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# वार्षिक रिपोर्ट
# Annual Report
## 2009-10

भाकृ अनुप
ICAR

भारतीय कृषि अनुसंधान संस्थान
Indian Agricultural Research Institute
(भारतीय कृषि अनुसंधान परिषद)
(Indian Council of Agricultural Research)
नई दिल्ली-110 012
New Delhi-110 012

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(मानद विश्वविद्यालय)
(Deemed University)
नई दिल्ली-110 012
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***Printed : July, 2010***

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# PREFACE

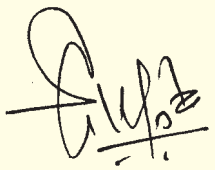
Indian Agricultural Research Institute is the premier agricultural research institution that has been serving the nation for more than a century. It was the harbinger of India's 'Green Revolution' and continues to provide leadership to the country's agricultural research. Today, Indian agriculture is at crossroads and we are facing new challenges. Therefore, the research programs of the Institute have been geared to meet them. Realizing the need to ensure national food as well as nutritional security and increasing farmers' income along with sustainable management of natural resources, the Institute focused its research on improving crop productivity as well as quality and developing technology for increasing the efficiency of inputs and the maintenance of natural resources sustainably.

The period under report has been very productive as evidenced by the development and release of eighteen varieties of field, vegetable, ornamental and horticultural crops. Furthermore, eight patents of various processes and products were granted and six technologies were licensed for commercialization. The Institute made several new initiatives in the area of research to meet the new challenges of changing climate, shrinking natural resources, emerging pests and increasing demand for high quality agricultural produce. Transfer of technology continued to get high priority by the launching of a new project in association with voluntary agencies. In order to improve the availability of new high yielding varieties developed by the Institute, we produced nearly eleven hundred tonnes of quality seeds that include more than four hundred ninety tonnes produced under farmers' participatory program. The Institute attracted 47 new projects worth Rs. 45.43 crores.

The 48$^{th}$ convocation of the Institute was held on February 13, 2010 with Her Excellency the President of India, Smt. Pratibha Devi Singh Patil as the chief guest.

The Institute's contribution to agricultural research and development was recognized by the publishers of 'Agriculture Today' by conferring the Institute with 'Agricultural Leadership Award' for the year 2009. Beginning with this year, the Institute's Annual Report will carry the information for the period from April 1 to March 31. However, this report contains the information for a period of 15 months from January 1, 2009 to March 31, 2010 to cover the period necessitated by the reporting on a financial year basis.

The report was compiled by a committee comprising Dr. R.K. Jain, Head, Division of Plant Pathology, Dr. Suresh Pal, Head, Division of Agricultural Economics, Dr. R.K. Sai Ram, Head, Division of Plant Physiology, Dr. Pritam Kalia, Head, Division of Vegetable Science, Dr. A.K. Vyas, Head, Division of Agronomy, Dr. A.K. Singh, Senior Scientist, Division of Genetics and Dr. K.M. Manjaiah, Registrar, P G School. The manuscript was edited by Mr. Chacko Thomas, Editor (English) and was produced under his supervision. I express my sincere gratitude to the members of the compilation committee and to all others, who have been associated in bringing out this report.



