (NAAT) is related to Zn efficiency differences among bread and *durum* wheat types.

5.3.8 Relationship between Biophysical Parameters and Performance of Wheat under Late Heat Condition

In a field experiment, 15 bread wheat and 5 *durum* wheat varieties were exposed to late heat by delayed sowing and their performance was compared to that of normal sown crops. The susceptibility index (SI) calculated as yield decrease due to stress relative to potential yield was higher for *durum* wheat compared to that for bread wheat. The relationship between mean yield and SI values showed that the genotypes like HD 2923, WR 1508, PBW 175 and Kundan were adapted to late heat stress as they combined low SI with high yields. Biophysical parameters such as leaf membrane stability index (MSI), canopy temperature depression (CTD) and leaf water spin-lattice relaxation time T_1 were measured and related to SI values. High correlation between SI values and MSI (r=0.57**), CTD (0.69**) and leaf water spin-lattice relaxation time T_1 (r=0.72**) indicated that these traits can be used as selection criterion for adaptation to temperature stress in wheat.

5.3.9 Interactive Effect of Gamma Radiation and Moisture Content on Germination and Plant Growth under Laboratory Condition

A laboratory experiment was conducted to study the effect of low doses of gamma radiation with various regimes of moisture on root and shoot length and germination (%). The wheat seeds (DL 1266-5) were soaked in water for different period to get the desired moisture absorbed by the seeds and then treated the seeds with various doses of gamma radiation. To observe the interactive effect of gamma radiation and moisture percentage, the shoot and root length and germination (%) were observed of the 7 days' old wheat seedlings.

It was observed that 0.03-kGy dose of gamma radiation was most effective in enhancing the metabolic activity, which led to higher germination percentage as well as establishment of seedlings with moisture content up to 28%. Negative correlation was observed between the dose of gamma radiation and germination percentage above the 0.03 kGy dose of gamma radiation. Similar correlation was also observed between the moisture content of seed and germination percentage. Shoot length of the wheat seedlings was increased with the 0.03 kGy dose of gamma radiation.

Higher doses of gamma radiation above the 0.03 kGy dose play an inhibitory role in increasing the shoot length. Interestingly, the treatment of gamma radiation was most effective in reducing the root length. The decreasing pattern of root length was observed with increasing dose of gamma radiation compared to that in control. It is assumed that some morpho-physiological changes might have occurred in the roots, which led to the stimulation of *in vivo* physiological function. Negative correlation was also observed between the moisture content of seed and shoots and root length of the wheat seedlings.

Effect of low doses of gamma radiation and moisture content on shoot length of 7-day old wheat seedlings (cv. DL 1266-5) grown under laboratory conditions

Treatments kGy	Root length (cm) At moisture level				Mean
	10 %	18 %	23 %	28 %	
Control	6.48	6.13	5.08	4.19	5.47
0.03	6.74	6.21	5.18	4.24	5.59
0.06	6.36	6.16	5.16	4.14	5.45
0.09	6.06	5.45	4.13	4.03	4.91
0.12	5.36	5.30	3.93	3.09	4.42
0.15	4.36	4.71	3.14	2.74	3.73
Mean	5.90	5.66	4.44	3.73	

*Mean of three replicates (each replicate consisted of 20 seedlings)

Effect of low doses of gamma radiation and moisture content on the root length of 7-day old wheat seedlings (cv. DL 1266-5) grown under laboratory conditions

Treatments kGy	Shoot length (cm) At moisture level				Mean
	10 %	18 %	23 %	28 %	
Control	12.31	8.19	7.06	6.00	8.39
0.03	11.05	8.02	6.87	5.67	7.90
0.06	10.69	6.63	5.53	4.43	6.82
0.09	10.19	4.80	3.94	2.94	5.47
0.12	9.07	2.70	3.01	2.14	4.23
0.15	5.88	1.83	1.69	1.60	2.75
Mean	9.86	5.36	4.68	3.80	

* Mean of three replicates (each replicate consisted of 20 seedlings)

Effect of low doses of gamma radiation and moisture content on germination (%) of wheat (cv. DL 1266-5) grown under laboratory conditions

Treatments kGy	Germination (%) At moisture level				Mean
	10 %	18 %	23 %	28 %	
Control	90	86	85	82	85.75
0.03	92	88	88	84	87.50
0.06	91	85	84	81	85.25
0.09	88	83	82	80	83.25
0.12	86	78	79	69	78.00
0.15	85	77	76	55	73.25
Mean	88.7	82.8	82.0	75	

* Mean of three replicates (each replicate consisted of 20 seedlings)

5.4 GENETICS

5.4.1 Wheat

5.4.1.1 Genetic enhancement/pre-breeding

Cytologically stable genotypes conferring resistance to leaf, stripe of stem rusts from the BC_2-F_2 generation derived from Lal Bahadur (mono 5B)*^{2}/*Aegilops markgrafii* (2n=2x=14, genome CC) and Chinese Spring x *Aegilops speltoides* (2n=2x=14, genome SS) crosses were identified.

5.4.1.2 Genetic analysis of synthetic wheat for resistance to leaf rust

Five synthetic hexaploid wheats were tested with leaf rust races. A recessive gene controlled the resistance in Syn.45 and Syn.46. A dominant gene controlled the resistance in Syn.55 and a partially dominant gene governed the resistance in Syn.74 and Syn.75.

5.4.1.3 Genetic analysis of synthetic wheat for resistance to stem rust

Syn.4 and Syn.55 carry the same dominant gene resistance to stem rust both at seedling and adult plant stages. Resistance was digenically controlled in Syn.86 in seedling, and 3 genes govern the resistance at adult plant stage.

5.4.1.4 Slow rusting studies to leaf rust in susceptible varieties

Analysis of five local varieties of wheat suggested that Kharchia Local is the fastest ruster variety for leaf rust indicating its usefulness as check variety in slow rusting studies.

5.4.1.5 Transfer of stem rust resistance into *T. durum*

Most of *T. durum* cultivars in India are susceptible to stem rust. An effective gene *Sr*31 derived from *Secale cereale* and available in several hexaploid bread wheat cultivars confers high resistance to Indian stem rust races. Cytologically stable lines exhibiting seedling resistance to 117-6 pathotype of stem rust were identified from two different crosses. Confirmation of the presence of *Sr*31 in selected *durum* lines was done by counting the number of satellite(s).

5.4.1.6 Introgression of *Yr*15 into HD 2329

Most of the present day wheat varieties grown in NWPZ and northern hills are susceptible to stripe rust and limit the yield. The effective gene *Yr*15 originating from *T. dicoccoides* G25 was incorporated through judicious backcrossing into popular wheat cultivar HD 2329 and an advance line BM 287. A study on the mode of inheritance and test of allelism showed that HD 2329*5/V 763-2312 indeed carries the resistance imparted by *Yr*15, which is of dominant nature.

The availability of *Yr*15 in the background of adapted wheat will enhance its use in wheat breeding in India and elsewhere.

5.4.1.7 Genetic analysis of *Triticum compactum* var. *amplissifolium* producing curved grain

Hexaploid wheat species *Triticum aestivum* sub species *compactum* var. *amplissifolium* produced small plump but curved or boat shaped kernels with low thousand kernel weight. The grain number per unit spike length is high. The trait of curved grain seems to be rare. The genetic analysis in F_2 (*T. aestivum* cv. NI5439 x *T. amplissifolium*), BC_1 (F_1 x NI5439) and F_3 generations revealed that the curved grain is governed by a single dominant gene. The gene symbol *Cvg* is proposed for this trait. The characters, short spike, and kernel colour are also controlled by a single but independent gene(s). The number of grains per unit spike length and thousand kernel weight are presumably governed by more than one gene and that both the traits showed some association with the character of short spike length. Linkage analysis indicated that the character of curved grain is linked with short spike length and the distance between these characters is 7.63 Kosambi unit.

5.4.1.8 Identification of new lethal genes

The genetic analysis of data in segregating generations of *Triticum aestivum* cross WR 95 x HW 2041 and its reciprocal revealed that WR 95 carries a recessive gene proposed as *apd*1 which leads to death of certain individuals when combined with another gene proposed as *apd*2 distributed among several hexaploid bread wheat genotypes. The phenomenon is described as apical death and appears at seedling stage.

5.4.1.9 RNA editing in mitochondrial genome of wheat

In order to find out the gene responsible for causing male sterility, transcript analysis was done by northern hybridization. Mitochnondrial genes *atp*A.*coxI* and 18 s rRNA were used to hybridize with total RNA isolated from both leaf and flower bud tissues of cytoplasmic male sterility (CMS) lines and fertility restored lines (hybrids) in two different hybrid systems. All genes studied displayed an identical transcription pattern in all cytoplasms and nuclear backgrounds; therefore, transcript analysis data suggest that these genes cannot be implicated in causing cytoplamic male sterility.

RNA editing and cytoplamic male sterility are two important and correlated phenomena in higher plants. RNA editing in *orf256,* which is implicated in causing cytoplasmic male sterility (CMS) universally, was investigated by designing primers for the region, sequencing and comparing the amplicon in both genomic DNA and cDNA of two different hybrids and respective CMS lines. This study provides the first preliminary report of RNA editing in *orf256* with high frequency of editing in fertility restored hybrids compared to male sterile lines. Editing sites are also conserved with respect to both hybrids at 381 position of C residue, and *Triticum araraticum* CMS showed a complete lack of editing.

5.4.1.10 Wheat quality analysis

To study quality differences between 1B/1R and non 1B/1R lines, quality analysis of contrasting genotypes was conducted. Screening of the breeding line over the years could hardly exhibit new variability in the high molecular weight glutenin subunit (HMWGS) profile. This trait is inherited and is used to segregate early generation progenies for end use quality. Protein from land races was fractionated on SDS-PAGE for Glu-1 composition. Five genotypes, viz., MPG 7, MPG 39, MPG 70, MPG 105 and MPG 117 with unique combination of 2*, 20, 5+10 were identified for the first time. Since subunit 20 was reported to show promise for *chapati* quality, the involvement of these lines in crossing programme might help in the development of superior *chapati* making varieties.

5.4.1.11 Characterization of core germplasm

Fifty parental wheat genotypes, including 20 agronomically superior, 18 contrasting for different quality traits like grain weight, size, *chapati* quality, etc., five differing for heat tolerant traits and seven NP varieties, were studied for polymorphism. In addition, 18 landraces collected from different parts of Madhya Pradesh were also included to study the variability and diversity related to various traits. Fifty SSR (microsatellite) primer pairs distributed on the three genomes (A, B and D) covering all seven chromosomes were chosen. Out of eighteen primer pairs studied so far, six mapped on D genome, five on A genome and seven on B genome. A large number of alleles were detected among wheat genotypes. The number of alleles ranged from 8 to 10 for a particular marker. The amplified products ranging between 100 and 500 bp were scored and markers were polymorphic at one or two loci. Unique DNA fingerprints discriminating the contrasting genotypes were obtained for some of the markers.

5.4.1.12 Screening for grain hardness

Over 100 wheat varieties were screened for grain hardness using Single Kernel Characterization System. The hybridization between hard and soft genotypes was attempted and F_2 raised for utilization of molecular markers in breeding for hard grain wheat varieties.

5.4.1.13 Validation for molecular markers for stem rust

To develop wheat varieties resistant to new stem rust race, viz., Ug99, validation of molecular markers for *Sr* 24 was under progress. Phenotyping of parental lines, viz., HW 2007, and HW 2017 was done.

5.4.1.14 Induced Pusa dwarfing genes

A local selection from Rishi Valley of Andhra Pradesh, christened as NP 200 (*Triticum dicoccum)* was released for cultivation during 1958-59, and used as the national check in the special trials of *dicoccum* ever since it was released. Though the variety is tall, it has special quality traits among *dicoccum* varieties. However, the variety being tall it lodges and causes considerable yield loss. The variety NP 200 along with another variety HW 5011 was subjected to 0, 10, 20, 30 and 40 Kr doses of gama ray irradiation at Bhaba Atomic Research Centre (BARC), Mumbai during *rabi* 2002-2003. A desirable dwarf mutant was picked from treatment 20 Kr at M_2 stage, during *kharif* 2003. The non-segregant semi-dwarf line having luxuriant growth, high tillering and resistance to yellow rust and powdery mildew was constituted at M_4 stage. The semi-dwarf mutant (HW 1095) was crossed with NP 200 and the F_1 showed the dominant character for tallness as that of NP 200, with the dark green foliage as that of the mutant. The other traits remain similar to those of NP 200. The F_2 segregation revealed that the semi-dwarfism in *dicoccum* is controlled by two independent complementary genes from AB genomes, which are designated as 'Pusa Dwarfing Genes of *Dicoccum*'.

Inheritance of semi dwarf stature in NP 200 derived Pusa dwarf *dicoccum* with parent NP 200 has been carried out. The data are presented below:

F_2 Segregation

Parents/Cross	Tall	Dwarf	F_1	Total	Ratio	X^2	P
HW 1095 x NP-200	87 Tall	106 Semi dwarf	- Tall	243 -	9:7 Tall: S. dwarf	1.850 -	50-70 -

5.4.1.15 Identification of pyramided diverse leaf rust resistance genes through use of molecular aids

The Wellington bred wheat lines (116) with multiple resistance genes, viz., *Lr* 9, *Lr*26 + *Lr*19, *Lr*19 +*Lr*24, *Lr*24+*Lr*26 and *Lr*9 +*Lr*19+*Lr*26 were subjected to HPI (host pathogen interaction). Out of 116 lines, WTN 163 carries three gene combinations, viz., *Lr*9, *Lr*19 +*Lr*26 and one line WTN 2001 carried two genes *Lr*19+*Lr*26. Hence, the successful introduction of alien genes and their identification through HPI and molecular markers is possible.

5.4.1.16 Collection, maintenance and characterization of wild species

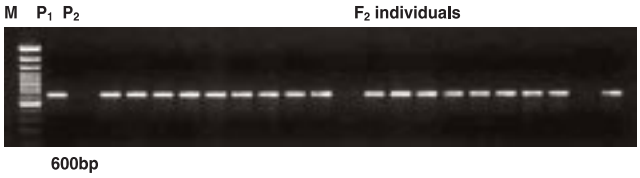
Around 650 wild accessions are being maintained continuously for characterization and screening of wild species for desirable attributes. Several interspecific and intergeneric crosses between wild and cultivated wheats were attempted. Promising interspecific and intervarietal derivatives have been evaluated. Novel intergeneric hybrid using maize as pollen donor has been developed for the first time in addition to haploids.

5.4.2 Rice

5.4.2.1 Marker assisted backcross breeding for development of provitamin A rich *indica* rice

Rice endosperm does not produce provitamin A owing to lack of key enzymes, phytoene synthase (*psy*) and phytoene desaturase (*crtI*) resulting into vitamin A deficiency (VAD) and associated disorders in the predominant rice eaters. Genetically modified rice lines (Golden Rice) that accumulate provitamin A (ß-carotene) in the endosperm were obtained in the background of Taipei 309 (*japonica*) and IR 64 (*indica*) under "Network Project on Golden Rice", and used to transfer the provitamin A trait through marker assisted backcross breeding to popular *indica* rice variety, viz., Swarna, which is widely grown in the areas where VAD is prevalent.

Inheritance of the transgene. Inheritance of transgene was studied by PCR amplification using *psy* specific primers



Transgene segregation in F_2 of cross Swarna x transgenic IR 64

in F_2 and BC_1F_1 populations derived from the cross Swarna x IR 64 and Swarna x Taipei 309. Significant deviation from expected 3:1 and 1:1 ratio for transgene segregation was obtained in F_2 and BC_1F_1 (when F_1 was used as male parent). However, the BC_1F_1 segregation ratio fitted well with

Transgene inheritance in F_2 and BC_1F_1 population

Cross	Gen.	Total no. of plants	Trans-gene +	Trans-gene -	Exp. seg. ratio	P value
Swarna x Taipei 309	F_2	244	212	32	3:1	<0.001
F_1 x Swarna	BC_1F_1	115	61	54	1:1	0.95
Swarna x IR 64	F_2	85	79	6	3:1	<. 001
Swarna x F_1	BC_1F_1	47	32	15	1:1	0.025-.001
F_1 x Swarna	BC_1F_1	110	63	47	1:1	0.10

expected 1:1 ratio when recurrent parent was used as male. The results indicate that transgene positive gametes are inherited in higher frequency from the male side resulting into segregation distortion. However, this needs to be verified in diverse background and by phenotypic characterization of the positive and negative plants for transgene expression.

Location of transgene. Bulked segregant analysis (BSA) approach was used for the location of transgenes using an F_2 mapping population derived from the cross of transgenic Taipei 309 with the popular *Indica* rice variety Swarna. The marker RM252 located in chromosome 4 was found polymorphic between bulks. The STMS marker RM 252, which amplified the products of 200 and 225 bp in the transgenic Taipei 309 and recurrent parent Swarna, respectively, was used for genotyping all 156 individual F_2 plants. Linkage analysis revealed RM 252 to be linked with the transgenes (*psy+crtI)* at a distance of 13.4 cM. The location of transgene will help in identifying flanking microsatellite markers for background selection on carrier chromosome.

5.4.2.2 Pyramiding of bacterial blight resistance genes *xa13* and *Xa21* in the parental lines of Pusa RH 10

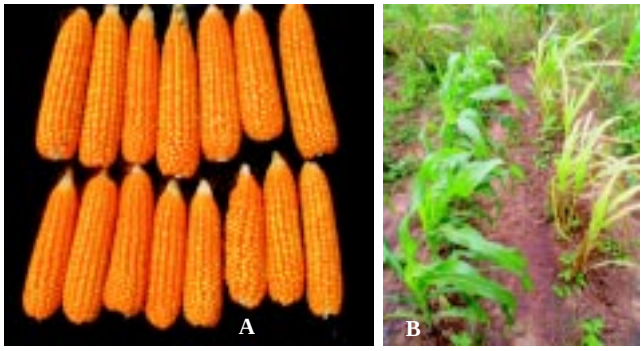
Bacterial blight (BB) is a severe disease of rice causing significant yield losses. The hybrid Pusa RH 10 and its parental lines Pusa 6A and PRR 78 are susceptible to BB. Pusa 6B and PRR 78 were crossed with IRBB 55 carrying *xa13* and *Xa21*. BC_1F_1 plants were generated in both crosses and analysed for the presence of genes using RG136 and pTA248 markers linked to genes *xa13* and *Xa21*, respectively.

For background selection, approximately 300 microsatellite markers providing genome wide coverage were used for parental polymorphism survey and nearly 20% markers were found polymorphic and used for background selection among BC_1F_1 plants positive for both the genes. The plants having more resemblance to recurrent parent based on their profile were selected for generating BC_2F_1 seeds. The selected plants had been used for backcrossing with respective recurrent parent. Incorporation of resistance to BB in Pusa RH 10 will help in stabilizing its production.

5.4.3 Maize

5.4.3.1 Molecular marker-assisted breeding for downy mildew resistance in maize

One hundred twenty-two hybrids (derived by reciprocal crossing of MAS-derived resistant lines with elite inbreds) were evaluated at Delhi and Hyderabad for their agronomic performance, and for their responses to sorghum downy mildew infection under artificial inoculation conditions at



A: MAS-derived hybrid, MGH 112, found highly promising at both Delhi and Hyderabad; B: SDM-resistant MAS hybrid vs. susceptible check at Mandya

Mandya, during *kharif* 2005. Based on these trials, eight highly promising maize hybrids were identified for coordinated trials. This is the first instance of successful transfer of QTLs for disease resistance in India.

5.4.3.2 Mapping QTLs for BLSB resistance in maize

A $F_{2:3}$ mapping population was generated for mapping QTLs for resistance to banded leaf and sheath blight (BLSB), caused by *Rhizoctonia solani* f. sp. *sasakii*. Phenotyping of nearly 200 F_3 families was undertaken at three locations in India (Delhi, Udaipur and Pantnagar) during *kharif* 2005. Genotyping of the mapping population was so far accomplished using 80 polymorphic microsatellite markers. QTL mapping (utilizing the genotyping and phenotyping datasets) would be completed by June 2006.

Panel showing genotyping of mapping population using bnlg 254 (A); F_3 families showing differential responses to BLSB at Udaipur (B), and Pantnagar (C)

5.4.3.3 Generation and evaluation of maize mapping populations

Two sets of recombinant inbred lines (RILs) were developed: (i) 100 RILs in $F_{8:9}$ stage, originally derived from a cross between CM139 (downy mildew susceptible) and NAI116 (downy mildew resistant); and (ii) 200 RILs in $F_{5:6}$ stage, originally derived from a cross between CA00106 (BLSB resistant) and CM140 (BLSB susceptible). These

RILs are invaluable for undertaking research activities on QTL analyses, molecular breeding and functional genomics for specific target traits.

5.4.3.4 Molecular characterization of Indian maize landraces and allele mining for agronomically important traits

Comprehensive molecular and phenotypic analyses of Indian maize landraces from diverse agro-ecologies in India was initiated. A set of 204 selected Indian maize landraces, including 73 landraces from North-Eastern Himalayan (NEH) region and 53 landraces from other regions in India were evaluated, along with two checks (Parkash and Pusa Composite 3) for their agronomic performance. This led to the identification of several promising landraces for various traits, including early flowering, ear characters and grain yield. Germplasm exploration in Sikkim and Meghalaya was undertaken to collect some of the most important landraces from the North-Eastern Himalayan (NEH) region.

5.4.4 Pearl Millet

5.4.4.1 Molecular characterisation of downy mildew resistant and susceptible inbred lines

Downy mildew (DM) of pearl millet caused by fungus *Sclerospora graminicola* is a devastating disease if occurs in epidemic form. ICRISAT scientists have evaluated eleven promising maintainer B-lines, viz., 863B, ICMB 01888, ICMB 03999, ICMB 01111, ICMB 01333, 834B, ICMB 05666, 843B, ICMB 97111, ICMB 04777, 81B and two restorer R-lines, viz., ICMR 356, ICMP 451 for downy mildew incidence against different pathotypes at four locations, namely, Durgapura, Jamnagar, Jalna, and Patencheru. Data on glasshouse seedling inoculation were recorded for DM incidence on all the above lines along with two susceptible checks (85-100% DM incidence).

All the above lines were grown along with the most susceptible lines WGI 154 and 7042 as DM spreader/indicator rows, to record the DM reaction of above lines. Due to the low incidence of DM during the crop season or due to inherent resistance for DM in the lines supplied by ICRISAT, the incidence of DM was neglegible in these lines. Seed of all the lines was multiplied by selfing and the sample seed of all the lines are being subjected to molecular characterisation. Detailed field and molecular characterisation on these lines will be carried out during *kharif* 2006.

5.4.4.2 Evaluation of recombinant inbred lines (RILs)

Small quantity seed of 146 F_5 self bulk harvested from the cross (841B x 863B) derived from different F_2s along with the seed of parental lines was received from the ICRISAT. This cross was attempted to combine DM and drought resistance in the recombined inbred lines. These RILs along with their parental inbred lines were grown for preliminary evaluation and seed increase using inbreds 7042, WG 126 and WG 154 as DM susceptible checks. Observations on days to 50% flowering, plant height, ear length, ear girth and susceptibility to DM was recorded on all the entries in this trial. All the RILs and parental lines were selfed to produce sufficient seeds for the next year's field evaluation and molecular analysis of the DM, resistant RILs. A total of 31 RILs, which appeared promising and exhibited 0% incidence of DM, were selected for molecular characterisation. The selected RILs are from F_2 nos.1,9,14,26,27,30,32,34,35,38,52,53,54,56,57,62,65,70,73, 76,87,98,103,104,109,119,127,136,143,152 and 158. These will be subjected to molecular analysis.