**(H.S. Gupta)**
*Director*

July 7, 2010
New Delhi

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# IARI : AN INTRODUCTION

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

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

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

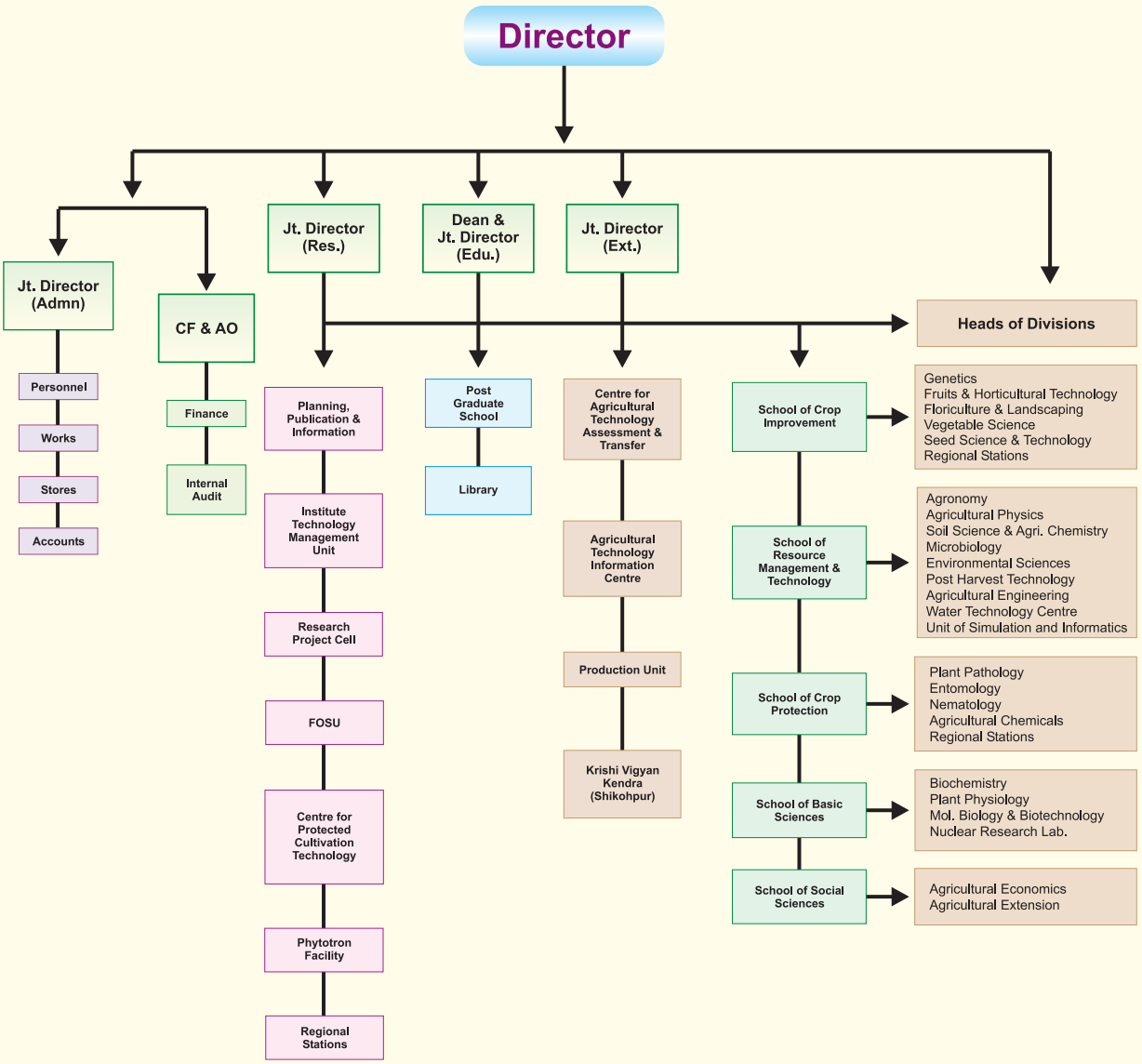
The mandates of the Institute are as follows:

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

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

The Institute has 20 divisions, 5 multi-disciplinary centres situated in Delhi, 8 regional stations, 2 off-season nurseries, one krishi vigyan kendra at Shikohpur, 3 all India coordinated research projects with headquarters at IARI, and 9 national centres functioning under the all India coordinated research projects. It has a sanctioned staff strength of 3237 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute constituted a total amount of Rs. 18867.85 lakh (Plan&Non-plan)for the year 2009-2010.

# Indian Agricultural Research Institute




## Organizational Structure

# विशिष्ट सारांश

भारतीय कृषि अनुसंधान संस्थान ने उन्नत प्रौद्योगिकियों तथा मानव संसाधन में विकास के साथ ही आधारभूत सामरिक और प्रायोगिक अनुसंधान की दिशा में अपने प्रयासों को और अधिक गति दी है। वर्ष 2009–10 में संस्थान ने अपने पिछले पाँच वर्षों से चले आ रहे अनुसंधान कार्यक्रमों को पूरा किया और उच्च प्राथमिकता वाले क्षेत्रों में नई परियोजनाओं को प्रारंभ किया। संस्थान ने विभिन्न संसाधनों, फसल और उत्पाद प्रबंधन प्रौद्योगिकियों के विकास के साथ–साथ कृषि, शाकीय, अलंकारिक और अन्य औद्यानिकी फसलों की 18 प्रजातियों का प्रजनन करते हुए प्रभावशाली योगदान दिए। संस्थान को विभिन्न प्रक्रियाओं और उत्पादों के 8 पेटेंट प्रदान किए गए और संस्थान ने वाणिज्यिकरण के लिए 6 प्रौद्योगिकियों को लाइसेंस दिया। वर्ष 2010 में कुल 144 छात्रों को डिग्रियां प्रदान की गईं। मुख्य उपलब्धियों का सारांश नीचे दिया गया है :

फसल सुधार स्कूल ने किस्मीय सुधार में महत्वपूर्ण योगदान दिए। गेहूं में, दो विभिन्न पारिस्थितिकियों अर्थात् उत्तरी और उत्तर पूर्वी मैदानी क्षेत्रों में समय से बोई जाने वाली सिंचित परिस्थितियों के लिए क्रमशः 5.04 टन/हैक्टर और 4.54 टन/हैक्टर की औसतन उपज के साथ एक उच्च उपजशील किस्म पूसा सिंधु गंगा (एचडी 2967) को जारी करने के लिए उसकी पहचान की गई। उत्तर प्रदेश, बिहार, झारखंड, पश्चिम बंगाल और असम राज्यों के लिए चावल–गेहूं सस्यन प्रणाली में देर से बोई जाने वाली परिस्थितियों के तहत वाणिज्यिक खेती के लिए एक किस्म पूसा बहार (एचडी 2985) जारी की गई। इसकी उपज 3.5–4.0 टन/हैक्टर के बीच है और बहुत देर से बोई जाने वाली परिस्थितियों के तहत 1000 दानों के भार में निम्नतम कमी होती है। महाराष्ट्र और कर्नाटक राज्यों में वाणिज्यिक खेती के लिए बारानी स्थितियों के तहत 2.0–2.2 टन/हैक्टर की औसत उपज के साथ और सीमित सिंचाई स्थितियों के तहत 3.0–3.2 टन/हैक्टर की औसत उपज के साथ एक अन्य किस्म पूसा बसंत (एचडी 2987) जारी की गई। उत्तरी पर्वतीय क्षेत्र (NHZ) की देर से बोई जाने वाली, सीमित सिंचाई परिस्थितियों के तहत खेती के लिए उत्कृष्ट बिस्कुट बनाने की क्वालिटी वाली उच्च उपजशील किस्म पूसा बेकर (एचएस 490) जारी की गई। दक्षिणी पर्वतीय क्षेत्र में खेती के लिए आवश्यकता आधारित सिंचाई के तहत 5.96 टन/हैक्टर की उच्च उपज क्षमता के साथ पूसा नवगिरी (एचडब्ल्यू 5207) जारी की गई। यह किस्म सभी तीनों रतुओं की प्रतिरोधी हैं और 101–102 दिनों में पक जाती हैं। चावल में, *बासमती* चावल की जीन रूप, पूसा 1301 विकसित की गई और अब यह परीक्षण की अग्रिम स्थिति में है। यह जीन रूप पूसा बासमती 1121 से झड़न के प्रति सहिष्णुता और दानों के गुणवत्ता लक्षणों, विशेष रूप से सुगंध और पके हुए दाने की गुणवत्ता की दृष्टि से उत्कृष्ट थी।