5.4.5 Chickpea

5.4.5.1 Marker assisted selection for race-4 of *Fusarium* wilt of chickpea

The F_2 population derived from a cross between the parent SBD 377, a simple leafed bold seeded, poor yielder but excellent general combiner and BGD 112, a wilt resistant line, was grown in the wilt sick plot. The phenotyping of the F_2 population for race-4 of *Fusarium* wilt was done. The leaves from individual plants were collected. DNAs were extracted for 94 individual F_2 plants along with parents. The genotyping of the individual plants along with parents is being done with already closely linked reported markers in order to select wilt resistant plants.

5.4.5.2 Populations derived through mutation breeding

M_1 populations (60 lines) with the treatment of ten varieties with gamma rays (500, 600, 700 Gy in *desi* and green, and 200, 300 and 400 Gy in *Kabuli* varieties) were raised. Simultaneously, M_2 population (90 lines from five treated varieties), M_3 (240 lines) and advanced M_4/M_5 (340 lines) populations were grown, and selected promising material was planted. M_1 population (280 lines) of gamma rays and chemical mutagens (EMS, MMS and SA) treated ten varieties (4 *desi*, 3 *Kabuli* and 3 green genotypes) with different doses has been planted during *rabi* 2005-2006 to screen and isolate the mutants for BNF and other morphological traits in consequent segregating generations. Another sets of gamma rays treated varieties were also raised simultaneously at off-season nursery at Dharwad and WSN, Dalang Maidan (HP). A few double recessive variants/ mutants were observed in M_1 populations with stunted plant growth with sterility.

5.4.6 Mungbean

5.4.6.1 Development of mapping populations

Generation advancement of the crosses was made last year. Five new crosses were attempted, viz., UPM99-03 x Pusa Baisakhi, PM4 x K851, IPM99-125 x BDYR2, ML818 x PS16 and PS16 x UPM99-03.

5.4.6.2 Analysis of diversity

Fifteen advanced breeding lines from diverse cross IPM 99-125 x Pusa Bold 2 along with check variety PDM 139 were characterized with 14 primers. Eight RAPD primers, five URP primers and one SSR primer, exhibiting polymorphism were used for diversity analysis. RAPD primers amplified 51 loci with mean resolving power of 7.371, whereas URP primers amplified 26 loci with mean resolving power of 5.875 and single SSR primer used amplified 5 loci with resolving power of 6.125. The maximum distance was recorded between clusters V and II. Cluster II comprised 12 genotypes, whereas in cluster V only one genotype was grouped, viz., PDM 139. The crosses between genotypes of these clusters are likely to yield genetic variability for selection of suitable breeding material. The studied material was also evaluated for morphological traits at two locations, i.e., IARI, New Delhi and IIPR, Kanpur. The genotypes were again grouped in five clusters. PDM 139 was grouped separately in cluster IV. The cluster means revealed significant variability for the studied traits. Based on molecular and morphological studies, the suggested crosses are PDM 139 x IPM 02-6 and PDM 139 x IPM 02-14.

5.4.6.3 Genetics of YVMV

Genetics of inheritance of resistance to YVMV in mungbean was reconfirmed (digenic recessive).

5.4.7 Pigeonpea

5.4.7.1 Conversion programme of cytoplasmic male sterility in desired agronomic bases

GT 288A is an established CMS line. Sterile cytoplasm from GT 288A was incorporated into Pusa 33, Pusa 2008, GPL- 100 and GPL 290. The material is in the BC_5 and BC_6 stages. Besides, CMS from GT 288A was transferred into Pusa 9 and Pusa 855 and the material is in BC_2 stage.

5.4.7.2 Interspecific hybridization progenies

Two hundred eighteen diverse progenies in F_4 developed from a cross C. *scarabaevoides* x Pusa 33 were evaluated for eight agronomic characters. These progenies are being evaluated every year in order to search for restorer for the ms line GT 288A as the line is derived from C. *scarabaevoides.*

5.4.8 *Brassicas*

5.4.8.1 Mapping populations for *Alternaria* blight

Screening for *Alternaria* blight of 434 germplasm lines of different species of *Brassica* and related genera was done. *Brassica carinata* entries NPC 9 and NPC 12 were found free from *Alternaria* blight. Interspecific crosses were attempted to develop mapping populations. Crosses were also attempted between *Brassica juncea* and *Sinapis alba*. Two *Brassica juncea* strains having *Alternaria* infection in traces are being rescreened in field and would be validated through the available molecular markers for white rust.

5.4.9 *Drosophila melanogaster*

5.4.9.1 Study of a Wnt gene cluster on chromosome 2L

Drosophila melanogaster is an outstanding model for genetics, developmental biology and functional genomics. A 200 Kb region (including a 4 Wnt gene cluster) was studied. Wnt ligands are powerful signaling molecules that direct cell behavior in several animals. The first wnt gene was discovered at IARI. Six Wnt genes were discovered in 2000. Identical clustering of the wnt4, Wnt4, 6 and 10 genes in *Drosophila*, mouse and humans suggests that this cluster is 500 million years old. There are no mutations in Dwnt6 and 10 and only a few in Dwnt4. These studies have applications in signal transduction, pharmacogenomics and drug development and will also achieve a mutational genetic analysis of this poorly studied region.

Twenty thousand mutational events were scored and 60 recessive lethals were identified in the greater Wnt region. The 60 lethal mutations were placed into 19 complementation groups and finely mapped to 15 sub regions. The 19 complons were mapped to known genes in the respective regions and nine of the 19 groups mapped to known genes. These are the first reports of mutations in CG 9138, CG 18304 and CG 4494 and the first report of embryonic lethals in wnt4. The phenotypes of the 7 complons were determined and studied.

Important novel observations are that Wnt 4 mutations show segment duplications. New biological material for functional analysis of 9 as yet unstudied genes was generated from this work.

Complon	CG/Gene	Function	Lethal phase	Phenotype at lethality
1, HL4	CG 9138 /SP1070	Notch binding	Embryo, Larva	Normal
2, HL18	CG18304	Structural constituent of cytoskeleton	Larva 2	Tracheal overgrowth
5, HL7	CG13777, Milton	kinesin associated mitochondrial adaptor activity	Larva 2	Near normal, head hole in a few larvae
6, HL11	CG 4698, Wnt4	Receptor binding, signal transducer activity	Embryo, larva	Denticle lawn in embryo, head open, female sterility in *trans* over other wnt4 fs alleles
7, HL13	CG8749, snRNP70	mRNA binding	Embryo, Larva	Dorso ventral defect, Head skeleton defect
10, AL1	CG4494, smt3	Protein binding	Embryo	Normal
13, AL16	CG10377, Hrb 27C	RNA binding	Larva l	Mouth apparatus duplicated
18, AL2	CG 4969. Wnt6	Receptor binding, signal transducer activity	Larva 1	Segment polarity loss, tracheal defect
19, AL3	CG4889, wg	Fz receptor binding, transducing activity	Larva 1	Dorso ventral defect, Head skeleton defect

5.5 AGRICULTURAL PHYSICS

5.5.1 Soil Physics

5.5.1.1 Influence of organics and chemical fertilizers on soil physical environment and performance of rice-wheat system

A field experiment was conducted during 2003-2004 at IARI research farm, New Delhi to study the effect of organics on soil physical environment *vis-à-vis* growth and yield of *basmati* rice-*durum* wheat cropping system. Treatments consisted of 120 kg N/ha (T1); three combinations of organic sources, viz., 20 kg N/ha each through green leaf manuring (GLM) and farm yard manure (FYM) (T2), 20 and 40 kg N/ha through GLM and FYM, respectively (T3), 20 and 80 kg N/ha through GLM and FYM + blue green algae (in rice) or *Azotobacter* (in wheat), respectively (T4) and a control (T5), were tested. Results revealed that T4 and T2 significantly lowered bulk density of 0-0.15 m and 0.15-0.30 m soil layers at rice harvest, but at wheat harvest, T2 and T3 showed reduced bulk density values for both the layers. Treatment T4 markedly increased the hydraulic conductivity of both the layers after rice and wheat harvest. This also enhanced the infiltration rate at wheat maturity. Greater macro porosity was found in T4 after rice, whereas after wheat, it was in T5 (control) and T2 in 0-0.15 and 0.15-0.30 m soil layers, respectively. The largest mean weight diameter was found in T2 (0-0.15 m) and T1 (0.15-0.30 m) after rice; but after wheat harvest, it was in T4. Although the grain yield of rice-wheat cropping system as a whole was marginally higher in T3 (6.8 Mg ha^{-1}) compared to T4 (6.3 Mg ha^{-1}), the growth parameters (plant height, 1000-grain weight for both rice and wheat, tillers /hill, panicle length and grains /panicle for rice and number of tillers /meter-row, earhead weight and number of grains /earhead for wheat) were superior in T4, confirming the beneficial effects of organic substitute compared to inorganic fertilizer. It can be concluded that supply of 50 to 80% of recommended nitrogen could be accomplished safely through organics without compromising the yield, and with better quality of produce.

5.5.1.2 Influence of mulching on soil and plant water status in wheat

A field experiment was conducted to study the effect of mulching on soil and plant water status in *rabi* wheat (cv. HD 2687) in a well-drained, loamy soil (Typic Haplustepts) with treatments, viz., black and transparent polyethylene, rice husk mulch and no mulch with reduced irrigation (3) and a control (no mulch with recommended irrigations). Transparent polyethylene was found to be the most efficient in conserving surface soil moisture, followed by rice husk, in top layers (0-0.15 and 0.15-0.30 m), while rice husk showed better performance in conserving moisture in deeper layers as well as maintaining the least residual moisture in the surface soil after crop harvest. Rice husk could also maintain better plant water status throughout the crop growth period under limited water supply, as reflected by relative water content (RWC) of leaves and leaf water potential (LWP). The extent of reduction of RWC following dry spell was less in rice husk, as compared to other treatments. LWP was also, in general, maximum under rice husk, both indicating its effectiveness in maintaining greater leaf water status. Seasonal average value of relaxation time under rice husk was also found to be the highest among various mulches. Throughout the season, specific leaf weight (SLW) was always maximum under control though rice husk showed relatively higher SLW, compared to other mulches. It can be concluded that rice husk performed better in maintaining optimum soil and plant water status in *rabi* wheat under limited irrigation. WATERMOD simulation model was used to evaluate the water status in soil and plant environment. The simulated ET was correlated with the observed values. Since WATERMOD does not include insect/pest/weed, there is a plan to use INFOCROP for further studies. The soil

thermal regime as modified by mulch incorporation was also quantified.

5.5.1.3 Leaf area index, biomass and grain yield of pearl millet as affected by irrigation and fertilizer

A field experiment was conducted to study the effect of fertilizer nitrogen on leaf area index (LAI), dry matter accumulation and grain yield of pearl millet [*Pennisetum glaucum* (L.) R. Br.]. The treatments consisted of five nitrogen levels, 0 (N_0), 20 (N_1), 40 (N_2), 80 (N_3) and 120 (N_4) kg N / ha under two water regimes, viz., rainfed (I_0) and recommended irrigations. Crop attained its peak LAI at 50 DAS. LAI of the rainfed crop was higher than that of the irrigated crop. It increased with increasing N levels at all crop stages. The combined interaction of irrigation and N was significant under irrigated condition than under rainfed condition. Biomass production reached the rapid growth phase after the 60-day stage and continued till it reached the maxima at the 70-day stage. The increase in biomass accumulation was generally faster in irrigated conditions and it also increased with the increase in nitrogen dose. The highest biomass (1080 g m^{-2}) was recorded in I_1N_4 compared to 742 g m^{-2} in I_0N_0. The grain yield in irrigated plots was significantly higher than that of the rainfed conditions which varied significantly with N rates.

5.5.1.4 Studies on water and nitrogen transport parameters

A study was conducted to evaluate the effects of modified moisture and temperature conditions on the transport parameters for water and nitrogen due to straw and polythene mulch applications. Results showed increasing hydraulic conductivity with increasing moisture content in the profile due to mulch application. Decrease in soil temperature resulted in marginal decrease in the conductivity which is mainly attributed to increase in water viscosity at lower temperatures. For nitrogen transport, the parameter in the transport equation studied is diffusion coefficient for nitrate and ammonical nitrogen. This parameter is found to be highly influenced by the physical and chemical environments of soil. Diffusion parameter for nitrogen decreased with decrease in water content due to increased tortuocity of the diffusion path. Higher temperature under mulching increased the mobility of the nutrient ion, resulting in higher diffusion coefficient.

5.5.1.5 Pedo-transfer functions

Prediction of soil moisture (retention, release and transmission) and nutrient availability (mainly nitrogen) on the basis of easily determinable soil parameters (soil texture, organic carbon, EC and pH) was developed for use in agro-management options for sustained productivity. Efforts are being done to evolve soil quality index by including physical, chemical and biological aspects.

5.5.1.6 Production functions for estimating the growth and yield of wheat

Agri-production functions to assess the grain yield of wheat under various biotic and abiotic stresses were developed which subsequently can help in developing a simple growth model. The aspects covered for this purpose were cultivars' diversity (in phenology, physiologic and genetic characters), latitudinal and longitudinal dependence, growth and yield under various biotic and abiotic stresses, identifying resource and agronomic management options under various production environments and extreme events (such as climate change). Functions developed are being used in designing a simple wheat growth model.

5.5.2 Agro-Meteorology

5.5.2.1 Weather based agro-advisories for Delhi region

Weather based agro-advisories service unit of Delhi, located at the Institute, is issuing weekly agro-met advisories for the benefit of farming community. Need based crop management information along with past week weather data and forecast for the next four days is being given in the advisories. Using the print and electronic media, weekly agro-met advisories bulletins were provided to the farmers on real time basis. This weather forecast generating agro-advisories has been helping farmers in taking tactical farm decisions related to crop management. A web page was developed and maintained (www.geocities.com/waasdelhi) for issuing agro-advisories and real time weather data along with medium range weather forecast.

Weather forecast verification was done on seasonal basis. It was observed that even under severe drought conditions as those prevailed during the 2004 monsoon season; the ratio scores were fairly high indicating the dependability of rainfall forecast. The usability percentage of the rainfall forecast was found to be above 75% during all the seasons. The impact assessment revealed that the forecast along with the agro advisories proved to be beneficial to the farmers to a great extent which has been the primary objective of the program.

5.5.2.2 Growing degree-days and plant growth and yield in mustard cultivars

To assess the impact of temperature as expressed in heat units (Growing Degree Days-GDD) on leaf area index (LAI) and biomass production in mustard, field experiments were carried out with two widely grown *Brassica* cultivars (Pusa

Jaikisan and Varuna) sown at weekly intervals starting the 1st October to 3rd December during two *rabi* seasons. GDD was computed up to maximum LAI and biomass stage, which was significantly correlated with both LAI and biomass production. About 82 per cent variation in biomass and 87 per cent in LAI in Varuna cultivar were explained through GDD while in the case of Pusa Jaikisan, the corresponding values were 91 and 80 per cent, respectively. Yields of the cultivars were highly influenced by the date of sowing and it was concluded that by and large the seed yields decreased as the dates of sowing were advanced, because of the prevailing low temperature conditions throughout the crop season. The highest yielding date was influenced by rainfall, both the amount and the distribution, during the early vegetative growth period.

5.5.2.3 Effect of row direction on radiation and water use efficiencies of mustard

An experiment was carried out to study the effect of direction of sowing on radiation and water use efficiencies of erect type (Pusa Agrani) and spreading type (Pusa Jagannath) mustard cultivars. Plant height, siliqua per plant, seed per siliqua, harvest index, total biomass and yield were found to be significantly higher in east-west direction compared to those in north-south in both the cultivars. Radiation-use-efficiency (RUE) is much higher in east-west direction than in north-south whereas it was the opposite in the case of water-use-efficiency (WUE) for spreading type of cultivars. Therefore, the farmers having assured irrigation should go for east-west direction of sowing whereas the farmers with limited/no irrigation should go for north-south direction of sowing of spreading type of mustard in northern India.

5.5.2.4 Simulating the impact of climate change on wheat cultivars

Wheat Growth Simulator (WTGROWS) was employed to evaluate the impact of climate change on growth and yield response of wheat cultivars. Cultivars responded differently to various abiotic stresses. Interaction effect of temperature and carbon dioxide change was significant within cultivars. The response to temperature rise, rainfall variations (for limited to moderate moisture availability) and radiation change were differential for cultivars. The impact for important cultivars was analyzed under various global climate change scenarios, and the agronomic and resource management options were identified for sustaining the crop's yield under various production environments. There is a need to link the relational database layers of bio-physical and socio-economic aspects, along with climate change scenarios, to the simulation models for evaluating the impact of the climate change. Presently the efforts in this direction are being done for Indo-*Gangetic* plains.

5.5.3 Remote Sensing and GIS

5.5.3.1 Crop growth of maize under long term fertilizer experiment in a typic haplustept

Under the AICRP on Long Term Fertilizer Experiment, maize crop was raised with 50%NPK, 100% NPK, 150% NPK, 100% NPK + FYM @ 15 t/ha/year and control. Spectral reflectance was appreciably lower in control compared to other treatments. However, there were not much differences among the treatments. In the initial growth stage, irrespective of treatments, per cent reflectance in the red region was below 12% whereas in infrared region, the values were between 30 and 36% in different treatments. Temporal variation of vegetation index (VI) and normalized difference vegetation index (NDVI) showed similar pattern in all the treatments but were of different magnitude. Higher VI and NDVI were obtained with 150% NPK. Crop under 150% NPK showed lower stress degree days (SDD) compared to others. Simple linear relationships were found between spectral reflectance and thermal index with dry matter at different growth stages and grain yield. Vegetation index showed significantly higher correlation with dry matter (r=0.86) at 80 DAS and grain yield (r=0.81) whereas a negative correlation (r=-0.79) was found with SDD during the corresponding periods.

5.5.3.2 Evaluation of normalized difference water index for agricultural drought assessment

Early detection is very important for mitigation of drought, which requires measures of its quantification at regular interval in real-time. Satellite remote sensing derived vegetation indices, viz., normalized difference vegetation index (NDVI) are regularly used for regional estimation and early warning of agricultural drought. With the availability of images from MODIS sensor aboard TERRA AM and PM satellites, it is now possible to generate normalized difference water index (NDWI) which uses both the bands in near infrared region (0.86 and 1.24 μm) and thus has advantages over NDVI. The NDWI is very sensitive to liquid water content of vegetation canopy thus making it a very suitable index for mapping and monitoring of agricultural drought. A study was carried out to evaluate the sensitivity of MODIS derived NDVI and NDWI to crop water stress, response of NDVI and NDWI to current rainfall and potential of multi-date NDWI images in delineating drought affected areas to monitor the progress of the agricultural drought. The NDVI and NDWI maps for the *kharif* season during drought and normal monsoon years were generated. It was observed that NDWI has a stronger relation with current rainfall than NDVI. The spatial comparison of changes in NDVI and

NDWI between the two years showed that NDWI was better than NDVI in picking up the intensity and extent of drought. Thus, NDWI based techniques are more promising than vegetation indices based on red and near-infrared wavelengths in assessing agricultural drought at regional scales.

5.5.3.3 Understanding and modelling bi-directional reflectance of wheat

The reflection of electro-magnetic radiation from natural targets on earth surface is highly anisotropic in nature, which besides being a function of target surface properties is also dependent on source-target-sensor geometry. In the case of vegetation, the bi-directional reflectance characterization has been shown to help in deriving canopy bio-physical parameters such as leaf area index (LAI), leaf angle distribution (LAD), chlorophyll content, biomass, etc. from remote sensing systems. The bi-directional reflection can be parameterized by canopy reflectance models like PROSAIL but such models should be validated first. An experiment was conducted with two wheat cultivars HD 2733 (erectophile and medium duration) and Kalyansona (planophile and long duration) to study the effect of canopy architecture on bi-directional reflectance of wheat, to relate plant biophysical parameters with bi-directional reflectance and validate the performance of PROSAIL canopy reflectance model. In general, the reflectance of HD 2733 was higher than that of Kalyansona at all combinations of view zenith and azimuth angles. It was observed that the canopy geometry has the least effect at hotspot position and the highest effect in dark-spot position on the reflectance of wheat. So, wheat reflectance at dark-spot position is better to study canopy geometry whereas reflectance at hot-spot position is better related to other crop biophysical parameters such as LAI. The PROSAIL model validation results showed that the model simulated well the overall shape of spectra for all combinations of view zenith and azimuth positions for both the wheat varieties.

5.5.3.4 Cropping system analysis from MODIS derived enhanced vegetation index profile

Vegetation index profile serves as a useful indicator of temporal variation in vegetation, hence mapping of cropping sequence (i.e. crops grown in different seasons at a place). A methodology was attempted to map the cropping sequence using 16 days composite of enhanced vegetation index (EVI) products having a spatial resolution of 250 m of moderate resolution imaging spectroradiometer (MODIS). The study area taken is a part of trans-*Gangetic* plains of India which has diverse cropping patterns. All the EVI products were stacked together to develop a temporal EVI profile, which was used to retrieve spatial and temporal variations of crops. EVI products were preferred to NDVI as they minimize much of the contamination problems present in the NDVI such as those associated with canopy background and residual aerosol influences; they are also more sensitive to leaf area index, canopy type and canopy architecture. The residual noise in temporal 16 days composite EVI profile was removed using Savitzky-Golay filtering for each pixel of the image. Filtered multi-temporal EVI profiles of major crop types reflect each crop's unique crop calendar (phenology). Major phenology events of crops such as the green up (vegetation index increase), peak greenness (maximum vegetation index), and senescence (vegetation index decrease) phases are detected for each crop. However, spectral angle mapper (SAM) classification technique was used to classify the image using EVI profile of pure pixels of each cropping sequence type to obtain cropping sequence map of the study area. The cropping sequence map so generated was validated with crop statistics obtained from the State Department of Agriculture. The same methodology is in progress to evaluate agricultural land use particularly the cropping system of trans-*Gangetic* plains over the years and finding out the possible driving forces for changes if any.

5.6 CROP MODELING

The Unit of Simulation and Informatics developed an application software for maize cultivars in respect of various agro-ecological regions, traditional cultural and agronomic management practices, input use efficiency and pest management options.

A user friendly information retrieval system for wheat, cotton, tomato and chickpea is being developed to provide the farmers, and researchers with the latest agro-techniques of the mentioned crops. The software would have potential in handling spatial information. This system is being developed using different markup and scripting languages and some front-end design tools, server side application implemented in active server pages and database layer implemented in Microsoft Access 2000.

Rice informatics for crop management decision system is a decision support system (DSS) emphasizing on different aspects of rice. The system was designed to support and facilitate the farmers, researchers, planners and managers with the knowledge of rice DSS modules such as weather, crop parameters, agro-techniques, water and nutrient management, and insect and pest management practices for different agro-climatic zones. The front-end is designed in ASP Net as platform with different markup and scripting languages and some front-end design tools. The back-end is designed in MS Access 2003.

The Unit also developed softwares on pesticide informatics encompassing different pesticides, their formulations, efficacy, dosages, waiting periods, maximum residual limit and safety to non-target organisms.