बाजरे में, जल्दी पकने वाली और तेजी से बढ़ने वाली मिश्रित किस्म पूसा कम्पोज़िट 612 जो कि डाउनी मिल्ड्यू रोग के प्रति प्रतिरोधी हैं, को जारी और अधिसूचित किया गया। मूंग में मोटे बीजों वाली किस्म पूसा 672, जिसके चमकदार आकर्षक बीज और पकाने की अच्छी गुणवत्ता थी, को उत्तरी पर्वतीय क्षेत्रों के लिए जारी और अधिसूचित किया गया। यह 1–1.1 टन/हैक्टर की औसत उपज देती है और 80 दिनों में पकती है। *ब्रैसिका* में बहु–सस्यन प्रणाली के लिए उपयुक्त किस्म एन पी जे 112 जिसकी कि औसत बीज उपज 1.47 टन/हैक्टर है और 107 दिनों की परिपक्वता अवधि है, को उत्तरी मैदानी क्षेत्रों सहित ज़ोन–II के लिए जारी और अधिसूचित किया गया।

सब्जियों में, बैंगन की बैंगनी–जामुनी रंग की गोल पिस्टल के सिरे वाली फलदार किस्म डी बी एल 02 की पहचान की गई और ज़ोन–I (जम्मू व कश्मीर, हिमाचल प्रदेश व उत्तराखण्ड के भाग) ज़ोन–IV (पंजाब, दिल्ली, उत्तर प्रदेश और बिहार) और ज़ोन–VI (हरियाणा, राजस्थान, गुजरात, दादर व नगर हवेली और दमन व दीप) में खेती के लिए जारी किया गया। इसमें प्रतिरोपण से पहली कटाई तक लगभग 55 दिन लगते हैं तथा इसका औसत फल भार लगभग 80–90 ग्राम तथा 38.2 टन/हैक्टर की उपज होती है। पूसा असिता, देश की पहली काली गाजर की किस्म को जारी किया गया और दिल्ली राज्य के लिए अधिसूचित किया गया। यह एक उष्णकटिबंधी गाजर है जो कि एन्थोसायनिन से समृद्ध है और इसकी 90–100 दिनों में उपज 25 टन/हैक्टर होती है। शीतोष्ण गाजर में पहली सार्वजनिक क्षेत्र की नारंगी रंग की हाइब्रिड पूसा नयनज्योति जिसमें 7.552 mg/100g β कैरोटीन होता है तथा 39.6 टन/हैक्टर की संभावित उपज है, को हिमाचल प्रदेश द्वारा जारी किया गया। मौसंबी मीठा संतरा संग्रह अर्थात् एम ओ एस 1 और एम ओ एस 3 की दिल्ली की परिस्थितियों के तहत सबसे अधिक आशाजनक के रूप में पहचान की गई। अंगूर में, हाइब्रिड 75–32 और हाइब्रिड 76–1 निरन्तर अच्छा

निष्पादन करते हुए पाए गए और तीन नए हाइब्रिड नामतः, हाइब्रिड 205–6–17, हाइब्रिड 2006–11–8 और हाइब्रिड 2006–12–1 जिनमें बैरी की क्वालिटी थी और जल्दी पकने वाले थे, का चयन किया गया। सेब में एक अर्ध प्रबल प्रकंद पूसा सेब मूलवृंत–1 की पहचान की गई। *प्रूनस जेपोनिका* को जब प्रकंद के रूप में इस्तेमाल किया गया तो इसने खुमानी, आड़ू, आलूबुखारे और चैरी को बौनापन प्रदान किया। अखरोट में, पूसा खोर की उत्कृष्ट क्लोन के रूप में पहचान की गई जिसमें विशिष्ट अकालपक्वता और पश्च फलन था।