The Unit analysed the changes in insect pests scenario of rice, maize, rapeseed-mustard, cotton and sugarcane in Indo-*Gangetic* plains during pre- and post-Green Revolution period. The number of important pests associated with different crops was found to have increased drastically during the post-Green Revolution period compared with the pre-Green Revolution phase mainly because of the intensive production technology involving higher doses of fertilizers, more irrigation and indiscriminate use of pesticides.

An experiment was conducted during *kharif* 2005 with Pusa Sugandha rice at IARI, New Delhi, for validating the pest damage mechanisms of rice stem borer with Infocrop model. To have graded infestation levels, tillers were artificially removed @ 10% and 20% each at 40 and 50 days after transplanting (DAT) before flowering, and @ 10%, 20% and 30% after flowering. The grain yields in different treatments ranged from 2737 kg/ha with 30% de-tillering after flowering to 4296 kg/ha in undamaged crop. Likewise total dry matter varied from 6951 to 10743 kg/ha in the same treatments. After calibration and validation, the model will be used for developing decision support tools for pest management.

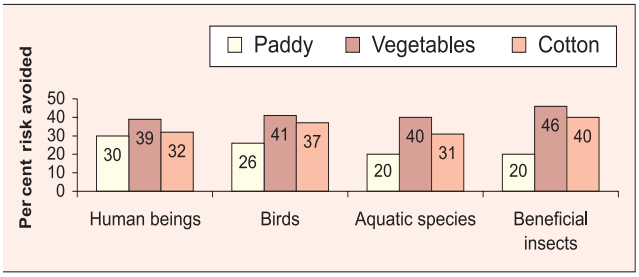
Analysis of incidence of aphid species on rapeseed-mustard and stem borer and shoot fly on maize and sorghum in relation to weather parameters revealed that with the rise in temperature, there may be faunal shifts as well as changes in crop-pest synchrony on these crops, influencing crop losses and management decisions.

6. SOCIAL SCIENCES AND TECHNOLOGY TRANSFER

6.1 AGRICULTURAL ECONOMICS

6.1.1 Pesticide Use and Sustainability of Agriculture: Emerging Issues and Policy Options

A study examined the pattern of pesticide use in major crops and assessed the economic and environmental impacts of adoption of IPM practices. The results showed that pesticide use in paddy, cotton and vegetables like tomato and cabbage was considerably high and the pesticides used are high and moderate risk posing chemicals. The expenditure on pesticide use was observed to be influenced by pesticide price, IPM training in farmers' field schools, better crop management practices like optimum nitrogen application, and farmers' perception about yield loss. The results also showed that inspite of partial adoption of different IPM practices by farmers, higher net return and reduced unit cost of production was observed under IPM practices in various crops. These results showed that a market exists for environment friendly pesticides in the study area and farmers are willing to pay a price premium. It was also estimated that the current use of IPM technology has the potential of avoiding pesticide risk hazards to different environment categories by 20-30 per cent in paddy cultivation and 39 to 46 per cent in vegetable cultivation. Hence, developing farmers' own capacity by imparting information, knowledge and skill through in-depth and intensive training as well as awareness programmes about pesticide hazards would go a long way in enhancing environmental benefits due to IPM adoption.



Estimated reduction in environmental risk from pesticide use due to IPM in selected crops

6.1.2 Identification of Pulling Factors for Enhancing Sustainable Development of Agriculture with Special Reference to Maize in India

Maize crop is gaining the status of a commercial crop because of its diversified end uses as food, feed and industrial raw material. Five states of India, namely, Bihar, Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh account for almost forty per cent of national maize area. It was observed that majority of farmers (54%) in this region were low adopters of modern technology and only 26 per cent of the total farmers surveyed were adopters. Adoption of HYV of maize in all the selected states resulted in increase in the yield of *kharif* maize by as much as 126 per cent in Rajasthan state for hybrid cultivars relative to local variety. In Madhya Pradesh, the increase in yield was observed even with the composite cultivars.

Effect of technological change on the yield and return from *kharif* maize cultivation

State	Traditional cultivars	Composite cultivars	% increase over traditional cultivars	Hybrid cultivars	% increase over traditional cultivars
Maize yield (tonne/ha)					
Bihar	1.92	2.28	19.02	2.15	12.09
Madhya Pradesh	1.58	2.87	81.80	3.55	124.92
Punjab	1.97	3.27	65.87	3.63	84.10
Rajasthan	1.67	2.55	53.09	3.77	126.33
Uttar Pradesh	2.49	N.C.	N.A.	4.24	70.35
Net return (INR/ha)					
Bihar	3823	5781	51.22	8248	115.75
Madhya Pradesh	1264	3472	174.68	6371	404.03
Punjab	6608	9925	50.20	10682	61.65
Rajasthan	1335	6326	373.86	10014	650.11
Uttar Pradesh	3314	N.C.	N.A.	9922	199.40

If the sampled farmer-households are considered as representative of the state, and the percentage of maize area under HYV for these households are considered true for the state as a whole, it can be inferred that there is an increase in net return in the range of INR 563 million in Punjab state to INR 3058 million in Madhya Pradesh state, which is considered to be one of the most poor states in the country. If the area under HYV is further increased by 10 per cent, the increase in net return will be even greater.

Change in state revenue due to adoption of HYV of maize

State	Maize area (000 ha)	Maize area under HYV* (%)	Maize area under HYV@ (000 ha)	Increased net return due to HYV of maize (INR/ha)	Increase in net return due to cultivation of HYV maize (INR million)	
					Business (usual)	Increase in area under HYV by 10%
Bihar	688	74	507	319	1619	1780
MP	958	87	836	3657	3058	3364
Punjab	165	92	152	3695	563	563
Rajasthan	1017	39	393	6835	2688	2956
UP	975	24	235	6608	1550	1705

*Based on field survey during the year 2002
@ Calculated from total maize area in the state and % maize area under HYV

Given the diverse uses of maize in the industrial sector, the demand for the crop is set to increase. Thus, with the increasing awareness and renewed thrust towards the hitherto neglected processing sector in the poor regions, employment of even the non-maize growing farmers and landless labourers of the region will increase. This will certainly augment income and contribute positively towards livelihood and food security.

6.1.3 Adoption and Impact of Resource Conserving Technologies on Farm Economy in Indo-Gangetic Plains

Mainly two resource conserving technologies (RCTs), namely, zero tillage and bed planting were found to be adopted by the farmers in the Indo-Gangetic plains of India. Zero tillage was the major RCT adopted by farmers in Bihar, Haryana, Punjab and Uttar Pradesh. Bed planting technology was the only RCT adopted in Rajasthan. The extent of adoption of zero tillage technology ranged between 59 % in Uttar Pradesh to 77 % in Haryana, while that of bed planting in Rajasthan was nearly 59 per cent. Adoption index was between 50 and 75 per cent for maximum number of adopters (52 %) in all the states. Only 34 percent of the farmers were found to adopt more than 75 per cent of technology.

Adoption of various RCT in study domain (% of RCT adopters)

RCT	Bihar	Haryana	Punjab	Rajasthan	UP
Zero tillage	97	100	100	-	100
Bed planting	21	12	19	100	-
Surface seeding	1	-	-	-	-
Rotary tillage	-	-	-	2	-
Leaf colour charts	-	-	-	-	1

Magnitude of RCT adoption (adoption index)

	Bihar	Punjab	Haryana	UP	Rajasthan	Overall
Less than 50	5	-	9	35	21	14
Between 50 to 75	55	56	38	44	69	52
More than 75	40	44	53	21	10	34
Average	76	74	77	59	59	

Adoption index is for zero tillage only, in all states, except Rajasthan for which it is for bed planting

It was further observed that the adopters of RCT in the Punjab state have substantial gain over the non-adopters in terms of both saving of input and output realized. The adopter farmers were able to save nearly 31 per cent input cost and realize 6 per cent higher yield and 35 per cent higher returns over the non-adopter farmers.

Gains from RCT adoption in wheat production, Punjab

Particulars	Adopter	Non-adopter
Input cost (Rs. / ha)	4172.73	6088.12
Yield (tonnes/ha)	4.77	4.52
Returns (Rs./ha)	9386.87	6973.88
Adoption gains		
Cost saving (%)	31.46	
Yield increased (%)	5.51	
Returns increased (%)	34.60	

6.1.4 Food Safety Measures and their Implications on India's Horticultural Exports

A study examined the structural changes in composition and direction of export of major horticultural commodities. Mangoes and onions account for the major share of the fruits and vegetables exports, respectively. The value of mango and mango product exports increased from Rs 71 crores in TE 1990 to Rs 427 crores in TE 2002, recording an impressive growth of 16 per cent during the post liberalization period (1991-2002). The processed products like mango pulp, mango juice, mango slice dried, mango slice in brine and mango squash recorded higher growth in value terms.

Changing composition of export of Indian mango and its products

Commodity	Value (in Rs. lakh)		% Share		CAGR (%)
	TE1990	TE2002	TE 1990	TE 2002	1991-2002
Mango fresh	2850	7793	37	17	8.3
Mango pulp	2880	26740	37	59	19.9
Mango juice	303	987	4	2	14.8
Mango slice dried	25	150	0.3	0.3	21.6
Mango slice in brine	113	926	2	2	19.4
Mango squash	3	87	0	0.2	19.2
Mango chutney	320	999	4	2	4.6
Mango pickle	356	2502	5	6	12.7
Jam jellies of mango	292	2523	4	6	20.9
Flour of mango	7	39	0.1	0.1	10.1
Total	7149	42747	100	100	15.9

The Netherlands, with a share of 9 per cent in total mango pulp exports, emerged as an important export destination. Japan, Germany, U.K., UAE, and Kuwait also recorded significantly high growth in unit value realization during the post liberalization period and thus constitute the priority countries for export of mango pulp from India.

Projected market share of major importing nations for Indian mango pulp

Countries	Probability of retention	Stability	Projected export market share in 2008 (%)
Saudi Arabia	0.00	Unstable	17.2
United Arab Emirates	0.00	Unstable	10.0
The Netherlands	0.43	Moderate	6.60
Yemen	0.37	Moderate	1.50
Kuwait	0.00	Unstable	11.3
USA	0.00	Unstable	2.40
UK	0.00	Unstable	8.50
Others	0.64	Highly stable	42.5

The Netherlands and Yemen were found to be moderately stable markets. The other group of countries also emerged as stable markets. Therefore, the diversification of export destinations away from the traditional markets is suggested in order to improve the stability in mango pulp exports.

Onion is exported from the country in four forms (at 8 digit ITC classification), i.e., onions fresh or chilled, preserved/prepared, dehydrated/dried and provisionally prepared. Substantial change in the composition of exports of onion and its products has taken place over the years, with the share of fresh onions in total onion exports falling to 83 per cent in TE 2002 from a high of 93 per cent in TE1990. There has been substantial change in the export markets for fresh onions with Bangladesh, Malaysia and United Arab Emirates and Sri Lanka emerging as major markets in 2004. Unit value realization is higher in Singapore, Sri Lanka, Malaysia and Mauritius for fresh onions. Hence, the focus should be to expand the market base in these countries. Bangladesh and Malaysia are highly stable export markets while Sri Lanka and Bahrain are unstable markets. It is estimated that by 2009, Bangladesh would account for the highest share of fresh onion exports followed by Malaysia, United Arab Emirates and Singapore. With the implementation of Free Trade Agreement with Sri Lanka, the declining trend in exports to Sri Lanka is expected to be reversed.

6.1.5 Co-integration of Horticultural Markets in India

The effect of arrival on prices of fruits and vegetables for major regulated Markets under Agricultural Produce Marketing act in the country was analyzed and it was found that the volume of supply of perishable commodities affected the price in the market adversely. The seasonality in the price indices of the horticultural commodities was more or less similar throughout the country with mild the variation. The analysis revealed that variation in the price could be minimized mainly through cold storage provision, and a small amount of shifting of commodities can take place from lower price areas to high price areas. The big fruit and vegetable markets in the nearby big cities were found to be interlinked, but distant markets need to be integrated for price stability. This can be done by improving the infrastructure like roads, transport, market yard, market information, etc.

6.1.6 Marketing Information Systems for Horticultural Commodities in India: Status, Constraints and Prospects

Market information (MI) is an important component for efficient marketing. However, the traders in India are not much aware of market information. An analysis of the extent of awareness on components of marketing information among wholesalers in different states showed that while the traders in most states, except Meghalaya, are aware of prices in various markets, they are only moderately aware of the arrivals of fruits and vegetables in local markets. Similarly, moderate information on processing is available to some traders in the states of Maharashtra, Karnataka and Himachal Pradesh, but the availability of information is poor in the Eastern states of the country. Sufficient information on cold storage is available to the wholesalers in the states of Maharashtra, Karnataka and Himachal Pradesh. The information on cool chambers and export agencies is poor in all the states except Maharashtra.

Extent of awareness of market information among wholesalers

Item of facility	Maharashtra	Karnataka	HP	Orissa	Assam	Meghalaya
Price information	Good	Good	Good	Moderate	Moderate	Poor
Arrival information	Moderate	Moderate	Moderate	Moderate	Poor	Poor
Processing information	Moderate	Moderat	Moderate	Poor	Poor	Poor
Grading	Good	Moderate	Moderate	Poor	Poor	Poor
Packing	Moderate	Poor	Moderate	Poor	Poor	Poor
Cold storage	Good	Good	Good	Poor	Moderate	Poor
Cool Chamber vehicle	Moderate	Poor	Poor	Poor	Poor	Poor
Export agency	Moderate	Poor	Poor	Poor	Poor	Poor

The traders, indeed, need more marketing related information on various aspects, especially information on price and arrival forecasts in order to improve their decision making capability.

Additional information needed by traders (%)

Item of information	Maharashtra	Karnataka	Orissa	HP	Assam	Meghalaya
Price forecast	100	100	100	100	100	100
Arrival forecast	56	45	20	79	40	50
Quality needed	90	80	79	80	50	60
Processing facility	90	84	80	80	89	60
Transportation	74	68	68	71	25	44
Best alternative market	66	48	20	48	45	40
International price	68	60	70	16	85	45

The information on quality (grade) of fruits and vegetables and their processing facilities and international prices is also desired by the traders.

The traders revealed that they take into consideration local as well distant market prices for taking decision on purchase price. Only a few traders get information on packaging, grading, processing and cold storage space. Generally, marketing information on transportation is also not available for distant markets as revealed by 50% of the traders. Around 80–90% of the traders get information through phone/mobile and fellow traders. Cost of procuring information ranged from Rs.1600/- to 2800/- per month. The traders hardly used internet for sourcing information.

The traders were of the view that demand forecast information can influence supply of fruits and vegetables by 10 - 20% and price by less than 5%. Reliable information on transportation can reduce the losses and wastage up to10%.

While the value loss of fruits and vegetables due to delay in information varied from 15 to 30 %, the loss due to lack of information varied from 30 to 50% in different markets in various states. While illiteracy and telephone or mobile were not a constraint for receiving MI, lack of provision of adequate information through radio/television and internet is still a problem.

During the 1990's, the growth in market arrivals of major fruits, namely, banana, orange, grapes and mangoes was the highest in Mumbai market relative to any other metro market.

The rate of growth of orange supply declined in Delhi and increased in Chennai over the last decade.

6.1.7 Impact of Trade Liberalization on Indian Agriculture

Some of the important policies related to agriculture are enumerated below:

- Simplified procedures to promote exports of vegetable seeds other than onion seeds were allowed under OGL (barring foundation and breeder's seeds) in 1980s.
- Provision for compensation was made for unrebated indirect taxes for production of agricultural products which were not refundable through duty draw back system.
- Thirty two Agri - export zones for agro-products including fruits, vegetables, flowers and dairy products notified.
- Foreign Trade Policy (FTP) identified agriculture for export expansion and potential for employment generation. Special Agricultural Produce Scheme (VKUY) to boost export of fruits, vegetables and flowers and minor forest produce/products launched. Export of these products qualify for duty free credit entitlement (5 % of f.o.b) for importing inputs
- Imports of seeds, bulbs, tubers and planting material was liberalized.
- Promotion of medical and herbal products emphasised.
- Custom peak duty to be reduced to 15 % in 2005-06 to 10 % in 2006-07.

The liberalized trade has led to a lot of agricultural imports into the country because of WTO obligation. However, India has reasonable limit of bound rates whenever needed.

Present basic custom and bound rate for fruits and vegetables

Commodity group	Basic custom rates (%)	Bound duty %
Apple	50	50
Pomegranate, litchi and custard apple	15	100
Onion	5	100
Planting material and vegetable seeds	5	10
Garlic, arecanut	100	100
Sweet potato and frozen vegetables	30	150
Other horticultural commodities	25-30	100

6.1.8 Study on Peri-urban Agriculture and Its Management in Delhi

Total geographical land in Delhi state is 1.47 lakh hectares which is spread over five agricultural development blocks. There is no cultivated land in Mahrauli and Shahadra blocks. In Alipur, Kanjhavala and Najafgarh blocks, cultivated land is spread in 165 villages. More than 60% land was under non-agricultural use in 2002. Net sown area was about 0.33 lakh hectares (23%), which produced only 1.2 lakh tonnes of cereals (6 per cent of the requirement of cereals). Among cereals, wheat was the major crop followed by paddy and *bajra*.

Pulse production in Delhi was negligible, not even 0.01 per cent of its requirement. Vegetable production was noted as 65 thousand tonnes, which was only 5 per cent of its requirement. Fruits production in the state was about half a per cent of its requirement, whereas milk production was about 12 per cent of the total milk requirement of the metro city. Therefore, the requirement of food grains along with vegetables, fruits and milk is met from adjoining states, i.e., Haryana and Uttar Pradesh.

The other commercial enterprise, which was economically very attractive to the farmers of Delhi was flowers. Although, Delhi is quite a big flower market in India whose annual turnover is about 100 crores, but Delhi contributes only 10% of its requirement.

6.2 AGRICULTURAL EXTENSION

6.2.1 Farming Systems Research and Extension for Sustainable Development

The project aims to design and validate viable farming systems for selected locations and develop TOT strategies. The specific objectives are to analyse different farming systems, make sustainable interventions for improving production and productivity of farming systems, empower farmmen and farmwomen to enhance their entrepreneurial skills and develop communication materials for transfer of technology. The project is being carried out in Gurgaon district (Haryana), North Delhi and IARI regional stations at Indore, Pusa and Katrain. In all, 100 farm families (big, small and marginal proportionately) were selected in each location making the sample size 500. One village in each location was identified for conducting action research to design a methodology of viable farming systems. Interview schedule covering the issues referred to in the objectives was developed, besides the use of PRA exercises for relevant information collection.

The results of PRA exercises provided understanding of various farming systems, their structural complexity and inter-relationships in terms of resources, biophysical, socio-economic and human elements; resource flows and interactions. The major farming systems were categorized as irrigated farming systems, rainfed and dry farming systems, mixed farming systems and urbanized farming systems. The predominant components in the systems in Delhi villages were rice, wheat, barley, mustard, vegetables and animal husbandry, whereas in the case of Gurgaon villages, these were *bajra*, pigeonpea, wheat, mustard, vegetables and animal husbandry.

The major problems identified were soil and water degradation, lack of technical and extension inputs, high level of ignorance and low level of literacy in both the genders, prevalence of unemployment and underemployment, drudgery among women, high cost of agricultural inputs, non-availability of quality seeds in time, low prices of produce, socio-cultural barriers; insufficient availability of fodder, feed and fuel, feminization of agriculture due to male-migration, low adoption of improved farm practice, etc. The low level of fertility in buffaloes, high mortality in buffalo calves, low milk yield and lack of technical know-how, etc. were the major constraints in animal production. There were positive attitudes towards agricultural diversification and entrepreneurship development in agriculture. Bee-keeping, mushroom cultivation, floriculture, dairying and post-harvest processing are the important areas for entrepreneurship development.

The major strengths of the systems in Delhi were infrastructure and marketing facilities and assured irrigation. There were no self-help groups in the villages under action research. Two farmers' cooperatives in Delhi village were observed, but they were non-functional.

Women contribute the most in the post-harvest technology like harvesting, winnowing, sorting, feeding and packing and storage. Though women do 70% of fieldwork, yet their contribution is not recognized as obvious from the fact that they are totally ignored for providing training in the field of agriculture. Food disparity in the diet of male and female children, which was much prevalent earlier, is on the decline now.

Drudgery of arduous tasks such as fetching water from distant areas, fuel collection and working in smoky kitchens, etc., is still prevalent. Intervention such as, designing more efficient gender friendly tools, etc., is required. Because of mechanization, several agricultural tasks of women have been taken over by men, rendering the women with more jobs, which are full of drudgery.

Based on the initial survey of the villages Saidpur

(Gurgaon) and Tiggipur (Alipur, Delhi), the interventions implemented in agriculture and animal husbandry are:

1. Two animal health care camps – one each in Tiggipur and Saidpur villages with participation of 50 farmers
2. Crop Demonstrations

Crop demonstrations in Tiggipur and Saidpur villages

	Crops and varieties	No. of demonstrations	Area (Acre)
a. Delhi	Fodder- PC 9, PC 23	9	4.50
	Wheat- HD2329	7	7.00
	HD2285	2	2.00
b. Gurgaon	Fodder- PC 23	17	8.50
	Maize - Pusa Panna	17	8.50
	Wheat - Kundan	1	0.50
	HD 2851	1	0.50
	HD 7413	1	0.50
	HD 2329	1	1.00
	HD 2687	1	0.50
		57	33.50

Four SHGs formed by mobilizing farmwomen in coordination with Anganwadi supervisors in Delhi. A number of discussions held with them and data are being collected.

The scope for diversification in the existing farming system was observed in both the locations. A focused group discussion supported with matrix ranking revealed a high potential for dairy and dairy products in Gurgaon and for vegetables, especially the exotic ones, in Delhi. The margin of profits in vegetables was perceived to be poor because of high competition, especially from exotic vegetables from the nearby hilly regions during off-season. Despite the high cost of inputs, the dairy was rated as the best enterprise.

Matrix ranking of agro based enterprise/diversification: Village Saidpur

	Floriculture	Dairy	Fruits	Mushroom	Poultry	Nursery	Seed production	Vegetables
Demand	7	8	5	1	3	4	2	6
Profit	7	8	6	1	3	2	4	5
Costs	2	5	8	5	4	7	2	6
Risk factor	5	8	7	2	1	4	3	6
Problems in practicing	7	7	6	3	1	2	3	5
Total	28	36	32	12	12	19	14	28

Preferred areas for diversification: dairy, fruits, vegetables, and floriculture

Matrix ranking of agro based enterprise/diversification: Village Tiggipur

	Vegetables	Fruits	Nursery	Mushroom	Fishery	Poultry
Demand	6	5	1	3	2	4
Profit	3	6	1	2	4	5
Costs	6	5	4	1	3	2
Risk factor	6	5	4	3	2	1
Problems in practicing	6	5	4	1	3	2
Total	27	26	14	10	14	14

6.2.2 Enhancing the Efficiency of Extension Organizations

The project aims at developing computer based interactive self-learning modules (SLM) on major functions of development management, entrepreneurship development and training management.

As per the plan, the questionnaire for data collection consisting of components such as general information, knowledge test, organizational climate and job satisfaction was developed. The knowledge test included the aspects like leadership, motivation, project management, evaluation, team building and conflict management. Self-rating scale was developed for assessment of gaps in management. Data were collected from 100 respondents to assess the gap in management skills and develop computer based interactive self-learning modules (SLM) on major functions.

6.2.3 Development of Participatory Extension Methodology and Strategy for Inter-Sectoral Micro-planning

The project components include: development of a model for sustainable extension through rural institution (cooperatives); empowerment of rural youth; and assessment of performance of development administration.

The questionnaires were finalized for data collection. A group discussion with a large number of farmers and farm women was held in selected villages to assess the problems related to input supply and marketing of the farm produce. Initiative was taken to form a farmers' cooperative society to tackle the problems.

6.2.4 Assessing the Socio-economic and Environmental Impact of Agricultural Technologies

The project intends to undertake on-farm comparative study of techno-economic feasibility of transgenic vis-à-vis non-transgenic popular varieties of cotton and to understand the farmers' perception and need of transgenic varieties including their socio-economic and environmental implications.

PRA with the farmers of the villages Pandhania, Chitavad, Bhoolgaon, Nagaon, Bagda and Jaswadi of the districts Dhar, Khargone and Khandwa of MP revealed an increase in the acreage under Bt. Cotton in the range of about 2 per cent to 40 per cent of area under cotton. Matrix ranking revealed the major criteria for selecting cotton varieties as

yield, incidence of pest and management cost, germination potential, input use and requirement of irrigation with respective mean perception scores as 9.33, 9.00, 8.33, 8.33 and 8.00. The farmers' perception study with criteria based ranking showed a higher preference to MECH 162 (score 10) with respect to criteria of germination potential, less incidence of bollworm and yield in comparison to other Bt. varieties MECH 12, MECH 184 and RCH 2 as well as non-Bt. varieties. Bt. cotton variety MECH 12 was ranked higher than MECH 162, MECH 184 and RCH 2 for boll size, quality and market value.

The selection of sample areas for survey of farmers cultivating Bt. cotton in Punjab as Firozepur, Bhatinda and Mansa was done in consultation with the Department of Agriculture as well as project officials of Monsanto engaged in the deployment of Bt. cotton in the area. Pilot surveys were undertaken in the villages Patrewala (Abohar) and Gidharbha (Mansa-Bhatinda). Bt. cotton plants had attained good physiological growth and farmers reported no incidence of bollworm. The availability of authentic Bt. cotton seed is the primary concern of farmers. During the survey, some incidences of sucking pest were reported for which the farmers were taking up the scheduled spray. The survey work is continuing.

6.2.5 Harnessing Information and Communication Technologies for Promoting Market-led Extension

The project seeks to study the marketing channels at the village level and identify the related problems and constraints in order to suggest a market led extension strategy. A detailed review of marketing schemes and programmes of various organizations, namely, NAFED, HAFED NDDB, APEDA, etc., was carried out.

6.2.6 Impact Analysis of Training Programmes

The study has been planned to assess the gain in knowledge and skills of the trainees, who participated in different trainings under Centre for Advanced Studies (CAS) and its utilization and constraints in a work situation. A sample of 120 trainees was drawn from six CAS trainings and a questionnaire for data collection was finalized.

6.2.7 Evaluation of Capacity Building in Rural Resource Management: A Pilot Action Research on Programme Evaluation

The international collaborative project between IARI and Michigan State University was initiated in October 2005. The project contemplates to undertake workshops on evaluation to enhance the participants' knowledge and skills in determining the impacts/outcomes of educational programmes and to develop a training module, and cases on evaluation of selected research and developmental projects.

The planning of training module was done based on the principles of adult learning or andragogy. The planning of three workshops to be conducted in three phases to impart training to twenty participants was done.

6.2.8 Reaching Un-reached Areas and Checking Rural Migration from Tribal Areas

IARI Regional Station, Indore is conducting front line demonstrations (FLDs) in the tribals dominated Jhabua district of Madhya Pradesh for the past two years in order to ensure "food and feed security" for the tribal farmers, and to check their migration to cities. During 2004-05, 31 FLDs of 10 newly evolved IARI-wheat varieties were conducted in 10 villages covering an area of 13 hectares. On an average, 75% increase in wheat yield was recorded in these demonstration plots. Continuing this extension activity during 2005-06, 66 FLDs involving 11 IARI-wheat cultivars, have been laid out in 12 villages covering an area of 25 hectares. These wheat varieties include four *durum* cultivars of high nutritional value which will help in overcoming malnutrition in these remote areas. These efforts have resulted in building-up confidence among the farmers of the region and in checking their migration to a considerable extent.

6.2.9 Alleviating Malnutrition through Popularization of Cultivation and Consumption of *Durum* Wheat

India, being predominantly a rice eating country, its population suffers from malnutrition. During hulling and polishing all the "vitamins and micronutrients" are lost and the rice is left only with 6.5 % to 7.0 % protein. Rice is zero in "Vitamin-A" as it does not contain ß-carotene. Thus, poor intake of protein, vitamin-A and iron in our diet causes malnutrition. In M.P., malnutrition is 10 % higher than the average malnutrition of the country. Total nutrition of wheat is much higher than that of rice; and it compares with pulses for vitamins and minerals. Of the two major wheat species under cultivation in India, *durum* is nutritionally superior to *aestivum* as it contains higher protein, ß-carotene (Vitamin-A) and minerals. Hence, an extensive campaign for popularizing the consumption of *durum* wheat through sale of *durum* products, e.g., *dalia* (porridge), semolina and flour, launched in 2004, was further intensified during 2005, creating wide awareness for inclusion of *durum* preparations in daily diet.

6.2.10 Crop Diversification through Introduction of Wheat in Non-traditional Areas

The Tamil Nadu farmers have grown paddy in all the three seasons. This has resulted in soil fertility degradation. The *rabi* season paddy requires more water (12-15 irrigations), and takes 140-150 days for maturity. The IARI Regional Station, Wellington since 2002 has successfully organised ARTs and FLDs in joint collaboration with the Tamil Nadu Agricultural University and the State Department of Agriculture. The spread of wheat technologies was achieved by imparting training to government officials (Agri. Deptt.) and farmers. The first variety released was COW (W-1) (HW 3094). There was a heavy demand of wheat seeds during 2005 season. The farmers are now gradually adopting wheat cultivation in Tamil Nadu.

6.3 TECHNOLOGY ASSESSMENT AND TRANSFER

6.3.1 Technology Assessment and Refinement through IVLP under Rice-Wheat Production System in Irrigated Agro-Eco Region of NCR, Delhi

The project was in its final phase and terminated in April 2005. However, a few interventions were carried out in the operational villages with the objective of intensification and diversification of the cropping system.

In rice-wheat cropping system, the intensification by including *moong* crop was assessed against the local practice of rice-wheat crop rotation. Under the diversification, pea and gram were included in place of wheat to ensure better economic returns, and improvement in soil fertility.

Benefits derived from the intensification and diversification of cropping system have convinced the farming community, to adopt these very fast.

6.3.1.1 Intensification of cropping system

Intensification of the rice-wheat cropping system was tested with the inclusion of the *moong* variety Pusa Vishal. The rice varieties included were PB 1, Pusa Sugandh 2, Pusa Sugandh 3 and Pusa Sugandh 4. The wheat varieties included were HD 2733, HD 2824 and PBW 373. Among the tried combinations, the combinations involving the rice variety Pusa Sugandh 4, the wheat variety PBW 373 and the *moong* variety Pusa Vishal was rated by the farmers as most remunerative and suitable in the intensification of cropping system, and the return was about 106.08 % higher as compared to that of the local checks of the rice-wheat cropping system. Though the per unit area yield of Pusa Sugandh 4 was less as compared to that of other aromatic rice varieties in the system but owing to better market price and good grain quality, it gave higher returns as compared to other aromatic rice varieties.

The aromatic rice varieties, due to their short duration, were found to save 2 - 3 irrigations and also found suitable for timely sowing of wheat.

Area of refinement: There is a need for disease and insect-pests resistant varieties of *Basmati* rice.

6.3.1.2 Diversification of cropping system

In diversification, pea as vegetable crop and gram as pulse crop in *rabi* season were taken in place of wheat crop after the harvest of rice crop in *kharif* season in the same field. It was noted that the inclusion of pea vegetable (rice-pea) in place of wheat resulted in 55.5 % higher return and gram (rice-gram) to the tune of 25.3 % higher return as

Impact of intensification and diversification of rice-wheat cropping system : 2004-2005

Crop rotation and yield (tones/ ha)	Treatment	Total grain yield (tonnes/ha)	Gross return (Rs/ha)	Return over operational cost (Rs./ha)	% increase in return over control
Intensification					
Rice (PB 1, 4.10) - wheat (4.84)	T1	8.94	79568	28538	-
Rice (S-2, 5.34) - wheat (HD 2733, 5.27) - *moong* (P.Vishal, 0.83)	T2	11.44	98660	37385	31.00
Rice (PB 1, 4.00) - wheat (4.70)	T1	8.70	77486	26881	-
Rice (S-3, 5.63) - Wheat (HD 2824, 5.02) - *moong* (P.Vishal, 0.85)	T2	11.50	99369	38819	44.41
Rice (PB 1, 4.02) - wheat (4.73)	T1	8.75	77969	26984	-
Rice (S-4, 4.87) - wheat (PBW 373, 4.99) - *moong* (P.Vishal, 0.79)	T2	10.65	117829	55609	106.08
Diversification					
Rice (PB 1,4.06) - wheat (4.71)	T1	8.77	78200	27012	-
Rice (PB 1, 4.06) - gram (BG 372, 2.46)	T2	6.52	79105	33852	25.32
Rice (PB 1,3.97) - wheat (4.66)	T1	8.63	76788	26468	-
Rice (PB 1, 3.97) - pea (Azad Pea 1, 8.13)	T2	12.10	89933	41163	55.52

Parentheses denote variety and yield. T1=control T2=experimental

compared to that obtained with rice-wheat cropping system. This system has added advantages like less use of nitrogenous fertilizers, and improved soil health thus saving the cost of cultivation by way of low input cost. This diversification has also been appreciated and adopted by 8 per cent progressive farmers in the area. However, the spread is gradual because many farmers perceive uncertainty in pulse production.

6.3.2 Prospects of New Growth Areas for Application of Agricultural Technologies in Different Agro-Eco Regions

6.3.2.1 Evaluation and transfer of improved agricultural technologies for sustainable productivity in semi-arid areas with limited irrigation facilities (Jhunjhunu and Churu districts of Rajasthan)

Orobanche management. For managing the weed in mustard crop, the nature of infestation and its causes were probed by discussions with the farmers, officials of agricultural department and the local Krishi Vigyan Kendra and by taking field observations during the crop season. In this exploratory exercise, the following factors having direct influence on the weed infestation were identified:

Irrigation status: In the completely rain-fed crop, the infestation was very little, and contrary to this, the irrigated crop had heavy infestation of the parasitic weed.

Time of sowing: It was observed that the early sown and the late sown crops had less weed infestation in comparison to the main season crop.

Crop rotation: During the last crop season trials, it was observed that when mustard crop was grown after cluster bean, caster, onion and sesame, the virulence of the parasitic weed was much less compared to that observed in the mustard crop grown following other *kharif* crops.

Method of irrigation: It was observed that the infestation of parasitic weed Orobanche was lower where flood irrigation method is adopted in comparison to that observed in sprinkler irrigation method.

Variety: The variety Durga Mani was earlier reported to be resistant to Orobanche.

Type of soil: It was observed by the farmers that the infestation of the weed was more in less fertile light soils in comparison to that in fertile heavy soils.

Considering the above factors, a comprehensive Orobanche management research plan was developed. On-farm trials were laid out under different situations, and both cultural practices and chemicals were tested. On cultural aspects, the on-farm research trails included the screening of different varieties for resistance/ tolerance to the weed, altering the date of sowing, different crop rotations, and natural enemies existing in the local habitat. For studying the effect of different recommended herbicides, on-farm trials were laid and different doses of these herbicides were used. Besides managing Orobanche in mustard crop, some new crops were introduced to study their performance as an alternative crop to mustard. The crops tried were safflower, lentil, *Aloe vera*, isabgol, gram, and barley. The findings of the study are as follows:

a. Three *Brassica caranata* lines possessed some degree of tolerance, and the lines were found to have 50% less weed infestation. However, the yields of these varieties were low and the varieties took longer time to mature in comparison to high yielding varieties like Pusa Bold and Pusa Jagannath .

b. The late sown crop had about 40% lower infestation than the timely sown crop.

c. The crop raised after clusterbean had a weed intensity 70% less than the control crop. Similarly, the crop after onion had 60% lower infestation than the control crop.

d. Two fungi and one insect were identified in the weed-infested field as the natural enemies of the parasitic weed, Orobanche.

e. Mustard seed treatment with bio-fungicide *Kali sena* and bio-fertilizers had a positive impact on the crop growth but no effect on the weed infestation.

f. Based on the root development pattern in weed infested and weed free mustard crops, a special aqua seed plough was developed. This plough was used to sow the crop without pre-sowing irrigation under dry conditions. The plough had a water tank and a provision of dropping water below the seed. This water provided sufficient moisture condition for germination of the crop. The farmers were asked not to irrigate the crop for 45 days. This period was enough for strong tap root development of the crop. The crop had 35 to 70% less weed infestation than the control crop.

g. In the study on alternate crops, the safflower, lentil, *Aloe vera* and isabgol crops came up nicely but owing to marketing problems and a few other constraints these crops were not picked up by the farming community at large, though some innovative farmers showed keen interest.

Introduction of new crop production technologies, Rabi 2004-2005

Mustard: IARI varieties Pusa Bold, Pusa Jagannath, Pusa Jaikisan gave 35.86%, 23.91%, and 21.73% higher yield, respectively than that of the local check variety T 59.

Gram: Two high yielding varieties Pusa 372 and Pusa 362 out performed the local checks in 85 demonstrations and gave 21.81% and 20% higher average yields in comparison to the control plot yield. Eight other advanced lines and new varieties of gram, including two white seeded, and one green seeded, gave higher yields compared to that of the control and the farmers were impressed by these varieties.

Wheat: Out of the four varieties tested, WH 711yielded 15.79% higher than the control, and Raj 3765 yielded 14.47% higher than the control.

Barley: The high yielding barley variety RD 2552 yielded 25% higher than the control, followed by RD 2035 with 17% higher yield.

Kharif 2005 demonstrations

Pearlmillet: Two composites (Pusa 383 and Pusa 751) and one hybrid HHB 94 were used in the demonstrations. Both the composites out performed the control and gave even better yield in comparison to that of the hybrid crop. The quality of grain and fodder was also good.

Mungbean: The mungbean varieties Pusa Vishal, Pusa 9531, SML and Pusa Ratna gave 63%, 52%, 38% and 20% higher yields, respectively, compared to that of the local check. Only a few virus-affected plants were seen in the demonstration plots of these varieties, whereas the crop in the control plots was seriously affected.

Cowpea: The varieties C152, V585 and Pusa Komal gave 35%, 11% and 20% higher yields, respectively, compared to that of the control.

Clusterbean: The variety HG365 gave 15% higher yield compared to those given by the local popular cultivars.

Soybean, maize, sorghum, and pigeonpea: Soybean, maize, sorghum and pigeonpea were introduced as new crops, and the farmers were enthusiastic to grow these crops.

Empowerment of farmers. Three cooperative societies and three farmers' clubs were formed. The societies are now cooperatively procuring production inputs and marketing their produce after processing. In this way, employment is being generated in the villages; the farmers are getting quality input at reasonable rates and good return by marketing their produce directly to the consumer.

6.3.2.2 Promotion of agri-horti system in tribal areas for improving socio-economic development of farmers

The programme was introduced in the tribal villages of Dhamtari and Raipur districts of Chhattisgarh and Gumla district of Jharkhand**.** During *rabi* 2004-2005, a total of 118 demonstrations on high yielding varieties were conducted in farmers' fields, of which 17 demonstrations were on wheat (HD 2285), 37 on gram (BG 372), 11 each on pea (Arkel) and lentil (L4076) and 42 demonstrations on mustard (Pusa Bold). The average yield of wheat (HD 2285), gram (BG 372), pea (Arkel), lentil (L4076), and mustard (Pusa Bold) were 1.42 tonnes/ha, 0.88 tonne/ha, 1.16 tonnes/ha, 0.96 tonne/ha and 0.43 tonne/ha, respectively.

During *kharif* 2005, a total of 211 crop demonstrations on paddy (PB1, S4), *guar* (BG 372), *bhindi* (Pusa A-4), *urd* (T9 and KU), soybean (NRC 12), *moong* (Pusa Vishal), *arhar* (UPAS 120), and Bottle gourd (Pusa Naveen) covering an area of 9.60 ha., 0.83 ha, 1.70 ha, 2.24 ha, 8.00 ha, 4.88 ha, 2.40 ha and 1.00 ha, respectively were conducted in Raipur district, Chhattisgarh. The yield data are being processed.

6.3.2.3 Assessment, refinement and promotion of improved technologies for sustainable rice-wheat based production system in irrigated areas

Under this project, in Rakhra, Patiala district, Punjab, the major emphasis has been on promotion of high yielding Pusa varieties of rice, wheat and other crops. Accordingly, during *kharif* 2005, a total of 24 paddy seed production plots (10 of PB1, 6 of Pusa1121, 2 of Pusa 2511 and 6 of Pusa 44) produced 20.5 tonnes, 14.4 tonnes, 4.2 tonnes and 19.8 tonnes of seeds, respectively. Similarly, seed production programme of Pusa Chari 9 was taken up at CIRB Regional Research Station, Nabha where 2.2 tonnes of quality seed was produced. The quality seed so produced was made available to the progressive farmers of different parts of Punjab through Young Farmers Association of Punjab.

In Gautam Budh Nagar district of UP, the main emphasis has been on introduction and promotion of improved varieties of different crops from IARI. During *kharif* 2005, a total of 20 demonstrations on paddy (12 of Pusa 1121 and 8 of Pusa 2511), 9 demonstrations on *jowar* (PC9) and 5 demonstrations on maize (PEMH2) were conducted in 3 villages. The paddy varieties Pusa 2511 and Pusa 1121 yielded on an average, 5.0 and 4.5 tonnes per hectare, respectively. The average green fodder yield of *jowar*, PC9 was 50 tonnes per hectare. The maize variety PEMH 2 recorded an average grain yield of 3.25 tonnes per hectare. Because of the observed higher economic returns, the introduced HYVs of the Institute are expected to cover more areas of Gautam Buddh Nagar and surrounding districts.

Three animal husbandry interventions were also implemented – the first on minerals and vitamins supplements for improving fertility in 8 buffaloes and 2 heifers, the second on control of ectoparasites in 38 buffaloes and 12 buffalo calves, and the third on control of endoparasites in 12 buffaloes and 8 buffalo calves. Production and reproductive parameters of these animals are being monitored.

6.3.2.4 Assessment and promotion of improved animal husbandry technologies for household dairy farming units in peri-urban areas of NCR

In the transfer of technology operational areas of the Institute (Sonepat, Gurgaon and Mahindergarh district of Haryana and Ghaziabad district of UP) three technological interventions were made for evaluating their utility for productive and reproductive parameters in milch animals.The interventions involved the following aspects:

- Control of endoparasites using suitable doses of piperazine and albendazole preparations in 74 buffalo calves and 32 buffaloes for enhanced productivity
- Minerals and vitamin supplements for improving fertility in 56 buffalo heifers and 48 lactating buffaloes
- Control of ectoparasites in dairy animals using deltamethrine sprays and swabing for improving the health condition and growth in 58 buffalo calves, and for increased milk yield and fertility of 124 lactating buffaloes.

Three animal health care programmes were organized in which 382 animals were given treatment and advice against various ailments. Under 3 farmers' training programmes, 209 farmers were made aware of improved management, feeding, breeding and healthcare practices of dairy animals.

6.3.3 Front Line Demonstrations

6.3.3.1 *Rabi* 2004-2005

During *rabi* 2004-2005, front line demonstrations of wheat were conducted on the following technologies:

(i) Newly released wheat varieties: HD 2687, PBW 502 and HD 2733; (ii) use of application of bio-fertilizers, and (iii) zero tillage

In all, 74 demonstrations allotted by DWR were conducted covering a total area of 32 hectares—16 hectares for newly released wheat varieties, 12 hectares for use of application of bio-fertilizers and 4 hectares for zero tillage in selected villages of Gurgaon district of Haryana and NCT of Delhi.

FLDs on Wheat

Technology Latest Varieties	No. of Demo.	Area (ha)	Av. yield (tonnes/ha)	% increase in yield
T1=Control plot		16.00	4.49	
T2=HD 2687	20		5.01	11.51
PBW 502	7		5.11	13.75
HD2733	6		5.39	19.80
HD544	2		3.93	-12.65
Application of bio-fertilizer				
T1=Control		12.00	4.54	
T2=Azotobactor and PSB	30		4.95	9.20
Zero tillage				
T1=control		4.00	4.61	
T2=use of zero tillage	9		4.84	4.94

Among all the varieties demonstrated, HD 2733 gave the highest increase in yield (19.80%). The use of bio-fertilizer (Azotobactor and PSB) improved the yield by 9.20 % over the control yield, i.e., 4.54 tonnes/ha.

Front line demonstrations on wheat and barley were conducted in 14 villages under Shimla, Solan and Mandi districts of Himachal Pradesh. Performance of the new wheat variety Shivalik was very good under late sown condition with a mean yield of 2 t/ha with 15 % increase over that of local checks. HS 375 has also shown 17% increase in yield over that of local checks under timely sown condition of high altitude. Barley variety BHS 352 has shown an average yield of 1.65 t/ha with an increase of 18% over that of local checks.

6.3.4 Transfer of Technology Programme: *Rabi* 2004-2005 and *Kharif* 2005

During *rabi* 2004-2005, 676 demonstrations on wheat, mustard, barseem, gram and lentil covering an area of 233.14 hectares were conducted in 25 villages of the districts of Sonepat, Gurgaon and Rewari in Haryana, Ghaziabad, Aligarh and Baghpat in UP, and Delhi villages.

Economic analysis of crop demonstrations under TOT programme - *rabi* 2004 -2005

Crop	Variety	Av. yield (tonnes/ha)	% increase in av. yield overcontrol	BC Ratio
Wheat	Local (Control)	4.02	-	1.48
	HD 2824	5.10	27.03	1.80
	HD 2733	5.53	37.75	1.94
	Raj 3765	5.11	27.28	1.81
	PBW 343	5.24	30.42	1.87
	WH 544	3.75	-6.73	1.38
	PBW 373	4.83	20.34	1.76
	PBW 502	4.73	17.68	1.75
Mustard	Local (control)	1.22	-	1.61
	Pusa Bold	1.65	34.85	1.96
	Pusa Jaikisan	1.54	36.14	1.84
	Pusa Jagannath	1.79	46.42	2.10
	Pusa Agrani	1.50	22.88	1.82
Berseem	Local (control)	60.00	-	1.91
	Maskavi	68.99	15.00	1.34
Gram	BG 372	1.71	-	1.60
Lentil	K 75	1.31	-	1.31

In wheat demonstrations, HD 2733 gave 37.75% increase in yield over that of the control plot with a BC ratio of 1.94 followed by PBW 343 with 30.42% increase in yield and 1.87 BC ratio. In the case of mustard, Pusa Jagannath

out performed all other varieties with an average yield of 1.79 tonnes/ha followed by Pusa Bold with 1.65 tonnes/ha as against 1.22 tonnes/ha of the control plot. In the case of barseem, the improved variety Maskavi gave 68.99 tonnes/ha as against 60.0 tonnes/ha of the control check.

During *kharif* 2005, 402 demonstrations were conducted covering a total area of 144.8 hactares on paddy, *arhar*, sorghum, *bajra*, *moong*, *bhindi*, bottlegourd, *guar* and cotton in the villages of Delhi, Sonepat and Rewari districts of Haryana, and Hapur in UP.