अलंकारिक फसलों में, गुलदान में सजावट के लिए, बुके तैयार करने के लिए और पुष्पीय सजावट के लिए सबसे अधिक उपयुक्त बहुत अच्छी स्पाइकों वाले दो आशाजनक ग्लेडिओलस हाइब्रिड जैसे कि पूसा किरण (लम्बी और मजबूत स्पाइकों पर सफेद रंग के पुष्पक) और पूसा शुभम (क्रीम/हल्के पीले रंग के पुष्पक) जारी किए जाने के लिए पहचाने गए। भा.कृ.अ.सं. की किस्म पहचान समिति ने 15–20 टन/हैक्टर की उपज क्षमता वाली फ्रेंच मैरीगोल्ड किस्म पूसा अर्पिता को जारी करने के लिए पहचान की। पीले गुलाबी फूलों वाली क्राइसेन्थिमम की तापीय और प्रकाश असंवेदी पुष्पित झाड़ीदार किस्म पूसा अनमोल जो कि प्रतिरोपण के बाद 100 दिनों में एक वर्ष में तीन बार भरपूर फूलों का उत्पादन करती है, को जारी करने के लिए उसकी पहचान की गई। क्राइसेन्थिमम की अन्य किस्म पूसा सेनटेनरी, जो कि 100–110 दिनों में फलती है और जिसकी प्रबल बढ़वार तथा बहुत बड़े पीले फूल होते हैं, को जारी करने के लिए इसकी पहचान की गई।

बीज विज्ञान अनुसंधान में, सोयाबीन, प्याज और मक्का में उन्नत खेत की स्थिति, एकरूपता और पौद की अगेती बढ़वार के लिए विभिन्न बीज उपचारों को मानकीकृत किया गया। संस्थान द्वारा 1092 टन क्वालिटी बीजों को उपलब्ध कराया गया जिसमें से 565 टन प्रजनक बीज थे और कृषक प्रतिभागिता कार्यक्रम के तहत 496 टन सहित नई किस्मों के सच्चे रूप से लेबल किए गए 527 टन बीज थे।

फसल आनुवांशिक संसाधन अनुसंधान द्वारा उपयोगी विशेषताओं वाली विभिन्न फसलों की अनेक प्रविष्टियों की पहचान की गई। भा.कृ.अ.प. द्वारा पर्ण रतुए के सभी रोग रूपों के विरूद्ध प्रतिरोध के लिए, गेहूं में एच एस 492 (INGR No. 09005) को आनुवंशिक स्टॉक के रूप में पंजीकृत किया गया। इसके अतिरिक्त विभिन्न प्राचलों जैसे दोजियों/वर्ग मीटर की संख्या (डब्ल्यू आर 1702) 1000 दानों का भार (डब्ल्यू आर 1617, आर डी 1151, आर डी 1152, आर डी 1271) दाने/स्पाइक (आर डी 1151, आर डी 1162) अल्पावधि और ताप सहिष्णुता (डब्ल्यू आर 1695, डब्ल्यू आर 1743) प्रोटीन अंश और दानों का भार (आर डी 1336) के लिए अनेक आनुवांशिक स्टॉकों की पहचान की गई। मक्का में, किस्मों पूसा अर्ली हाइब्रिड मक्का–3, पूसा एक्स्ट्रा अर्ली हाइब्रिड मक्का–5, पूसा कम्पोज़िट–3 और पूसा कम्पोज़िट–4 को पी पी वी एण्ड एफ आर ए के पास विद्यमान किस्मों के रूप में पंजीकृत किया गया।

सूक्ष्मजीवी आनुवांशिक संसाधनों के संबंध में, ऐस्कोमाइसीट, बसिड्योमाइसिटिज़ और ड्यूटेरोमाइसिटिज़ के 615 कवकीय नमूनों को एच सी आई ओ में प्रविष्ट किया गया जिससे कि कुल नमूनों की संख्या 48,837 तक बढ़ गई। जोड़ी गई महत्वपूर्ण नई प्रजातियां थीं *ऐस्टेरीडेला क्रोटोनिस–कॉडेती, ऐस्टेराइना गाम्सी, ए. प्राताप्राजी, बारटालिना केरीनिसिस, बी. पिसिडी, इरनॉप्सिस पेवोनिये, आई. ज़ेरोमफिडसिस, मेलियोला महामुलकरी, एम. मानोहाराचराइ, एम. रचामी, फिलाकोरा जिमेनीमी, सिफफिनेरूला काथारनथी, एस. फ्लाकोर्टीय, एस. गिरीजए, और उरोमासिस टर्मीनालिया*।