Performance of crop demonstrations under TOT programme during *kharif* 2005

Crop	Variety	Av. yield (tonnes/ha)	% increase in Av. yield over control	BC ratio
Paddy	PB1	4.77	13.06	1.71
	Pusa1121 (Pusa Sugandh1)	4.27	1.25	1.85
	Pusa 44	5.10	20.87	1.35
	Local	4.22		1.22
Arhar	Pusa 991	1.17	10.22	2.32
	Pusa 992	1.28	19.96	2.52
	UPAS 120	1.40	31.68	2.72
	Pusa 2021	1.31	23.24	2.54
	Pusa 2001	1.38	29.80	2.64
	Local	1.07		2.34
Sorghum	PC 9	29.66	19.03	1.27
	Local	24.92		1.17
Bajra	HHB 94	1.62	25.06	1.22
	HHB117	1.58	25.06	1.20
	Local	1.26		1.01
Moong	Pusa Vishal	0.78	20.77	1.19
	Local	0.65		1.13
Bhindi	Pusa A4	13.05	20.93	1.41
	Local	10.79		1.30
Bottle gourd	Pusa Naveen	16.96	18.69	2.31
	Local	14.29		1.99
Guar	HG 365	1.05	27.25	2.1
	Local	0.82		1.86
Cotton	Pusa 8-6	0.84	25.37	
	Local	0.67		

To popularize pulse crop under rice-wheat cropping system, seven *arhar* (pigeonpea) demonstrations of 0.2 ha area each were laid out in Samastipur, Muzaffarpur, Darbhanga and Nalanda districts of Bihar. The performances of these demonstrations were very satisfactory.

In the year 2005, IARI Regional Station, Wellington has organised two state level training programmes on increasing wheat productivity in Tamil Nadu (17th and 18th August, 2005) and Karnataka (4th and 5th October , 2005)

Similarly, front line demonstrations (covering an area of 34 hectares) of released wheat varieties, viz., HW 3094 (COW (W-1), HW 2044, HW 5001 and HD 2833 were organised. In 15 districts, 70 ARTs have been organised. There were 5 farmers' *melas*-one each in Kenthorye, Thalavadi, Peiyur, Vandavasi and Adhiparashakthi-on wheat varieties and wheat cultivation in Tamil Nadu.

6.3.5 Transfer of Technology Programme including High-tech Vegetable Cultivation in Peri-urban Areas, Ghaziabad (UP) - *Rabi* 2004-2005

During *rabi* 2004-2005, 389 demonstrations on wheat, mustard, gram, pea, lentil, turnip, cabbage and berseem covering an area of 146.72 hectares were conducted in 2 villages of Ghaziabad district in UP as per the details given below.

Comparative performance of crop demonstrations in Ghaziabad district of U P

Crop variety	No. of demo.	Av. yield (tonnes/ha)	Local yield (tonnes/ha)	% increase in yield
Wheat				
HD 2824, Raj 3765, Pusa 544	23	4.79	2.79	27.90
Mustard				
Pusa Bold Pusa Jaikisan Pusa Agarni JD 6 Pusa Jagannath	219	2.13	1.62	31.72
Barseem : (Maskavi)	89	96.94	76.00	27.50
Gram : (BG 372)	3	1.85		new introduction
Lentil : (K 75)	27	1.55	1.35	15.40
Veg. pea: (Azad Pea 1)	6	10.67	8.70	22.66
Turnip: (PTWG)	7	21.09	17.50	20.53
Pusa Sarson Sag	8	10.87		new introduction
Cabbage: (Golden Acre, Green Boy)	17	81.06	53.50	51.52

Among the three wheat varieties (HD 2428, Raj 3765 and Pusa 544), HD 2428 performed best in both the villages giving an average yield of 5.11 tonnes/ha. Of the five mustard varieties (JD 6, Pusa Agrani, Pusa Jaikisan, Pusa Bold and Pusa Jagannath), Pusa Bold gave the highest average yield (2.20 tonnes/ha) followed by Pusa Jaikisan (2.09 tonnes/ha) and JD 6 (2.07 tonnes/ha). Berseem (Maskavi) gave an average green fodder yield of 96.84 tonnes/ha. Gram (BG 372) gave an average yield of 1.85 tonnes/ha whereas lentil

(K 75) gave 1.55 tonnes/ha. Pea (Azad) gave a green pod yield of 10.67 tonnes /ha. In other vegetables, Turnip (PTWG) recorded an average yield of 21.09 tonnes /ha. Pusa Sarson Sag gave 10.8 tonnes/ha and cabbage (Green Boy) yielded 104.2 tonnes /ha.

During 2005, a total of 203 demonstrations on different crops covering an area of 67.64 hectares were conducted in the two villages. Pusa Sugandh 4 *Basmati* type variety of paddy performed well (4.43 tonnes/ha) in both the villages followed by Pusa Basmati 1 (4.13 tonnes/ha). In *bajra*, the variety HHB 94 gave an average yield of 2.84 tonnes/ha in Piplera village. Of the vegetable crops demonstrated, bottle gourd (Pusa Naveen), *bhindi* (Pusa A-4) and vegetable *guar* (Pusa Navbahar) performed very well in both the villages giving high economic returns to farmers. The pulse crops demonstrated were summar *moong* (Pusa Vishal), black gram (KU and T 9) and pigeon pea (UPAS 120). The *moong* variety Pusa Vishal gave an average yield of 0.86 tonne/ha. The overall average yield of black gram varieties KU and Type 9 were 0.88 and 0.81 tonne/ha, respectively. The pigeonpea variety UPAS 120 yielded 2.31 tonnes /ha. The average fodder yield of sorghum variety PC 9 was 40.18 tonnes/ha. The farmers accepted the PC 9 variety of sorghum for green fodder for livestock as it remains green for longer time and is palatable.

6.3.6 Centenary Year *Pusa Krishi Vigyan Mela*

The three-day centenary year *Pusa Krishi Vigyan Mela* of the Institute on the theme "Prosperity through Seeds" was inaugurated by Shri Sharad Pawar, Hon'ble Union Minister of Agriculture, Consumer Affairs, and Food and Public Distribution on February 14, 2005. Dr. Mangala Rai, Secretary, Department of Agricultural Research and Education and Director-General, Indian Council of Agricultural Research presided over the inaugural function and Dr. S. Nagarajan. Director, IARI gave the welcome address.

While inaugurating the *mela*, the Hon'ble Minister lauded the contribution of IARI in steering the country from a situation of food deficit to one of food security. He said that the theme of the *mela* was not only timely but also relevant in the context of future agriculture because the "Seed" was always the basic input for increasing and sustaining agricultural production. The Hon'ble Minister assured that the Government would provide all necessary support to the farmers in the context of globalization, WTO, information communication technology (ICT), marketing structure, banking support, agriculture loan on low interest, and crop insurance, etc.

The farm literature brought out by the Institute on this occasion was released for the use of farmers. The best

Shri Sharad Pawar, Hon'ble Union Minister of Agriculture, Consumer Affairs, and Food and Public Distribution inaugurating the Centenary Year *Pusa Krishi Vigyan Mela*

performing three farmers in IARI-AIR: *Gehoon Pathshala* 2004-2005 were given away the prizes for the promotion of such *pathshalas*.

Dr. Mangala Rai in his presidential address exhorted the farmers to adopt technologies which would accelerate their income by way of diversified agriculture through horticultural crops, value addition of agri-products, beekeeping, etc. Dr. S. Nagarajan in his welcome address stated, farmers need information communication technology so that knowledge-led information reaches their doorsteps'. He said: 'the Indian Agricultural Research Institute is developing new models and concepts to address the problems of the farming community particularly in remote and backward areas.' He also mentioned that for effective transfer of technology, synergy among research system, extension system and public/ private sector involving the farmer was required. Dr. N.N. Singh, Co-chairman, Mela Organizing Committee briefed about the *mela* activities and their importance in the present technology-transfer scenario. Dr. B.S. Parmar, Joint Director (Research) proposed a vote of thanks.

The *mela* provided a unique opportunity to the farmers to have a glimpse of the latest agricultural technologies through live demonstrations on major *rabi* crops like wheat, mustard, chickpea, lentil, pea, vegetable, flowers and horticultural crops, etc., on the farm. The other major attraction of the *mela* were direct scientists-farmers interaction in *kisan goshthi*, lectures on latest agricultural technologies by the experienced progressive farmers for enhancing the production, income and employment on their farms; operational farm machinery demonstrations; a video film-show on the latest agricultural technologies; a workshop on farm women empowerment, etc.

In the valedictory function of the *mela* on February 16, 2005, Smt. Sheila Dikshit, Hon'ble Chief Minister of Delhi,

who was the chief guest, appreciated the IARI-AIR model of *"Gehoon Pathshala"* and advised the continuance of such programmes by this esteemed Institute as well as other institutions/universities so that the latest agriculture technology could reach the unreached speedily. More than 22,000 persons consisting of farmers, farm women, students, extension workers and others visited the *mela* from all over the country covering 23 states and union territories. Seventy organizations including research institutions, public/private sector companies, NGOs, etc., participated to display and demonstrate their exhibits.

6.3.7 Agricultural Technology Information Centre (ATIC)

The Agricultural Technology Information Centre (ATIC) of the Institute is effectively providing products, services, technologies and information to different stakeholders through a 'Single Window Delivery System'. About 10650 farmers/entrepreneurs, development officials, students, NGO representatives, etc. from 21 states and one union territory of India visited ATIC during the year for farm advisory, diagnostic services, purchase of technological inputs/ products and trainings. Purpose-wise the maximum number of farmers visited ATIC to purchase/enquire about seeds/ varieties (3970). This was followed by those seeking information related to horticultural and medicinal plants (3235), plant protection (2750), agro-based enterprises (1470), farm literature (2350), dairy (445) and agricultural implements, (110), etc. Statewise, out of the total farmers who visited ATIC, U.P. (27%) ranked first followed by Haryana (22%), Delhi (20%), and Rajasthan (9%). Nine hundred and sixty farmers/entrepreneurs from 9 states were able to get information on various aspects of agriculture through Pusa Help-line and Kisan Call Centre (IInd level). The total number of phone queries received in ATIC from farmers and others were 1675. Purpose-wise, the maximum calls made by the farmers were related to seed availability (445), followed by production technology (370), plant protection (360), agro-based enterprises (185) and others (315). Seeds, publications, etc., worth about Rs. 6,67,588/= were sold by ATIC during the period.

Two bulletins, *Rabi Fasalon ki Unnat Takniki* and *Kisanon Ke liye Sangthanatmak Sahayata*, and two issues of the six monthly magazine *Prasar Doot* were published during this year. Ten pamphlets on cereals, pulses and vegetables were also printed and distributed free to the visiting farmers. Besides, more than hundred farmers got farm advisory services through letters during the period under report.

6.3.8 Participation in Significant Events

The CATAT and ATIC participated in various events to exhibit IARI technologies.

Participation of CATAT and ATIC in various events

Name of event	Place of event	Period
Field day	Pipli and Thirpali Badi villages in Jhunjhunu and Churu districts, Rajasthan	January13, 2005
Exhibition during International Conference on " Soil Water Environmental Quality - Issues and Strategies" organised by the Indian Society of Soil Science	IARI, New Delhi	Janaury 28 to February 1, 2005.
Krishi Expo 2005	Pragati Maidan, New Delhi	March 9-13, 2005
Krishi Mela	KVK, Shikohpur	March 22, 2005
Infra Educa,2005	Birla Auditorium, Jaipur (Rajasthan)	May 23-25, 2005
Infra Educa,2005	Pragati Maidan, New Delhi	June24-25, 2005
International Exhibition on Food Drinks and Hospitability	Pragati Maidan, New Delhi	August 2-5, 2005
Field Day cum *Kisan Goshthi*	Bhurekha village, Mathura district	September 8, 2005
Field Day cum *Kisan Goshthi*	Jharsa and Khanduri villages, Churu (Rajasthan)	September 14, 2005
Field Day cum *Kisan Goshthi*	Thirpalibadi and Pipli villages, Jhunjhunu (Rajasthan)	September 15, 2005
PUSA Krishi Vigyan Mela	Chirawa village, Jhunjhunu (Rajasthan)	October 6, 2005
Farmer Goshthi cum Exhibition	Khair, Aligarh (U. P.)	October 13- 14, 2005
Kisan Mela Avam Pashu Vigyan Pradarshani	IVRI, Izzatnagar, Bareilley.	October 18-20, 2005
Exhibition on National Convention of Krishi Vigyan Kendra organised by the Indian Council of Agricultural Research	NASC Complex, New Delhi	October 27-28, 2005
India Service R&D, 2005	Vigyan Bhavan, New Delhi	November 7-9, 2005
Agro-Industrial Fair	IARI, New Delhi	November 8-9, 2005
International Trade Fair	Pragati Maidan, New Delhi	November14-27, 2005

6.3.9 *Pathshalas* on Rice and Cotton

Seeing the tremendous response of the farmers to wheat school on air, the Institute planned two *pathshalas* on rice and cotton. The rice school was sponsored by APEDA, and cotton school was sponsored by Nuziveedu Seeds Ltd. Secundrabad. The rice school was started on May 16, 2005 and cotton school on June16, 2005. More than seven hundred farmers participated in the rice school and six hundred farmers, participated in the cotton school. The farmers were from five north Indian states. In all, 20 and 15 lessons were covered under the rice and cotton schools, respectively.

6.3.10 *Kisan Mela* and *Kisan Gosthi*

The annual *kisan mela* and *kisan gosthi* were organized at IARI Regional Station, Pusa (Bihar) on April 8, 2005. A large number of farmers, development workers, entrepreneurs, etc., from neighboring districts, especially, Samastipur, Muzaffarpur, Vaishali, Madhubani, Darbhanga, East Champaran, Begusarai, Munger, Araria, Shivhar, Sitamarhi, etc., participated in the *mela* and in *kisan gosthi*.

The major attractions of the *kisan mela* were: display of new agricultural technologies, farmer-scientist discussions through *kisan gosthi*, and availability of useful farm literature. Field visits were also organized to the farm area for popularizing the high yielding varieties of wheat, paddy and other crops. The occasion was marked by a cultural programme performed by Song and Drama Division, Ministry of Information and Broadcasting, All India Radio, Darbhanga.

6.3.11 Farmers' Day

For popularization and wider dissemination of IARI technology particularly new improved varieties to the farmers, IARI Regional Station, Pusa (Bihar) organized a farmers' day at Jagatsingpur village, Samastipur district during the wheat crop season.

A farmer's day was also organized at IARI Regional Station, Tutikandi, Shimla where new wheat and barley technologies were demonstrated to the hill farmers. This day was also celebrated as centenary day as part of the centenary programme of the Institute.

6.3.12 Krishi Vigyan Kendra (KVK), Shikohpur, Gurgaon

The Institute's Krishi Vigyan Kendra (KVK) at Shikohpur, Gurgaon is playing a vital role in combating unemployment of rural youth through technological empowerment and in improving the farmers' awareness and farm productivity through various transfer of technology programmes. The salient achievements of KVK programmes and activities during the year under report are as the follows:

6.3.12.1 Front line demonstrations (FLDs)

FLDs on oilseeds, pulses and cereal crops are playing a catalytic role in transferring and disseminating crop technologies in the area. During *rabi* 2004-2005 and *kharif*, 2005, 119 demonstrations (covering an area of 62.28 ha) on oilseeds, pulses and cereal crops were organized in the farmers' fields of 7 villages in 3 blocks of Gurgaon district. Out of 119 demonstrations, 37 demonstrations on mustard (var. Pusa Jagannath), 9 demonstrations on gram (vars. Pusa Pragati and Uday), 7 demonstrations on lentil (var. L 4076), 36 demonstrations on wheat (vars. HD 2687, HD 2633, HD 502, PBW 502), 12 demonstrations on *arhar* (vars. Pusa 855 and Pusa 991), 5 demonstrations on *moong* (var. Pusa Vishal), 8 demonstrations on paddy (vars. Pusa Basmati 1 and Pusa Sugandh 4), and 5 demonstrations on soybean (vars. PS 10-24 and PS10-42) were laid out in the farmers' fields.

A bumper crop of *moong* (var. Pusa Vishal) introduced first time in the operational area through front line demonstration programme in the farmers' fields in Rathiwas village of Gurgaon district

The average yields of mustard, gram, *lentil, wheat, arhar, moong,* and paddy were 1.76, 1.58, 1.28, 4.72, 1.81, 1.04, and 5.08 tonnes per hectare, respectively. The comparative results revealed that the average yields of mustard, gram, wheat, *arhar*, and paddy were increased by 8.65%, 12.48%, 2.90%, 12.42%, and 7.96%, respectively, over that of the farmer's practice in these crops. Lentil, *moong* and soybean crops were introduced for the first time in the area.

6.3.12.2 Trainings for different target groups

The major objectives of on-campus and off-campus trainings are to generate opportunities for income, to provide technical know–how to the practising farmmen and farm women and to update the knowledge of in-service personnel. The details of trainings organized during 2005 are as follows:

Vocational trainings for rural youth. Eleven vocational training courses on various subjects —Bee-keeping (1), dairy farming (1) dress designing and tailoring (2), landscaping

A trainee receiving the certificate after completing a month-long training course on "Dress Designing and tailoring"

and beautification (1), tractor repairing (1), motor winding (1), and custom service in plant protection (1), establishment and management of fruit orchards (1), vermiculture technology (1), and preservation of seasonal fruits and vegetables (1) – were organized. Through these trainings, 209 youths (139 male and 70 female) were benefited.

In-service trainings. Two in-service trainings (refresher course) on integrated pest management (IPM) and integrated plant nutrient management (IPNM) were organized for 24 Agriculture Development Officers (ADOs) of Haryana Agriculture Department, Gurgaon during the year 2005.

Day long on-campus trainings. During the period, 3 day-long on-campus training programmes for the progressive/FLD farmers were organized to update the knowledge about the production technologies of oilseeds, pulses, vegetables and cereal crops. Seventy farmers were benefited through these day-long on-campus trainings.

Off campus trainings. During the period, 31 off-campus trainings (in villages) were organized for the practising farmmen and farm women. Out of 31 trainings, 10 on plant protection, 7 on animal health care, 1 on bee-keeping, 7 on crop production, and 6 on horticulture were organized in different villages of Gurgaon district. Through these trainings, 862 farmers (716 male and 146 female) were benefited.

6.3.12.3 On-farm testing

The KVK conducted on-farm testing (OFT) on site specific nutrient management (SSNM) in collaboration with the Potash Phosphate Institute, Canada (India Programme). During 2005, 4 trials each on mustard, wheat, and chickpea were organized. Results of these trials revealed that the average production of mustard, wheat and chickpea increased by 46.3%, 14.3%, and 25.7%, respectively, with SSNM technology over that of the control plots (farmers' practice) as recommended in the soil test report of PPIC, Canada.

6.3.12.4 Agricultural extension activities and farm advisory services

For speedy dissemination of technologies in the farmers' fields, the KVK celebrated/organized various extension activities in the villages and at KVK campus involving *kisan mela*, field days on different crops, women in agriculture day, world food day, animal health day, honey day, method demonstrations, camps/campaign on plant protection and animal health care, lectures delivered by the SMS of KVK in the meetings/trainings of kisan clubs organized by the line departments, programmes on TV/Radio, field visits of scientists/SMS in the farmers' fields, visits of farmers at KVK, etc. One hundred ninety animals were also treated for different types of ailments through animal health camps.

The *Krishi Vigyan Patrika*, a quarterly newsletter of KVK in Hindi, continues to provide 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 reported period, 6895 (4914 male and 1981female) members of different farming communities were benefited through different programmes. Among the beneficiaries, 67% (4620) belonged to OBC, 12.50%(850) to SC and 20.50% (1425) to the other categories.

7. EMPOWERMENT OF WOMEN AND MAINSTREAMING OF GENDER ISSUES

7.1 EMPOWERMENT OF WOMEN IN AGRICULTURE (NATP/MM PROJECT)

The project was implemented for a period of three and a half years. The project terminated in the month of March 2005. The project was conducted under an NATP Mission Mode Project in eleven villages of three rural blocks of Delhi as an endeavour towards social, psychological and economic empowerment of farm women. A total of 600 farm women were mobilized to form 40 self help groups with 15 members in each group. A series of awareness camps, training programmes for capacity building and interventions for drudgery reduction and empowerment were carried out and data were collected 'before' and 'after' the interventions.

The data revealed significant impact in terms of drudgery reduction through improved farm tools and implements. Regarding the parameters of empowerment, the socio-psychological impact assessment was done in terms of confidence building, self-esteem, decision making, capacity enhancement and social empowerment on a five -point scale which revealed a definite positive shift for all the parameters. Amongst the five parameters, the overall shift was greatest in 'confidence-building'. Besides these parameters, there was also a change towards a more favourable attitude of the rural women towards agricultural technologies, animal husbandry and entrepreneurship development which also resulted in better socio-economic status coupled with the self-help group savings. The self-help group approach can undoubtedly focus on development and empowerment of rural women with appropriate interventions for drudgery reduction, capacity building and entrepreneurship development.

7.2 CAPACITY BUILDING FOR FARM WOMEN

With the objective of capacity building of farm women in various activities like agricultural operations, post harvest technologies and animal care, CATAT organized 25 capacity building training programmes under research projects and in TOT programme operational villages of Sonepat district. The women were trained in preparation of preserves using potatoes, and in preparing chips, laccha and papad, and given practical demonstration on utilization of lemon and tomatoes in preparing sqash, pickle, and sauce.The women were also trained in improved breeding, feeding management and health care practices for milch animals. They were made aware of improved management practices like naval treatments, control of gut acting endoparasites, and control of ectoparasites of their animals besides feeding practices for growing stock, pregnant and milch animals. Advantages of urea-mollases treatment of straw, urea mollases enriched concentrate ration, urea mollases multinutrient bricks, and complete balanced feed blocks were also explained. They were also trained in storage of preserves and grains at domestic level.

A farm women empowerment workshop on February 15, 2005 was organized during Pusa Krishi Vigyan Mela held from February 14 to 16, 2005 at New Delhi. The workshop was organized with the collaboration of YWCA, Najafgarh, Delhi schools and farm women of Delhi, Haryana and U.P. Smt. Vibha Shastri, an active social worker, was the chief guest at this workshop. A debate on *"Krishi ke badalte parivesh me mahilaon ka sashaktikaran avashyiak hai"* a skit on a social issue, a dance on agricultural theme and an agricultural quiz were the main attractions of the workshop. This is the platform where farm-women get direct opportunity to get solutions for their agricultural problems from women scientists of the Institute.

An exhibition for display of rural crafts and household utilities prepared by farm women of Shiwadi village (Haryana) was organized on November 13, 2005 on the occasion of the visit of Dr. J.B. Penn, Under-Secretary for Farm and Foreign Programme, US Dapartment of Agriculture. Dr. Penn showed keen interest in the exhibition and was impressed by the active participation of rural women in the exhibition.

7.3 GENDER IMPLICATIONS IN SMALL FARMING SYSTEMS: STRATEGY FOR WOMEN EMPOWERMENT AND DEVELOPMENT (NATP /CGP PROJECT)

The project was carried out for a period of three years.

The project ended in March 2005.The project aimed to analyse the gender implications in small farming systems and develop strategy for gender empowerment and development was planned and carried out in north-western plains of Indo-Gangetic region covering Haryana, Punjab, Delhi and western UP. A total of 1200 respondents (600 men and 600 women) for direct interview and 4 groups of key informants (15 no. in each) of both genders in each of 30 selected villages for SWOT analysis were contacted for primary data collection.

The SWOT analysis revealed high awareness about the importance of women's education and women's participation in development process. Though the participation of women in agriculture is highly significant, yet their contribution is not yet recognized. Both men and women genders have strong receptivity for change to diversity agriculture and raise income and employment in the farm. The small farming system was categorized by nuclear family, illiteracy among women, medium annual income, low social participation, medium socio-economic status, very poor technical knowledge and skills, agriculture as the main occupation, and women as the major contributor in agriculture. Mostly joint decisions were taken in the farming business. Comparatively the involvement of women in animal husbandry decisions was more than that in agriculture. There was not significant variation about genders involvement in decision making process among states. The mean knowledge scores of men about rice, wheat and *bajra* production technologies were 25.45, 29.64 and 4.76 and scores of women were 6.96, 11.68 and 4.76, respectively.

The major constraints in small farms were: lack of food security, traditional and urban mixed life style, poor access to extension, high drudgery of women, post harvest losses, lack of technical knowledge, very poor literacy among women, problems of soil and water conservation, lack of proper market, rigid family and social norms, poor access to credit and capital inadequacy, lack of infrastructure support, unrewarding profession and works, lack of initiatives and motivation, low risk ability, poor purchasing power and lack of awareness.

The major suggestions for improving small farm and gender empowerment were: bringing women into an equal position with men in agriculture, reducing drudgery through appropriate tools, fruitful utilization of gender time for productive works, capacity building through self awareness, self development and self organization of SHGs and their leadership training to women, empowerment of women for full participation in agriculture, diversification of production micro-credit and training, vocational training for entrepreneurship development/self employment, professional job training for extension personnel, more supportive environment for women to participate (gender sensitization, infrastructure support, savings and credit on associations and groups, technical training on appropriate technology, income generation through professional enterprise).

The strategy for SHG mobilization with possible stages and measuring group dynamics was worked out. The strategy for entrepreneurship development of gender in different enterprises was also developed with possible steps and interventions. The methodology suggested for SHG and ED may be used for gender empowerment and development and thereby making the small farm more productive and profitable.

7.4 GENDER EMPOWERMENT AND FARMING SYSTEM DEVELOPMENT: AN ACTION RESEARCH PROJECT (DST)

The DST sponsored project was initiated in December 2005 and will run for a period of three years. The project focuses on gender empowerment and farming system development (both socio-economic and bio-physical aspect) through appropriate science and technology interventions. The project envisages to adopt a synergetic approach to address the gender-specific issues for attaining socio-economic upliftment of resource poor farming community. It is envisaged to introduce specific and relevant on-farm production, post-harvest management including processing and value addition, drudgery reduction in farm operations, entrepreneurship development and streamlining of marketing channels, etc., at individual and group levels. The project intend to induce desirable behavioural changes in the target groups of gender to be able to meaningfully participate and benefit in terms of generation of additional income and employment and greater technology awareness. The specific technical programme under the project is as follows:

1. Analysis of the existing farming systems.
2. Identification of existing common interest groups.
3. Development and execution of science and technology based interventions in the identified areas.
4. Identification of areas for drudgery reduction and introduction of interventions.
5. Introduction of interventions for entrepreneurship developmental skills.
6. Assessment of impact of interventions and standardization of strategies for further replication in similar areas.

The project was undertaken in Gurgaon district of Haryana state. An extensive survey of the region was made and a cluster of three villages in each of the selected blocks, viz., Pataudi and Farukhnagar was chosen for implementing the project activity. The villages are Banspadamka, Tajnagar and Safedarnagar in 'Pataudi' block, and Sanpka, Jamalpur and Johri Khurd in 'Farukhnagar' block. A few literature and references relevant for the objectives of the project were collected and reviewed. The process for recruitment of the project staff was started.

8. POST-GRADUATE EDUCATION AND INFORMATION SYSTEM

8.1 POST-GRADUATE EDUCATION

8.1.1 Admission during the Academic Session 2005-2006

The Institute admitted 94 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 throughout the country. The admission of 76 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, the 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	76	94	170
Foreign students*	3	7	10
Total	79	101	180

*Foreign students were from the countries, namely; China, Ethiopia, Iran and Srilanka

8.1.2 Convocation 2005

The 43rd convocation of the Institute was held on February 11, 2005. Shri Sharad Pawar, Hon'ble Union Minister of Agriculture who was the chief guest, delivered the convocation address. In his convocation address, the chief guest emphasized on the urgent need to integrate growth with environment protection. The chief guest also highlighted the need to introduce a capsule course on identification of domestic and global market trends. This would be necessary to equip Agri-graduates with sufficient knowledge on tracking market trends.

Dr.S. Nagarajan, Director, IARI, highlighted the research achievements of the Institute during the year 2004. 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 revised *P.G.School Calendar* (2005-2006), and the *Journal of IARI Post Graduate School*, and a number of IARI varieties were released during the convocation.

At this convocation, 76 M.Sc. and 69 Ph.D. students were awarded degress. Ebhin Masto R (SS &AC) and Subhash Kumar Singh (Genetics) were given the 'Best Student of the Year 2004 awards for Ph.D. and M.Sc., respectively. Five recipients of Ph.D. degrees, namely, Atul Kumar (Plant Pathology), Firoz Hossain (Genetics), Chandran K.P. (Agricultural Statistics), J.Loganathan (Entomology) and Md.Burhan Uddin Choudhury (Agricultural Physics); and 5 recipients of M.Sc. degrees, namely, Priya Vijyan (Molecular Biology & Biotechnology), Manish Kumar (Environmental Sciences), Nilabrata Goswami(Computer Application), Arnab Gupta (Seed Science & Technology) and H. Mohan (Plant Genetic Resources) were awarded the IARI Merit Medals for their outstanding academic performance. Five faculty members, namely, Dr. (Ms) Lata (Microbiology), Dr.B.R. Yadav (Water Science & Technology), Dr.R.K. Sairam (Plant Physiology), Dr.R.K. Jain (Plant Pathology) and Dr. (Ms.) Gita Kulshrestha (Agricultural Chemicals) were awarded Best Teacher Awards for their outstanding contribution to teaching.

A Ph.D. student receiving the degree certificate from Shri Sharad Pawar, Hon'ble Union Minister of Agriculture, Consumer Affairs, and Food and Public Distribution at the 43rd convocation

The 35th Lal Bahadur Shastri Memorial Lecture was delivered by Shri Montek Singh Ahluwalia, Deputy Chairman of Planning Commission, on February 10, 2005 on the topic 'Challenges Facing Indian Agriculture'. The function was presided over by Shri Bimal Jalan, former Governor, Reserve Bank of India.

The XIV Hooker Award for the biennium 2002-2003

consisting of a cash prize of Rs.15,000/- and a commendation certificate was awarded to Dr. Naveen Kalra, Principal Scientist and Incharge, Unit of Simulation and Informatics, IARI, for his outstanding research contributions in "Crop modelling and environment sciences".

The IX Dr. B.P. Pal Memorial Award for the year 2004 consisting of a cash prize of Rs.10,000/-, a Gold Medal and a commendation certificate was awarded to Dr. Vijay Pal Singh, Principal Scientist, Division of Genetics, IARI for his outstanding research contributions to "Pyramiding of bacterial blight resistance genes and development/release of elite germplasm/varieties particularly for quality attributes of commercial value in rice".

Dr. (Mrs.) S. Padmaja Rao, Seed Technology Division, IGFRI, Jhansi, received the 5th Hari Krishna Shastri Memorial Award of IARI for the year 2004 consisting of a cash prize of Rs.25,000/- and a commendation certificate for her outstanding research contribution to "Physiological and genetic improvement of rice and seed production technologies in fodder crops".

Prof. Virendra Lal Chopra, former DG, ICAR & Secretary, DARE and Member, Planning Commission, Government of India, and Dr. Hari Krishna Jain, former Director, IARI were awarded the degree of Doctor of Science (*Honoris Causa*) for their significant contributions in the fields of agricultural research and research management, and for the wide acclaim earned by them from the national and international scientific community.

8.1.3 Training Programmes

Several training programmes were organized by the Institute during the year 2005.

Training programmes organized during the year 2005

Training programme	Period
Division of Agricultural Economics	
• ·Conceptual and methodological issues in the new regime of international trade	November 29 – December 19, 2005
Division of Agricultural Engineering	
• Motor winding for rural youths	June 27 – 28, 2005
Division of Agricultural Extension	
• Management of appropriate technology for sustainable agriculture	January 11 – 27, 2005
• Motivation and empowerment for professional excellence among agricultural scientists	March 4 – 24, 2005
• Attitudinal orientation of scientists for organizational productivity	August 17 – September 6, 2005
• Capacity building for organizational development	December 3 – 23, 2005
Division of Agricultural Physics	
• Remote sensing in agriculture with special emphasis on drought management	March 23 – April 16, 2005
Division of Biochemistry	
• Recombinant DNA techniques	January 5 – 25, 2005
• Advanced biochemical and molecular techniques	March 1 – 21, 2005
Division of Fruits & Horticultural Technology	
• Propagation, micro-propagation, tissue culture and nursery science	August 16 – October 10, 2005
• Development and management of fruit orchards	September 12 – 17, 2005
Indo-Israel Project	
• Protected cultivation	April 11 – 16, 2005 December 12 – 17, 2005
• Greenhouse technology for growing horticultural crops	December 1 – 10, 2005
Division of Microbiology	
• *Uttar Bharat me jevic kheti evam sambhavanayen*	July 5 – 11, 2005
• Molecular techniques in rhizobiology	February 20 – March 19, 2005
• Sample survey techniques in agricultural research	January 11 – 31, 2005
Division of Plant Pathology	
• Mushroom cultivation	September 19 – 24, 2005

Training programme	Period
Division of Seed Science & Technology	
• Advances in hybrid seed production and quality enhancement technology	March 21–24, 2005
• Seed quality testing and evaluation	April 24 – 30, 2005
• DUS testing	September 12 – 17, 2005
• Recent advances in seed quality enhancement	September 27 – October 6, 2005
• Seed testing	October 17 – 22, 2005
Division of Soil Science & Agricultural Chemistry	
• Soil testing, plant analysis and water quality assessment	September 15 – 28, 2005
Unit for Simulation and Informatics	
• Computer basics in the application in office automation	June 6 – 10, 2005
Water Technology Centre	
• Planning and design of water harvesting structure in watershed management	March 1 – 8, 2005

8.2 INFORMATION AND DATABASE

8.2.1 Agri-Informatics

A crop protection information dissemination system (AgProtect) is being developed to provide effective, timely and right information to farmers, crop growers (commercial), researchers and planners. This system is based on 3-tier client-server architecture. The front-end is designed in C#. Net of visual studio with ASP. Net as platform. The back end is designed in MS Access 2003. All the validations are done in the middle tier.

8.2.2 Software Development

8.2.2.1 Research management system

A web-based computer software was developed to monitor and update research monitoring of IARI projects using database in MS Access and front-end through ASP.NET.

8.2.3 Bioinformatics

8.2.3.1 Comparative study of abiotic (salt) stress protein between glycophytes (salt sensitive) and halophytes (salt tolerant) using Insilco approach

The study shows that there is a very high homology of salt stress proteins between the two groups of plants.

8.2.3.2 Phylogenic analysis of biotic stress factors in various crop plants on the basis of 3D comparative protein modeling and structure prediction

The study suggests a close similarity between these proteins and their structure. On the basis of fold recognition approach, the antifungal protein of *Arabidopsis thaliana* shares two identities, i.e., 98% identity with *Raphanus sativus* (PDB ID: layj) and 58% identity with *Aesculus hippocastanum* (PDB ID: 1bk8).

8.2.3.3 Identification of position and analysis of the gene involved in pentose phosphate pathway in *Oryza sativa* w.r.t. *Arabidopsis thaliana* using comparative genomic approach

On the basis of the study, it was found that the location of genes of enzyme 6-Phosphogluconate dehydrogenase in *A.thaliana* is on chromosome nos. 1 and 5, whereas in *Oryza sativa*, it is present on chromosome nos. 6 and 11.

8.2.3.4 *In silico* prediction of the structure and function of hypothetical proteins of *Oryza sativa*

A new domain was found in the protein BAC 78599 with similarity to SAD 1/UNC-84 domain.

8.2.4 Internet Activities

IARI website is being maintained and upgraded and Internet services are being provided to scientists and students of the Institutes.

8.3 LIBRARY SERVICES

8.3.1 Acquisition Programme

8.3.1.1 Books

During the year, the Library procured 826 publications, which included 331 in Hindi, and 495 in English costing Rs. 33, 42,614/-. The Library also acquired 400 gift publications, 140 IARI theses and 26 ICAR/RFT theses and 134 ICAR award winning theses/documents.

8.3.1.2 Serials

The Library procured 806 journals/serials through subscription, gifts, and exchanges. It subscribed to 427 foreign journals (out of which 135 had online access) and 227 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.

Two hundred nine (209) annual/scientific/technical reports of different institutions and 297 bulletins were received in the Library. The expenditure on Serial Acquisition Programme from Plan and NATP was Rs. 2,87, 86,043/-.

8.3.2 Documentation Activities

8.3.2.1 AGRIS project

IARI Library was declared an input center for 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, 653 articles were scanned, processed and sent to DIPA, ICAR for inclusion in AGRIS Index.

8.3.2.2 Development news in agriculture

Four thousand seven hundred twenty (4720) news papers were scanned and 67 news items pertaining to IARI as well as ICAR were sent to the Director, IARI, and Principal Scientist (ICC).

8.3.2.3 Document processing

In all, 1085 documents consisting of books, bulletins, post-graduate IARI and Hindi books were processed (classifying and cataloguing).

8.3.3 Resources Management

8.3.3.1 Binding of publications

In all, 4760 volumes consisting of 16,000 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 170-180 users, who consulted approximately 3500-4000 documents everyday. During the period, 18000 publications were issued to its members. In all, 360 documents were issued under Inter Library Loan System to various institutions including NISCAIR. Three hundred 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 1,12,401 pages of photocopies of scientific and technical literature officially. Sixty-three (63) scientists were issued the Free Facility Cards for photocopying, and 278 orders were booked for official jobs.

8.3.4 CD-ROM Workstation

Seven international prominent databases were subscribed to amounting to Rs. 23,00,000/- for providing CD-ROM service on ERL platform on Red Hat Linux Server. 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 60,215, which generated revenues amounting to Rs. 68,874/-. The scientists of IARI accessed through the Intranet (Local Area Network).

8.3.5 Digitization of Old and Rare Publications

A memorandum was signed with C-DOC (Ministry of Information Technology) to digitize the oldest documents on 4 September 2004. During the period, 28,81,103 pages of 4,725 publications were scanned. Old documents published after 1950 were not covered under this project for reasons of copyright.

8.3.6 Activities under NATP Sub Project, LIS

8.3.6.1 Role as a national lead centre under LIS sub component of NATP

The NATP authorities declared the IARI library as the National Lead Centre for their sub-project of "Library Information Strengthening". In this context, the IARI library has to play a vital role for all ICAR institutes'/SAUs' libraries in accessing their requirement, guiding them in their technical matters, coordinating with these institutes and finally approaching the NATP authorities for releasing the required financial assistance. For creating the networking environment, this Library has provided all the requisite technical expertise and introduced an international service provider for better service and communication.

8.3.6.2 Monitoring of LIS project and review meeting

As per the directives of the NATP, the last meeting of the 1st Phase was organized at West Bengal University of Animal and Fishery Sciences, Kolkata from 6 to 7 May 2005 to review the progress of the 1st Phase and to assess the requirement for 2nd Phase of all the 38 agricultural universities and 84 ICAR institutes covered under this project.

9. PUBLICATION ACTIVITIES

An important mandate of the Institute is to develop an information system, add value to information and share the information nationally and internationally. Publications are an important component of the information system. During the year, the Institute brought out several regular and *ad hoc* publications both in English and Hindi. The details of the publications brought out during the year are given below:

Regular Publications (English)

- IARI Annual Report 2004-2005 (ISSN: 0972-6136)
- IARI News (Quarterly) (ISSN: 0972-6144) - 4 issues
- IARI Current Events (Monthly) - 12 issues

Ad hoc Publications (English)

Technical Bulletins

- Carrot: Seed Production Technology (TB-ICN:30/2005)
- Achievements in Neem Research (ICN:31/2005)
- A Technical Bulletin on "Molecular Characterization of *Ber*" (ICN: 32/2005)
- Drainage Technology for Land Improvement (ICN: 33/ 2005)
- Global Warming: Indian Estimates of Greenhouse Gas Emission from Agricultural Fields (TB-ICN: 34/2005)
- Grape Cultivation in Non-Traditional Areas (TB-ICN: 35/2005)
- Drip Irrigation Technology to Save Water and Enhance Crop Yields (TB-ICN: 36/2005)
- Heavy Metal Contamination through Sewage Irrigation in Peri-urban Areas of National Capital Territory of Delhi (TB-ICN: 37/2005)
- Seed Production Agronomy of Aromatic Rice (TB-ICN: 38/2005)
- Maize Cyst Nematode, *Heterodera zeae* – A Key Nematode Pest of Maize and its Management (TB-ICN: 39/2005)

Books

- Wheat Seed Production, Processing & Storage (ISBN: 81-88708-07-0)
- Souvenir (1905-2005), IARI (ISBN: 81-88708-08-9)
- A Practical Manual of Crop Production (ISBN: 81-88708-09-7)
- Advances in Microbiology at IARI (1961-2004) (ISBN: 81-88708-10-0)
- Manual on "Growth and Development of Horticultural Crops" (ISBN: 81-88708-11-9)
- Wheat for Tropical Areas (ISBN: 81-88708-12-7)
- Hundred Years of Plant Pathological Research at IARI (1905-2005) (ISBN: 81-88708-13-5)
- Phytoremediation of Heavy Metal Contaminated Soils (ISBN: 81-88708-14-3)

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 Prabandhan* (ISBN: 81-88708-15-1)
- *Rabi Ki Phaslon Kee Unnat Ttakneek* (ICN:H-21/2005)
- *Audyanik Phaslon Kee Utapadan Takneeki* (ICN:H-22/2005)
- *Paryavaran Sanrakshan* (ICN:H-23/2005)
- *Krishi Udyamiyon Kee Sangathankatmak Sahayata* (ICN:H-24/2005)
- *Bagvani Utpadon Tatha Khadyanno Ke Parirakshan Ke Liye Kam Lagat Vali Bhandaran Prodhygikiyan* (ICN:H-25/2005)
- *Kisan Jigyasa Avam Samadhan* (ICN:H-26/2005)
- *Gahoon Kee Unnat Utpadan Takneek* (ICN:H-27/2005)
- *Phaslon Ke Pramukh Rog Aur Unka Samekit Prabandhan* (ICN:H-28/2005)
- *Subzi Utpadan Kee Unnat Prodyogikiyan* (ICN:H-29/2005)
- *Bhoomi Sudhar Hetu Unnat Prodyogikiyan* (ICN:H-30/2005)
- *Vishva Ushaman : Kheton Se Green House Gas Utsarjan Ka Bhartiya Akalan* (ICN:H-31/2005)
- *Gair-Parampara Kshetron Mein Angoor Kee Kheti* (ICN:H-32/2005)
- *Drip-Sinchaiee Prodyogikee : Pani Kee Bachat, Paidavar Main Badhat* (ICN:H-33/2005)
- *Neem Anusandhan Kee Uplabdhiyan* (ICN:H-34/2005)

10. COMMERCIALIZATION AND IPR ACTIVITIES

The mandate of the Business Development Cell 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 BDC during the year:

Patents Filed

- A process for the detoxification of chlorpyrifos residues in drinking water.
- A process of expressing and isolating recombinant protein from prokaryotic cells.
- Composition for early, profuse sporulation, under solid state, of the improvised isolate of *Trichoderma harzianum* and a process thereof.
- Novel super absorbent hydrogel/s and the method of obtaining the same.
- Process for the preparation of –5-substituted-1,3,4-oxadiazole-2-thiols as new urease and nitrification inhibitors.

MoUs/Agreement Signed

- A memorandum of understanding (MoU) was signed on 3.2.2005 between IARI and Tamil Nadu Agricultural University (TNAU), Coimbatore for exchange of information on market intelligence of agricultural commodities.
- A memorandum of understanding (MoU) was signed between IARI and Mahyco Research Foundation and Mahyco Seeds Ltd. on 7.4.2005 for commercialization of technology of superfine grain aromatic Hybrid Pusa RH-10 for five years.
- A memorandum of understanding (MoU) was signed on 9.8.2005 between IARI & DST (National Centre for Medium Range Weather Forecasting, NOIDA) for the national network of agro- meteorological advisory services for the next term of five years.
- A memorandum of understanding (MoU) was signed on 26.8.2005 between IARI and Bejo Sheetal Seed Pvt.Ltd., Jalna on Bt.Brinjal for a period of one year.
- An agreement for consultancy services to be provided to Basmati Export Development Foundation on DNA profiling and rice quality, grain quality and cooking quality analysis and training was signed on 23.9.2005 for a period of one year.

Other Activities

- An interface meeting between IARI and seed industry was organized at IARI as part of the Centenary Krishi Vigyan Mela on 15.2.2005. The industry professionals visited important research laboratories and experimental research farm to have discussions with the scientists in the labs and demonstration plots. The purpose of the dialogue was to explore the possibilities of long term associations through suitable agreements/MoUs between IARI and the agri-business industry.
- An "Awareness Programme on Intellectual Property Rights" was organized by the Business Development Cell from May 17 to 18, 2005. The emphasis of the programme was to equip the scientists with the knowledge on patent filing procedures including the provisions in the New Patent Act 2004, traditional knowledge, plant variety protection and Farmers' Rights Act.

  Twenty-six scientists from 20 ICAR institutes covering the institutes under the Divisions of Crop Sciences, Natural Resource Management, and Horticulture of ICAR participated. The programme was divided into 5 sessions, namely (i) Filing Patents: Procedural & Strategic issues; (ii) IPR in Indian Agriculture; (iii) IPR in Biodiversity; (iv) IPR in Agricultural Product and Exports; and (v) Case Study Presentation: Success Stories. The lectures were given by experienced faculty drawn from ICAR; IARI; National Research Development Corporation (NRDC); Delhi University; NBPGR; Patent Office, Govt. of India; Patent Attorneys and National Institute of Science Communication & Information Resources (NISCAIR).
- A capacity building programme for Indian agricultural research, extension & development (RED) organizations in globalized agricultural economy sponsored by the Indian Council of Agricultural

Research and Centre for International Trade in Agriculture was organised from September 15 to 16, 2005 at NRL Auditorium, IARI, New Delhi. Ninety-seven (97) participants from 27 ICAR institutes and 4 state agricultural universities located in north Indian states of U.P., Uttaranchal, J & K, Punjab, Haryana participated in the programme organized by the Business Development Cell. Dr.B.S.Parmar, Joint Director (Research) was the Nodal Officer for this programme.

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 2005 are given in the following table.