जैव वर्गिकी और पहचान सेवाओं के तहत वर्ष 2009–10 के दौरान एच सी आई ओ में 615 रोगग्रस्त कवकीय नमूनों की प्रविष्टि की गई जिससे कि नमूनों की कुल संख्या 48,837 तक बढ़ गई। इसके अतिरिक्त 270 कवकीय कल्चरों की पहचान की गई जिससे आई टी सी सी को 42 विभिन्न कल्चरों से समृद्ध किया गया। सूत्रकृमि विज्ञान जैव वर्गिकी सेवाओं के तहत, 29 प्रकार के नमूने (12 नई प्रजातियों और 3 किस्म जातियों का प्रतिनिधित्व करने वाली 31 प्रकार की स्लाइडें) और सूत्रकृमियों के 90 वैट सस्पेंशनों को राष्ट्रीय संग्रह में जोड़ा गया, जिससे कुल संख्या 2253 प्रकार की प्रविष्टियों और 3302 वैट प्रविष्टियों तक बढ़ गई।

फसल एवं संसाधन प्रबंधन अनुसंधान से उत्पादन प्रणाली के टिकाऊपन के बारे में और अधिक जानने का अवसर प्रदान हुआ है। पलवार (गेहूं पुआल 5 टन/हैक्टर अथवा *सेसबेनिया* पलवार) एवं आयरन फर्टिलाइजेशन (अधिकतम दोजियां निकलने और फूल आने से पूर्व की स्थिति में 50 कि.ग्रा. आयरन सल्फेट/हैक्टर + आयरन सल्फेट के दो पर्णीय छिड़काव) का प्रभाव वायुजीवी चावल की उत्पादकता बढ़ाने में दिखाई पड़ा है। चावल सघनता प्रणाली (SRI) के तहत *एजोस्प्रिलियम* एवं *बैसिलस* जैसे पादप बढ़वार को बढ़ाने वाले राइजोबैक्टीरिया के साथ गीली धान का संरोपण चावल की अधिक पैदावार हासिल करने में मददगार था। प्याज में 0.75 कि.ग्रा/हैक्टर की दर से पेंडीमिथालिन और तदुपरांत प्रतिरोपण के 30 दिन पश्चात् 0.75 कि.ग्रा./हैक्टर की दर से पेंडीमिथालिन के अनुक्रमिक अनुप्रयोग से प्रभावी खरपतवार नियंत्रण हुआ।

*CROPWAT* मॉडल का इस्तेमाल करते हुए प्रमुख फसलों (चावल, गेहूं व मक्का) का फसल वाष्पन–वाष्पोत्सर्जन ($Et_c$) किया गया तथा उसकी तुलना सामान्य मान से आंकलित $Et_c$ के साथ की गई। फसल वाष्पन–वाष्पोत्सर्जन के पूर्वानुमान हेतु विभिन्न नेटवर्क आर्किटेक्चर,

स्थानांतरण और लर्निंग कार्यों के साथ 20 कृत्रिम न्यूरल नेटवर्क (ANN) मॉडलों का एम ए टी, एल ए बी (मेटलेब) के साथ लाइजिमेट्रिक आंकड़ों और मौसम विज्ञान सूचना का उपयोग करते हुए दिल्ली में उगाई गई गेहूं फसल के लिए विकास, प्रमाणन और परीक्षण किया गया। मेवात (हरियाणा) में किए गए एक अध्ययन में जल बचत प्रौद्योगिकियों के लिए जल के समायोजन के बाद जल की उपलब्धता, कटाई क्षमता और उपयोगिता तथा उसका उत्पादन एवं किसानों की आय पर प्रभाव का मूल्यांकन किया गया।