Name of funding agency	No. of projects
Within India	
DBT, DST, ICAR, CICR, CSIR, NCPA, Ministry of Environment & Forest, DOAC, DRDE, NAAS, CPCB, etc.	66
AP Cess Fund, National Fellow Scheme of ICAR	51
NATP	33
Outside India	
PPIC, USAID, IAEA, CGIAR, CIMMYT	08

12. BUDGET ESTIMATES

Rs. in lakh

Subhead	Budget estimates 2004-2005		Revised estimates 2004-2005		Budget estimates 2005-2006	
	Plan	Non-Plan	Plan	Non-Plan	Plan	Non-Plan
Estt. charges including wages	-	5535.00	-	5525.00	-	5565.70
OTA	-	4.50	-	4.50	-	4.50
TA	35.00	21.00	29.95	31.00	25.00	8.60
Other charges	1615.24	1080.00	889.84	1540.00	971.91	1117.00
Works	424.00	459.50	30.92	999.50	40.00	489.20
Other items/fellowships	-	170.00	-	262..00	-	170.00
Total	**2074.24**	**7270.00**	**950.71**	**8362.00**	**1036.91**	**7355.00**

13. STAFF POSITION

(As on 31.12.2005)

Category	No. of posts	
	Sanctioned	Filled
A. SCIENTIFIC STAFF*		
1) Research Management Personnel	7	5
2) Principal Scientist	73	42
3) Senior Scientist/Scientist (S.G.)	182	44
4) Scientist	391	368
B. TECHNICAL STAFF		
1) Category III	27	25
2) Category II	414	356
3) Category I	463	392
C. ADMINISTRATIVE STAFF		
1) Group A	20	12
2) Group B	304	277
3) Group C	267	238
D. SUPPORTING STAFF		
1) SS Grade IV	193	184
2) SS Grade III	388	349
3) SS Grade II	648	616
4) SS Grade I	484	461

* Excluding the cadre strength of Directorate of Maize Research & NRC on Plant Biotechnology

14. MISCELLANY

I. On-going Projects at IARI as on 31.12.2005

a) School of Crop Improvement	38
b) School of Resource Management	28
c) School of Crop Protection	18
d) School of Basic Sciences	14
e) School of Social Sciences	13
Total	**111**

II. Scientific Meetings Organized

a) Workshops	3
b) Seminars	10
c) Summer institutes	1
d) Farmers' day (s)	15
e) Others	44
Total	**73**

III. Participation of Personnel in Scientific Meetings

India

a) Seminars	165
b) Scientific meetings	190
c) Workshops	117
d) Symposia	120
e) Others	60
Total	**652**

Abroad

a) Seminars	3
b) Scientific meetings	14
c) Workshops	6
d) Symposia	5
e) Others	5
Total	**33**

IV. Publications

a) Research/symposia papers	1193
b) Books/chapters in books	195
c) Popular articles	370
Total	**1758**

V. Honours and Awards

1. Dr. S. Nagarajan, Director, IARI received the Borlaug Award 2005 in agriculture instituted by Coromandel Fertilizers Limited. He was also presented with the Dr. Amrik Singh Cheema Award by the Young Farmers' Association, Rakhra, Punjab.
2. Dr. B.D. Kaushik, Head, Division of Microbiology received the K.S. Bilgrami Gold Medal for outstanding work in BGA.
3. Dr. K.A. Nayeem, Head, IARI Regional Station, Wellington received the Jewel of India Award and the Life Time Achievement Award from the International Institute for Education and Management, and the Indian Solidarity Council, respectively.
4. Dr. P.K. Chhonkar, Head, and Dr. B.S. Dwivedi, Senior Scientist, Division of Soil Science and Agricultural Chemistry received the Dhiru Morarji Award of the Fertilizer Association of India for the best scientific article published in the Indian Journal of Fertilizers.
5. Dr. S. Chowdhury, Head, IARI Regional Station Pusa received the Dr. B.P. Pal Memorial Award for development of wheat varieties.
6. Dr. K. Vijayaraghavan, Principal Scientist, Division of Agricultural Extension was honoured with the Dr. K.N. Singh Memorial Award for the excellence achieved in extension research.
7. Dr. S.M.S. Tomar, Principal Scientist, Division of Genetics was nominated Member of the National Academy of Science, India.
8. Dr. D. Prasad, Principal Scientist, Division of Nematology, received the PP Singhal Memorial Award instituted by PI Industries Ltd., Udaipur.
9. Dr. V.G. Malathi, Principal Scientist, Division of Plant Pathology received the Dasgupta Memorial Lecture Award from the Indian Phytopathological Society.
10. Dr. A.K. Bhatacharya, Principal Scientist, WTC received the Gold Medal of Soil Conservation Society of India for research work.

11. Dr. (Ms.) Prem Dureja, Principal Scientist, Division of Agricultural Chemicals received the Rafi Ahmed Kidwai Award (ICAR) for the biennium 2003-2004 in the field of natural resource management.
12. Dr. F.U. Zaman, Principal Scientist, Division of Genetics received the Rafi Ahmed Kidwai Award (ICAR) for the biennium 2003-2004 in the field of crop improvement and crop protection.
13. Dr.(Ms.) S.Ganguli, Principal Scientist, Division of Nematology received the Outstanding Scientist Award by Society of Plant Protection Sciences.
14. Dr. Ram Roshan Sharma, Principal Scientist, Division of Vegetable Science and Mr. Anil Kumar Gupta, Technical Officer, CATAT jointly received the Ram Nath Singh Award for writing a book on *Strawberry: Adhunik Utpadan Takniken*
15. Dr. B.M. Prasanna, National Fellow, Division of Genetics received the Joginder Singh Memorial Award for Maize Genetic Breeding.
16. Dr. (Ms.) Premlata Singh, Senior Scientist, Division of Agricultural Extension received the ISEE Fellow Award (North Zone) for her outstanding contributions made in the field of extension education.
17. Dr. R.N. Padaria, Senior Scientist, Division of Agricultural Extension was conferred with the Young Scientist Award for his outstanding work in the field of extension education by the Indian Society of Extension Education.
18. Dr. T.K. Behera, Sr. Scientist, Division of Vegetable Science was conferred with the Associateship of the National Academy of Agricultural Sciences (NAAS) w.e.f. January, 2005.
19. Dr. Jitendra Kumar, Senior Scientist, Division of Agricultural Chemicals received the Visiting Scientist INSA Award, 2004-05 in the field of agricultural chemistry.
20. Dr. Parimal Sinha, Senior Scientist, Division of Plant Pathology received the P.P. Singhal Memorial Award for the year 2005 instituted by PI Industries Ltd., Udipur.
21. Dr. Neera Singh, Senior Scientist, Division of Agricultural Chemicals received the Hambolt Fellowship (Germany).
22. Dr. K.V. Prabhu, Senior Scientist, Division of Genetics received the Fellowship of NAAS, and the V.S. Mathur Memorial Award for contribution in the field of wheat genetics and plant breeding.
23. Dr. Rajendra Kumar, Senior Scientist, Division of Genetics, was nominated Member, National Academy of Sciences for outstanding contribution in the field of genetics and plant breeding.
24. Dr. Vanita Jain, Senior Scientist, Division of Plant Physiology, received the DST – Boyscast Fellowship 2005-06.
25. Dr. A.S. Hari Prasad, Scientist, Division of Genetics, received the Srinivasa Ramanujam Memorial Award for crop improvement.

VI. Resource Generation (Including Consultancy) & Commercialization of Technology

1) Consultancy Services, etc. (Rs. in Lakhs)

Consultancy service	Rs. 13.06
Contract research	Rs. 3.96
Contract service	Rs. 12.69
Training	Rs. 13.57
Total (A)	**Rs. 43.28**

2) Revolving Fund

	Sale Proceeds Revenue Generated (Rs. in Lakhs)
(a) Seed	Rs. 119.97
(b) Commercialization	Rs. 14.25
(c) Prototype manufacturing	Rs. 36.87
Total (B)	**Rs. 171.09**

3) Post Graduate School Receipt

Training Programme

(a) Foreigners & Indians	Rs.2,57,680/-

M.Sc/Ph.D Programme

(b) Institutional economic fee from foreign scholars under Work Plan	US$ 92800 +Rs. 3,97,812/-
(c) Receipt from Registrar (A) Account No. 5432: all fees of ICCR, Work Plan and Indian scholars, etc., and forms sale through post	Rs. 36,52,521/-
(d) Cash transferred from Syndicate Bank to Director's Account No. C-49 from sale of Ph.D. forms	Rs. 2,13,900/-

(e)	Receipt deposited in Director's Account No. C-49 due to refund of IARI Fellowships from CSIR & UGC Fellows + Misc. receipt of degree, PDC and other fees	Rs.1,84,265/-
Total (C)		**US$ 92800 + Rs. 47,06,178**
Grand Total (A+B+C)		**US$ 92800 + Rs. 261,43,178**

VII. Significant Suggestions Given/Decisions Taken at Senior Management Personnel (SMP) Meetings during the Period January 1 to December 31, 2005

Academic Council

- Institution of a divisional level annual award in the name of late Dr. S. P. Raychaudhuri, an "icon" in the field of plant pathology.
- Introduction of two new courses (each of 3 credits), namely, 'Principles and Practices of IPM', and 'Food Package Engineering'
- Establishment of an international agriculture unit at IARI. Two paid international courses will be offered by the trained faculty identified for foreign students, and well furnished accommodation will be reserved for these students.
- Proposal for a post doctoral fellow/visiting professor programme at IARI. The Institute may enter into MOU with Kansas State University through exchange programmes for Project Director/ Visiting Professor.
- For the first time, seven Scientists of NCIPM were inducted into the P.G. Faculty in their related disciplines.

Extension Council

- The participation of some farmers and BDO or his representative should be ensured in the Extension Council meetings so that their points of view and suggestions may also be taken care of.
- The IARI website should be connected with TAFE website on mutual sharing basis. The extension component should be focused in the MOU between the two websites.
- With a view to including animal based production systems under the TOT programmes, collaboration may be made with NDRI, Karnal, and Buffalo Institute, Hissar.
- The seed production programme in farmers' fields should be closely supervised and all the parameters should be considered for ensuring seed quality.
- Researches should be undertaken to generate base line data and evidences for developing location specific conceptual/extension models/ methodologies in the areas like commercial agriculture, farmers' distress situations, marketing extension, sustainability issues, etc.
- IARI-AIR (All India Radio) collaborative programmes on crops like pulses, cotton, oilseed, vegetables, fodder etc. should be taken up on the pattern of wheat school on AIR (*Gehoon Pathshala*) and *Chawal Pathshala*.
- In FLDs and other TOT programmes, due attention should be given to sociological/psychological dimensions.
- The KVK should undertake studies on impact analysis on technology absorption and enhancement of social living of people in the region.
- Tours of farmers of KVK villages should be conducted to the identified institutes located in the areas having similar agro-socio-economic conditions.
- The KVK should act as 'show piece window' of IARI and the visits of dignitaries, foreign visitors, etc., should be arranged to the KVK on important occasions.
- A data base may be developed in consultation with the Unit of Simulation and Informatics (USI) for creating a knowledge base and application of appropriate technological interventions in order to tackle the crisis situation due to unexpected calamities like Tsunami.
- Priority action should be taken to establish facilities of Internet Price Ticker at ATIC and OEP area at Churu/Jhunjhunu (Rajasthan) as agreed by NCDEX without any financial implications on IARI. Initiative should also be taken up to provide weather web-station facility at Churu/Jhunjhunu with the financial support of NCDEX.

Research Advisory Council

- In the changing research policy environment and with the tremendous growth of the National Agricultural Research system, IARI should redefine its role, responsibility and mandate. The Institute should put in place a planning mechanism so that in the next ten years it becomes the country's premier institution in the field of strategic research in all the different disciplines of agricultural sciences.

- The improved crop varieties released by IARI scientists should be studied for their impact following the standard methodology available for this purpose. The study should focus on varieties which have already made an impact and have covered large areas in farmers' fields.
- The Regional Station, Amartara, should focus on rootstock research on apple and other temperate fruits.
- IARI should work on technology to rejuvenate the old mango/apple orchards.
- IARI should take the lead in the field of pre-breeding and genetic enhancement so that thousands of genetic stocks available with the NBPGR help to diversify the genetic base of improved varieties and bring in useful traits for yield, disease, pest resistance and quality parameters.
- Impact of Bt cotton on soil biota should be undertaken in large scale field trials.
- IARI should carry out a major analysis on growth rates of foodgrains in the last 40 years starting with 1965-66, with ten-year intervals. The factors responsible for decline in growth rates in the last 10 years should be identified and recommendations made for the revival of the high growth rates.
- The Institute should have a major research programme on more efficient use of fertilizer and water in crops like rice.
- The Nuclear Research Laboratory (NRL) should be reorganized as a Centre for Sustainable Agriculture using some of the most modern techniques and equipments. The recommended mandate of the Centre would be: monitoring on a regular basis the different sustainability parameters in different parts and production systems in the country; coordinating research at IARI in the field of organic farming; taking new initiative on precision farming using advanced instrumentation; undertaking farmers' field-based applied microbiology in order to make microbes as the future factories of plant nutrients and other energy inputs in agriculture; and harnessing advances in modern biotechnology and information technology for the development of sustainable production systems. The Centre should become a link between some of the existing divisions of IARI and on-farm research through refinement and testing of technology packages.
- Integration of extension and economic studies should be reflected in the work of the School of Social Sciences.
- Engineering component should be the major focus in biofuel projects. Competitiveness in production cost and its efficiency should be kept in mind for ethanol production.
- The Water Technology Centre of IARI should have two important components in its research programmes. First, the Centre should carry out studies in various irrigation command areas to determine the efficiency factor in the use of irrigation water both during conveyance and on-farm application. Second, the Water Technology Centre should study some of the watershed management programmes of the Government and come out with recommendations on making them more effective. The main thrust of the Water Technology Centre should be to carry out on-farm research with a view to increasing water use efficiency both in the irrigated and rainfed lands.
- The Institute should develop a uniform format for presentation of work by different schools.

VIII. Infrastructural Development

Unit of Simulation and Informatics

- Bioinformatics laboratory is being strengthened with structural cabling, more servers and computers.

Nuclear Research Laboratory

- Phase-I of the National Physical Instrumentation Research Facility.
- Controlled Environment Plant Growth Chamber Facility.
- Bio-Physics Lab, Nutriophysiology Lab, Eco-Hydrology Lab, Chemometrics Lab.

CATAT

- A Price Ticker Board from NCDEX, Bombay has been installed in ATIC which displays current and future rates of agricultural commodities of major agricultural markets/mandies of country. It helps the visiting farmers and agri-preneurs in decision making for sale of their farm produce.

IX. All India Coordinated Research Projects in Operation during the year 2005

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
2. All India Coordinated Project on Long Term Fertilizer Experiments
3. All India Coordinated Research Project on Soil Test Crop Response
4. All India Coordinated Research Project on Tillage Requirements of Major Indian Soils for Different Cropping Systems
5. All India Coordinated Research Project on Floriculture Improvement
6. All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries
7. All India Coordinated Research Project on Honey Bees
8. All India Coordinated Research Project on Biological Control of Crop Pests
9. All India Coordinated Research Project on Soybean
10. All India Coordinated Research Project on Sub-tropical Fruits.

X. Foreign Visitors During 2005

Sl.No.	Name and designation(s)	Month
1.	An 11-member delegation (diplomatic staff) led by H.E. the High Commissioner of the Republic of Kenya	January
2.	A 6-member delegation of the Ministry of Agriculture under the World Bank funded Project Programme in the Republic of Tajikistan.	January
3.	H.E. Chinasac Thanesnant, Ambassador of Thailand along with the First Secretary, Embassy of Thailand	February
4.	A 6-member delegation accompanied by H.E. Yasmin Turuphial, Minister (Counsellor) of the Embassy of Venezuela	February
5.	A 6-member delegation from the Ministry of Agriculture, Republic of Tajikistan	February
6.	A group of 10-extension specialists from Small-holder Agriculture Improvement Project (SAIP), Dhaka, Bangladesh	February
7.	Her Royal Highness Crown Princess Mahachakri Sirindhorn of Thailand	February
8.	A 30-member delegation sponsored by the Food and Agriculture Organization (FAO), from Bangladesh	February & March
9.	A 2-member delegation from the Ministry of Agriculture, Zambia	March
10.	A 4-member delegation from Bagasari Flour Mills, Jakarta, Indonesia	March
11.	A 15-member delegation from various countries attending the meeting of Heads of Training Institutes sponsored by the Afro-Asian Rural Development Organization (AARDO) at New Delhi	March
12.	A group of Governing Board Members of ICRISAT led by Dr. William D. Dar, Director-General, ICRISAT, Hyderabad	March
13.	A group of CIMMYT Scientists (Biofortification Programme), International Maize and Wheat Improvement Centre, Mexico	March
14.	Dr. N.E. Borlaug, Nobel Laureate, USA	March
15.	H.E. General Marcel Ranjeva, Foreign Minister of Madagascar and others	March
16.	A 15-member delegation led by Prof. Qu Zhenyuan, General Secretary, Chine Agriculture University, Beijing, China	March
17.	A 5-member delegation (representatives of Agrion B.V. and Wagenin UR companies) from Senter-novem, an organization of the Netherlands, Ministry of Economic Affairs	April

Sl.No.	Name and designation(s)	Month
18.	H.E. Ernest Debrah, Minister of Agriculture, Ghana, and others	April
19.	A 5-member delegation led by H.E. Dr. Abdolmahdi Bakshandeh, Deputy Minister of Agriculture, Planning and Finance, Government of Iran	August
20.	A 3-member delegation from ACIAR led by Dr. Tony Fisher, ACIAR Regional Manager, South Asia, ACIAR, Canberra	August
21.	A 19-member delegation from the Ministry of Higher Education, Afghanistan	September
22.	Mr. Jacques Diouf, Director-General, Food and Agriculture Organisation (FAO), Rome	September
23.	An 8-member delegation from the Ministry of Agriculture and Cooperative, Nepal	September
24.	A 4-member Thai group led by Mr. Apichal Chingaripa, Director, Planning Division, Department of Agricultural Extension (DOAE), Thailand	September
25.	H.E. Haneef Atmar, Minister for Rural Rehabilitation and Development, Afghanistan	October
26.	A 14-member delegation from Irish Republic	October
27.	A group of 22 officers from various developing countries like Bulgaria, Ethiopia, Guyana, Iraq, Indonesia, Mongolia, Thailand, etc.	October
28.	Dr. Rolf Jordens, Vice Secretary-General, UPOV, Geneva, Switzerland	November
29.	A 39-member French delegation	November
30.	H.E. Han Chand On, Ambassador, Democratic People's Republic of Korea	November
31.	Mr. Mohammad Ismail Qureshi, Secretary, Ministry of Agriculture, Food and Livestock, Government of Pakistan	November
32.	A 4-member delegation led by H.E. Dr. Nickey Iyamba, Minister of Agriculture, Water and Forestry, Namibia	December
33.	A 3-member delegation led by Dr. Nienke Beintema, Head, Agricultural Science and Technology Indicators (ASTI), IFPRI of CGIAR	December
34.	A 2-member delegation from Jordan	December
35.	Prof. Ali Abdel Hamid Hussain of Zagazing University, Academy of Scientific Research Technology (ASRT), Egypt	December
36.	A 6-member delegation led by Mr. Cai Yauming, Secretary-General of Shanghai Municipal Agricultural Commission, China	December
37.	A 3-member delegation led by Mr. Salim Bin Aidh Al-Thubeiti, Director-General of Fisheries at Jeddah from Saudi Arabia	December

Her Royal Highness Crown Princess Maha Chakri Sirindhorn of Thailand interacting with Dr. S. Nagarajan, Director, IARI during a visit to IARI

His Excellency Ernest Debrah, Minister of Agriculture, Ghana signing the visitors' book at IARI

Appendix 1

Members of Board of Management of IARI

(As on 31.12.2005)

Chairman

1. Director, IARI

Members

2. Dean & Joint Director (Education), IARI

3. Shri J.N.L. Srivastava
   25, NRI Colony Mandakini
   Greater Kailash, Part-IV
   New Delhi- 110 019

4. Prof. K.V. Peter
   Vice Chancellor
   Kerala Agricultural University
   Vellanikkare, P.O.: Thrissur
   Kerala- 680 565

5. Dr. N.N. Singh
   P.D., Directorate of Maize Research

6. Dr. P.K. Aggarwal
   Head
   Division of Environmental Sciences, IARI

7. Dr. B.B. Singh
   Head
   Division of Genetics, IARI

8. Dr. B.D. Kaushik
   Head
   Division of Microbiology, IARI

9. Dr. D.V. Singh
   Head
   Division of Plant Pathology, IARI

10. Dr. G.C. Srivastava
    Head
    Division of Plant Physiology, IARI

11. Dr. C. Ramasamy
    Vice Chancellor
    Tamil Nadu Agril. University
    Coimbatore, Tamil Nadu – 641 003

12. Dr. G. Kalloo
    DDG (CS), ICAR, New Delhi

13. Dr. Sushil Kumar
    Director, NDRI, Karnal

14. Dr. N.B. Singh
    Agril. Commissioner
    Department of Agril and Cooperation
    Ministry of Agril., Krishi Bhawan
    New Delhi-110 001

15. Dr. M.D. Pathak
    Centre for Research & Development
    of Waste & Marginal Land
    Lucknow (U.P.)

16. Dr. A.K. Tyagi
    Prof. & Head
    Deptt. of Plant Molecular Biology
    South campus, Benito Juarez Road
    Delhi University, New Delhi-110 021

17. Shri Naresh Sirohi
    R-4/86, Raj Nagar, Ghaziabad, U.P.

18. Shri Balbir Singh
    VPO- Jawa, Saharanpur, U.P.

19. Mr. Radhey Shyam
    Deputy Director Finance- ICAR
    New Delhi

20. Shri Narendera Kumar
    Development Commissioner
    Govt. of NCT of Delhi
    5/9 Under Hill Road, Delhi-110 054

21. Joint Director (Res.), IARI

22. Joint Director (Extn.), IARI

Member-Secretary

23. Joint Director (Administration), IARI

Appendix 2

Members of Research Advisory Council of IARI

(As on 31.12.2005)

Chairman

1. Dr.H.K.Jain,
   Ex-Director, IARI,
   40, Surya Niketan,
   Vikas Marg Extension,
   Delhi-110 092

Members

2. Dr.G.L.Kaul,
   Ex-Vice Chancellor,
   Assam Agriculture University,
   K.A.-59 (F.F.), Kaushambi,
   Ghaziabad-201 012, U.P.

3. Dr.V.P.Gupta,
   Ex-Vice Chancellor,
   GH-10 / 69A, Sunder Apartments,
   Paschim Vihar, New Delhi-110 087

4. Dr. Ashish Datta,
   Director,
   National Centre for Plant Genome Research,
   JNU Campus, New Delhi

5. Dr. S.S. Magar,
   Vice Chancellor,
   B.S.Konkan Krishi Vidyapeeth,
   Dopoli, Distt. Ratnagiri,
   Maharashtra

6. Prof. S. Kannaiyan,
   Ex-Vice Chancellor,
   Tamil Nadu Agricultural University,
   AL-85, 4th Street, 11th Main Road,
   Anna Nagar, Chennai- 600 040

7. Dr. S.N. Shukla
   Assistant Director-General (F&FC)
   ICAR, New Delhi

8. Director, IARI

Member-Secretary

9. Joint Director (Research)
   IARI, New Delhi

Appendix 3

Members of Academic Council of IARI

(As on 31.12.2005)

Chairman

1. Dr. S. Nagarajan (up to 13.10.2005)
   Dr. A.K. Singh (from 14.10.2005)
   Director, IARI

Vice-Chairman

2. Dr. R.C. Gautam,
   Dean & Joint Director (Edn.), IARI

Members

3. Dr. Mruthyunjaya
   Dy. Director General (Edn), ICAR

4. Dr. A.K. Singh
   Director, NBPGR

5. Dr. S.D. Sharma
   Director, IASRI

6. Dr. B.S. Parmar
   Joint Director (Research)

7. Dr. B.S. Hansra
   Joint Director (Extension)

8. Dr. Panjab Singh
   Vice Chancellor, BHU, Varanasi

9. Dr. C. R. Hazra
   Vice-Chancellor, IGKV, Raipur

10. Dr. (Mrs.) Manju Sharma
    Former Secretary, DBT, Govt. of India

11. Dr. B.L. Jalali
    Former Director (Research), CCSHAU, Hissar

12. Dr. R.P. Singh
    Project Director (Maize)

13. Dr. K.R. Koundal
    Project Director, NRC on Plant Biotechnology

14. Dr. P. S. Datta
    Professor & Project Director, N.R.L.

15. Dr. A.K. Singh
    Project Director, Water Technology Centre

16. Dr. V.C. Mathur
    Professor of Agril. Economics

17. Dr. J. S. Panwar
    Professor of Agril. Engineering

18. Dr.(Ms.) Aparna Chattopadhyay
    Professor of Agril. Extension

19. Dr. M. Bhavanarayana
    Professor of Agril. Physics

20. Dr. V.K. Sharma
    Professor of Agril. Statistics

21. Dr. Mangal Parsad
    Professor of Agronomy

22. Dr. Prikhshayat Singh
    Professor of Biochemistry, IARI

23. Dr. G. P. Gupta
    Professor of Entomology, IARI

24. Dr. H. C. Joshi
    Professor of Environmental Sciences, IARI

25. Dr. R.D. Singh
    Professor of Genetics, IARI

26. Dr. A. K. Chakrabarti
    Professor of Horticulture, IARI

27. Dr. A. P. Singh
    Head, Division of Floriculture and
    Landscapping, IARI

28. Dr. A.K. Chakrobarti
    Head, Vegetable Crops

29. Dr. K. S. Jauhari
Professor of Microbiology, IARI

30. Dr. K.C. Bansal
Professor of Mol. Biol. & Biotechnology, IARI

31. Dr. P. Bahadur
Professor of Plant Pathology, IARI

32. Dr. Manoranjan Saha
Professor of Nematology, IARI

33. Dr. G. Narayanasamy
Professor of Soil Science & Agril. Chemistry, IARI

34. Dr. D.B. Saxena
Professor of Agril. Chemicals

35. Dr. J.N. Singh
Professor of Seed Science & Technology

36. Dr. P.K. Malhotra
Professor of Computer Application, IASRI

37. Dr. G.C. Srivastava
Professor of Plant Physiology

38. Dr. B.R. Yadav
Professor of Water Science & Technology

39. Dr. B.B. Mondal
Professor of Plant Genetic Resources

40. Dr. R.K. Rai
Master of Halls of Residences

41. Shri N.S. Pakhale
Head, IARI Library

42. Shri P.K. Jain
Dy. Registrar

43. Dr. R.K. Jain,
Pr. Scientist, Plant Pathology
Elected Faculty Representative

44. Dr. B. Subrahmanyam
Pr. Scientist, Entomology,
Elected Faculty Representative

45. Shri Palmuragan
President, PGSSU

46. Shri Priya Ranjan Kumar
Elected Students' Representative

Member-Secretary

47. Shri P.C. Jacob
Registrar (Academic)
P.G. School, IARI

Appendix 4

Members of Extension Council of IARI

(As on 31.12.2005)

Chairman

1. Dr. S. Nagarajan
   Director, IARI

Member-Secretary

2. Dr. Baldeo Singh
   Head
   Division of Agricultural Extension, IARI

Members

3. Dr. R.C. Gautam, Head,
   Division of Agronomy, IARI

4. Dr. B.B. Singh, Head,
   Division of Genetics, IARI

5. Dr. P.K. Chhonkar, Head,
   Division of Soil Science &
   Agricultural Chemistry, IARI

6. Dr. H.S. Gaur, Head,
   Division of Nematology, IARI

7. Dr. (Ms.) Malvika Dadlani, Principal Scientist,
   Division of Seed Science & Technology, IARI

8. Dr. Aparna Chattopadhyaya,
   Prof., Division of Agricultural Extension, IARI

9. Dr. A.P. Srivastava, Principal Scientist,
   Division of Agricultural Engineering, IARI

10. Dr. (Ms.) Pratibha Sharma, Principal Scientist,
    Division of Plant Pathology, IARI

11. Dr. Anjani Kumar, I/C,
    KVK, Shikohpur, Gurgaon, Haryana

12. Dr. R.K. Chowdhary, Project Coordinator,
    National Seed Programme, IARI

13. Dr. H.N. Pandey
    Head,
    IARI Regional Station, Indore

14. Dr. Joginder Singh, Additional Commissioner (Crop),
    Department of Agriculture & Cooperation (DOAC)
    Ministry of Agriculture, Krishi Bhawan,
    New Delhi

15. Dr. K.L. Khurana, Director (A.H.),
    Govt. of NCT of Delhi
    MSO Building, 11th floor, IP Estate, New Delhi

16. Dr. D.K. Thakur, Joint Director (Agri.),
    Govt. of NCT of Delhi
    MSO Building, 11th floor, IP Estate, New Delhi

17. Dr. Ram Kumar, Pr. Sci., (Dairy Extension),
    NDRI, Karnal

18. Dr. Y.R. Meena, Director,
    Farm Information, Dte. of Extn.,
    M/o Agri., IASRI Campus, Pusa, New Delhi.

19. Dr. P. Das, DDG (Extn.,), ICAR,
    KAB, Pusa, New Delhi.

20. Sh. P.C. Jacob, Jt. Dir. (Admn.),
    IARI

21. Dr. Subhash Chandra, Jt. Dir. (Extn.),
    IARI

22. Dr. B.S. Parmar., Jt. Director (Res),
    IARI

Appendix 5

Members of Staff Research Council of IARI

(As on 31.12.2005)

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 31.12.2005)

Chairman

1. Director, IARI

Members

2. Joint Director (Research)
   IARI
3. Joint Director (Extension)
   IARI
4. Dean & Joint Director (Education)
   IARI
5. Head
   Division of Agril. Extension
   IARI
6. Head
   Division of Microbiology
   IARI
7. Head
   Division of Plant Pathology
   IARI
8. Head
   Division of Floriculture and Landscaping
   IARI
9. Head
   Division of Fruits & Horti. Technology
   IARI
10. Head
    Division of Seed Science & Technology
    IARI
11. Head
    Division of Vegetable Sciences
    IARI
12. Project Director
    NRCPB
13. Dr. R.L. Mishra,
    PC, Division of Floriculture, IARI
14. Head
    IARI Regional Station-Katrain, HP
15. DDG (CS), ICAR
    Krishi Bhawan, New Delhi

Member-Secretary

16. Joint Director (Administration), IARI

Appendix 7

Members of Institute Joint Staff Council of IARI

(As on 31.12.2005)

Chairman

1. Dr. S. Nagarajan
   Director, IARI

Official Side Members

2. Dr. R.C. Gautam,
   Dean & Joint Director (Education), IARI
3. Dr. B.B. Singh, Head
   Division of Genetics, IARI
4. Dr. O.P. Singh, Head
   Division of Agricultural Engineering, IARI
5. Dr. Sanjay Kumar, Head
   IARI Regional Station, Tutikandi (Shimla)
   w.e.f. 20/12/03 to 19/6/2005
6. Dr. K.A. Nayeem, Head
   Reg. Station Wellington w.e.f. 20.6.2005 to 1.12.2006
7. Chief Finance & Accounts Officer, IARI

Secretary (Official Side)

8. Mr. P.C. Jacob, Joint Director (Administration), IARI

Staff Side (Elected) Members

1. Shri Amar Singh
2. Shri Subed Chandra Dikshit
3. Shri Jai Singh
4. Shri Radhey Krishan Thakur
5. Shri Pramod Kataria
6. Shri Ganesh Rai
7. Shri Rohtash
8. Shri Bijender Singh
9. Shri Sita Ram
10. Shri Shashi Kant Kamat
11. Shri Madan Lal

Secretary (Staff Side)

12. Shri Vijay Kumar Sharma

Appendix 8

Members of Grievance Committee of IARI

(As on 31.12.2005)

Chairman

1. Dr. A.K. Singh
   Project Director
   Water Technology Centre, IARI

Official Side

2. Dr. B.B. Singh
   Head
   Division of Genetics, IARI
3. Shri K.P.S. Gautam
   Senior Administrative Officer, IARI
4. Shri Z.H. Khilji
   Finance & Accounts Officer, IARI

Member-Secretary

5. Shri Shailesh Bhatnagar
   Assistant Administrative Officer, IARI

Staff Side

1. Dr. S.K Mishra
   Senior Scientist
   Division of Genetics, IARI
2. Dr. Y.K. Kala
   Technical Officer (T-5)
   Division of Genetics, IARI
3. Shri Virendra Kumar Aggrawal
   Private Secretary
   Division of Genetics, IARI
4. Shri Mahesh Kumar
   SSG-I, Publication Unit (English),
   IARI

Appendix 9

PERSONNEL

(As on 31.12.2005)

Director's Office

Director
Dr Singh, A.K.

Jt. Director (Research)
Dr. Parmar, B.S.

Dean & Jt. Director (Education)
Dr. Gautam, R.C.

Jt. Director (Extension)
Dr. Hansra, B.S.

Jt. Director (Administration)
Mr. P.C. Jacob

Incharge (Publication Unit)
Dr. Srivastava, K.D.

Principal Scientist (PPI Unit)
Dr. Ganguly, A.K.

Principal Scientist (BDC)
Mr. Saxena, J.P.

Chief Administrative Officer
Mr. Deshmukh, G.R.

Chief Finance and Accounts Officer
Mr. Yadav, D.P.

Editor (Hindi)/T-9
Mr. Dubey, A.K.

Editor (English)/T-9
Mr. Thomas, C.

Sr. Administrative Officers
Mr. Gajmoti, S.K.
Mr. Jain, P.K.
Mr. Malik, J.P.
Mr. Ravi Kumar

Registrar (Academic)
Mr. P.C. Jacob

IARI Library

Head (Library Services)
Mr. Pakhale, N.S.

Agricultural Chemicals

Head
Dr. (Ms.) Kulshrestha, G.

National Fellow
Dr. Gopal, Madhuban

Principal Scientists
Dr. Devakumar, C.
Dr. Dikshit, A.K.
Dr. (Ms.) Dureja, Prem
Dr. Gajbhiye, V.T.
Dr. Gupta, R.L.
Dr. Rangaswamy, S.
Dr. Saxena, D.B.
Dr. Tomar, S.S.
Dr. Walia, Suresh

Sr. Scientists/Scientists (S.G.)
Dr. (Ms.) Gupta, Suman
Dr. Jitender Kumar
Dr. (Ms.) Mukherjee, Irani
Dr. (Ms.) Singh, Neera
Dr. (Ms.) Singh, S.B.

Scientists
Dr. (Ms.) Anupama Mann
Dr. Rajesh Kumar
Mr. Shakil, N.A.

Agricultural Economics

Head
Dr. Singh, R.P.

Principal Scientists
Dr. Atteri, B.R.
Dr. Mathur, V.C.
Dr. Puran Chand
Dr. Tyagi, V.P.
Dr. Vasisth, A.K.

Sr. Scientists/Scientists (S.G.)
Ms. Bisaria, Geeta
Dr. Kar, Amit
Dr. (Ms.) Singh, Alka

Scientists
Mr. Badal, P.S.
Dr. Parmod Kumar
Mr. Ranjeet Kumar
Mr. Sekar, I.
Mr. Shiv Kumar
Dr. Singh, N.P.

Agricultural Engineering

Head
Dr. Singh, O.P.

Professor
Dr. Panwar, J.S.

Principal Scientists
Dr. Adlakha, S.K.
Dr. Dogra, A.K.
Mr. Kalra, M.S.
Mr. Saxena, J.P.

Dr. Sharma, H.S.
Dr. Shrivastava, Ranjan
Mr. Singh, Amar
Dr. Singh, J.K.
Dr. Srivastava, A.P.
Dr. Tomar, S.S.

Sr. Scientists/Scientists (S.G.)
Dr. 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.) Chattopadhyay, Aparna

Principal Scientists
Dr. Bahal, Ram
Dr. (Ms.) Bhagat, Rekha
Dr. (Ms.) Jhamtani, Anita
Dr. Vashishtha, S.B.
Dr. Vijayaraghavan, K.

Sr. Scientists/Scientists (S.G.)
Dr. Dommeti, U.M.R.
Dr. Padaria, R.N.
Dr. (Ms.) Sharma, Poonam
Dr. (Ms.) Singh, Prem Lata
Ms. Singh, Rashami
Dr. (Ms.) Wason, Monika

Agricultural Physics

Head
Dr. Kalra, Naveen

Professor
Dr. Moharir, A.V.

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.
Ms. Khali, Ananta
Dr. Sahoo, R.N.

Agronomy

Head
Dr. Ahlawat, I.P.S.

Professor
Dr. Mangal Prasad

Principal Scientists
Dr.Chillar, R. K.
Dr. Giri, Gajendra
Dr. Mishra, B.N.
Dr. Rai, R.K.
Dr. Sharma, A.R.
Dr. Sharma, S.N.
Dr. Singh, R.K.
Dr. Singh, Ranbir
Dr. Yaduraju, N.T.

Sr. Scientists/Scientists (S.G.)
Dr. Ashok Kumar
Dr. Behra, U. K.
Dr. Das, T.K.
Dr. Gangaiah, B.
Dr. Idnani, L.K.
Dr. Rana, D.S.
Dr. Rana, K.S.
Dr. Shivay, Y.S.
Mr. Shivakumar, B.G.

Scientists
Dr. Dinesh Kumar
Mr. Sharma, K.S.S.

Biochemistry

Head
Dr. Lodha, M.L.

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. Gupta, G.P.

National Fellow
Dr. Paul, A.V.N.

Principal Scientists

Dr. (Ms.) Anand, C.M.
Dr. (Ms.) Dhingra, S.
Dr. Gautam, R.D.
Dr. Gujar, G.T.
Dr. Khanna, S.C.
Dr. Prasad, S.K.
Dr. Prem Kishore
Dr. Ramamurthy, V.V.
Dr. Srivastava, K.L.
Dr. Subrahmanyam, B.
Dr. Vishwanath

Sr. Scientists/Scientists (S.G.)

Dr. (Ms.) Dey, Debjani
Dr. (Ms.) Sharma, Kirti
Dr. Sharma,R.K.
Dr. (Ms.) Srivastava, Chitra

Scientist

Dr. Paul, B.

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
Mr. Sharma, Dinesh Kumar
Mr. Shiv Prasad
Mr. Singh, Omveer
Dr. (Ms.) Singh,Renu
Dr. (Ms.) Usha Nina

Farm Operation Service Unit

Incharge

Dr. Kamble, H.G.

Floriculture and Land-scaping

Head

Dr. Singh, A.P.

Principal Scientists

Dr. Misra, R.L.

Sr. Scientists/Scientists (S.G.)

Dr. Prasad, K.V.
Dr. Sindhu, S.S.
Mr. Singh, Kanwar Pal
Dr. Singh, K.P.

Scientists

Dr. Kishan Swaroop
Mr. Kumar, P. Naveen
Dr. Raju, D.V.S.

Fruits and Horticultural Technology

Head

Dr. Singh, Room

Principal Scientist

Dr. Sharma, Y. K.

Sr. Scientists/Scientists (S.G.)

Dr. Bhagat, S.K.
Dr. Dubey, A.K.
Dr. Grover, R.P.
Dr. Singh, A.K.
Mr. Singh, Kashmir
Mr. Singh, Sanjay Kumar
Dr. (Ms.) Usha, K.

Scientists

Mr. Patel, Vishwa Bandhu
Dr. Pramanick, P.K.
Mr. Srivastava, Manish

Genetics

Head

Dr. Singh, B.B.

Professor

Dr. Singh, R.D.

National Fellows

Dr. (Ms.) Chandrashekaran, S.
Dr. Prasanna, B.M.

Principal Scientists

Dr. Chawdhary, H.B.
Dr. Faruqui, O.R.
Dr. Govil, J.N.
Dr. Jitender Kumar
Dr. Kharakwal, M.C.
Dr. Malik, B.S.
Dr. Malik, R.S.
Dr. Mishra, B.K.
Dr. Naresh Chandra
Dr. Rajendra Kumar
Dr. Rana, V.K.S.
Dr. Sapra, R.L
Dr. Sethi, A.P.
Dr. Singh, Jagmail
Dr. Singh, R.D.
Dr. Singh, S.S.
Dr. Singh, Vijay Pal
Dr. Sinha, V.C.
Dr. Soloman, Sunil
Dr. Tickoo, J.L.

Dr. Tomar, S.M.S.
Dr. Unnikrishnan, K.V.
Dr. Yadav, S.S.
Dr. Zaman, F.U.

Sr. Scientists/Scientists (S.G.)
Dr. Dikshit, H.K
Dr. Gadug, R.N.
Dr. Jain, Jaagrati
Dr. Lal, S.K.
Dr. (Ms.) Mahindroo, Anju
Dr. Omvir Singh
Dr. Prasad, R.C.
Dr. Rajendra Kumar
Dr. Sharma, R.K.
Dr. Sharma, Rajiv Kumar
Dr. Singh, A.K.
Mr. Singh, Bhanwar
Mr. Singh, Brahm
Dr. Singh, G.P.
Dr. Singh, Rishi Pal
Dr. Singh, R.V.P.
Dr. (Ms.) Sujata
Dr. Vinod Kumar
Dr. Yadav, D.K.

Scientists
Dr. Hari Prasad, A.S.
Dr. Jain, Neelu
Dr. Singh, Vijendra

Microbiology

Head
Dr. Kaushik, B.D.

Professor
Dr. Johari, K.S.

Principal Scientists
Dr. (Ms.) Dolly Wattal Dhar
Dr. Singh, C.S.
Dr. Singh, P.K.
Dr. Vinod Kumar

Sr. Scientists/Scientists (S.G.)
Dr. (Ms.) Annapurna, K.
Ms. Arora, Anju
Dr. (Ms.) Lata, Ram Nain
Dr. Pabbi, Sunil
Dr. (Ms.) Pal, Sangeeta
Dr. Saxena, A.K.
Dr. (Ms.) Singh, Geeta
Dr. Singh, Yudhvir
Dr. (Ms.) Shukla, Livleen
Dr. Verma, O.P.

Scientist
Dr. (Ms.) Prasanna, Radha

Nematology

Head
Dr. Gaur, H.S.

Professor
Dr. Saha, M.R.

Principal Scientists
Dr. Dhawan, S.C.
Dr. Ganguly, A.K.
Dr. (Ms.) Ganguly, S.
Dr. Goswami, B.K.
Dr. Jain, R.K.
Dr. Kaushal, K.K.
Dr. (Ms.) Laxmi, K.V.
Dr. Meher, H.C.
Dr. Mishra, S.D.
Dr. Prasad, D.
Dr. Singh, Rambir
Dr. Srivastave, A.N.

Sr. Scientists/Scientists (S.G.)
Dr. Chawla, Gautam
Dr. (Ms.) Kamra, Anju
Dr. Pankaj
Dr. (Ms.) Rao, Uma
Dr. Sirohi, Anil

Scientists
Dr. (Ms.) Mittal, A.
Dr. Sharad Mohan

Plant Pathology

Head
Dr. Singh, D.V.

Professor
Dr. Bahadur, P.

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, F.R.
Dr. (Ms.) Ramachandran, Padma
Dr. (Ms.) Sharma, Pratibha
Dr. Sharma, R.C.
Dr. Singh, U.D.
Dr. Srivastava, K.D.

Sr. Scientists/Scientists (S.G.)
Dr. Baranwal, V.K.
Dr. Dubey, S.C.
Dr. (Ms.) Jayaraman Jayashree
Dr. Khan, Q.Z.
Dr. Mandal, Bikash
Dr. (Ms.) Prameela Devi, T.
Dr. Sharma, R.K.
Dr. (Ms.) Shelly, Praveen
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. Sairam, R.K.

Sr. Scientists/Scientists (S.G.)
Dr. Arora, Ajay
Dr. (Ms.) Jain, Vanita
Dr. Madan Pal
Dr. (Ms.) Natu, Poonam
Dr. (Ms.) Santosh Kumari
Dr. Singh, V.P.
Dr. Vijay Paul

Scientist

Dr. Pandey Renu

Post Harvest Technology

Head
Dr. (Ms.) Sethi, Vijay

Principal Scientist
Dr. Samuel, D.V.K.

Sr. Scientists/Scientists (S.G.)
Dr. (Ms) Kaur, C.
Dr. Pal, R.K.
Dr. Ram Vidya Sagar
Dr. Ram Ashrey

Scientists
Dr.Abhijit Kar
Dr. Jha, Sunil Kumar
Dr. (Ms) Sethi Shruti

Seed Science and Technology

Head
Dr. Sharma, S.P.

Professor

Dr. Singh, J.N.

Principal Scientists
Dr. Choudhary, R.K.
Dr. (Ms.) Dadlani, M.
Dr. Gaur, Ashok
Dr. Kant, K.
Dr. Mathur, D.S.
Dr. Parihar, S.S.
Dr. Singh, Jai
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. (Ms.) Varier, Anuradha
Mr. Yadav, S.K.

Scientists

Mr. Arun Kumar, M.B.
Dr. (Ms.) Basu, Sudipta
Dr. Lal, S.K.
Dr. Pandey, Sunil
Mr. Singh, K.K.

Soil Science and Agricultural Chemistry

Head
Dr. Chhonkar, P.K.

Professor
Dr. Narayanasamy, G.

Principal Scientists
Dr. Datta, S.C.
Dr. Deopal
Dr. Nad, B.K.
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.)
Mr. 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. Chakrabarti, A.K.

Principal Scientists
Dr. Joshi, Subodh
Dr. Kalia, Pritam
Dr. Mishra, J.P.
Dr. Sharma, R.R.

Sr. Scientists/Scientists (S.G.)
Dr. Behera, T.K
Dr. Munshi, A.O.
Dr. Raj Kumar
Dr. Ravinder Kumar

Nuclear Research Laboratory

PD & Professor

Dr. Datta, P.S.

National Fellow

Dr. Sachdev, M.S.

Principal Scientists

Dr. Chopra, S.K.
Dr. Garg, A.K.
Dr. Kaim, M.R.S.
Dr. (Ms.) Nagarajan, Shanta
Dr. (Ms.) Sachdev, P.
Dr. Sud, Y.K.
Dr. Varade, P.B.

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. Bhattacharya, A.K.
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. Arjamadutha Sarangi
Dr. Babu Ram
Dr. Dubey, S.K.
Dr. Kalra, B.S.
Dr. Khanna, Manoj
Dr. Misra, A.K.
Dr. Rao, M.S.
Dr. Singh, D.K.
Dr. Singh, Man

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 Sujuth, S.
Mr. Mishra, A.K.

Indo Israel Project

Incharge

Dr. Sirohi, N.P.S.

Sr.Scientists/Scientists (S.G.)

Dr. Munsni, A.D.
Dr. Singh, Balraj

Scientists

Dr. 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. Paramanik, K.K.
Dr. Sanjay Kumar
Dr. Sharma, S.K.

IARI Regional Station, Indore

Head

Dr. Pandey, H.N.

Principal Scientist

Dr. Verma, P.K.

Sr. Scientists/Scientists (S.G.)

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