सूक्ष्म जीवविज्ञान के तहत, 9 नवीन जीन और मॉल्यूक्यूल के लिए अति गर्म अथवा ठंडे वातावरण में रोगाणुओं का पूर्वेक्षण, खनिज फॉस्फेट घुलनशीलता के लिए जिम्मेदार जीनों की पहचान तथा कवक, जीवाणु और साइनो–बैक्टीरियल मैट्रिक्स का उपयोग करते हुए संरोप्य स्ट्रेन की बॉयोफिल्म के विकास पर मुख्य ध्यान दिया गया। सूक्ष्मजीवी निवेशों के माध्यम से चावल आधारित फसलचक्र प्रणाली (गेहूं एवं सब्जियों सहित) में जैविक खेती टिकाऊ फसल बढ़वार के लिए ''प्रभावी सूक्ष्म जीवों'' के विकास; मूल्य संवर्धित उत्पादों विशेषकर रंजकों के लिए साइमो–बैक्टीरिया की उपयोगिता; *एज़ोला* सत की जैव रसायन प्रोफाइलिंग तथा उनका पादप बढ़वार पर प्रभाव, जैविक अवशिष्ट का पुनः चक्रण तथा सूक्ष्मजीवी कंसोर्रिया विकास तथा प्लास्टिक के जैव अपघटन के लिए प्रकाश अनुवर्ती बॉयोफिल्में उच्च प्राथमिकता वाले अन्य अनुसंधान क्षेत्र थे।

मृदा प्रबंधन अध्ययन के तहत पाए गए निष्कर्षों में शामिल थे : ताप प्रतिबल के विरूद्ध जैव विविधता को बढ़ाने और मृदा जैविक कार्यों की प्रतिरोधिता और लचीलेपन के लिए NPK + गोबर की खाद का अनुप्रयोग सर्वाधिक प्रभावी था। मक्का की तुलना में गेहूं में SOC विखंडन में कहीं अधिक सुधार हुआ। फसल उत्पादन के साथ–साथ मृदा जैविक कार्बन बनाए रखने के लिए खाद के अनुप्रयोग द्वारा 50 प्रतिशत तक RDF को प्रतिस्थापित किया जा सका जिससे 50 प्रतिशत तक रसायनिक उर्वरकों की बचत हुई। पोषक पदार्थ तत्वों के 100 प्रतिशत जैविक स्रोत को पाने वाले खेतों में कार्बन प्रबंधन सूचकांक (CMI) में अधिकतम सुधार देखने को मिला। गेहूं पैदावार में नियंत्रित उपचार की तुलना में सीवेज गाद (SS) के अनुप्रयोग से कहीं अधिक वृद्धि हुई। 1:9 + 50 प्रतिशत NPK में SS + RS में अधिकतम पैदावार प्राप्त की गई जो कि आंकड़ों की दृष्टि से NPK की सुझाई गई खुराक के बराबर थी। गेहूं फसल में चावल भूसी तथा 50 प्रतिशत NPK के साथ सीवेज गाद का अनुप्रयोग किए जाने के कारण गेहूं के बाद एकत्रित मृदा नमूनों में उल्लेखनीय सुधार दर्ज किया गया जिसके फलस्वरूप NPK की 50 प्रतिशत तक बचत हुई।

AICRP - LTFE के तहत वर्ष 1971–72 से भा.कृ.अ.सं. खेत पर किए गए दीर्घावधि परीक्षण में अन्य सभी उपचारों के अन्तर्गत हासिल पैदावार की तुलना में NPK की सुझाई गई मात्रा अथवा सुपर ऑप्टीमल NPK (सुझाई गई NPK का 150 प्रतिशत) के साथ 15 टन प्रति हैक्टर की दर से गोबर की खाद के अनुप्रयोग से मक्का एवं गेहूं में अधिकतम दाना पैदावार दर्ज की गई। कम लागत वाले प्रोग्रामेबल कैलोरीमीटर (LCPC) का निर्माण किया गया जिसका उपयोग मृदा परीक्षण डेटा एवं लक्षित पैदावार से चयनित फसलों (वर्तमान में गेहूं व मक्का के लिए) में सुझाए गए उर्वरक को प्रदर्शित करने में किया जा सकेगा।

संरक्षित कृषि प्रणाली के लिए बेहद सर्दी वाले महीनों के दौरान ऑफ–सीजन समर स्क्वाश खेती के लिए प्रवणता सुरंग उपयुक्त एवं किफायती रूप से व्यावहारिक पाई गई। 60 प्रतिशत छाया सघनता का काला छायादार नेटहाउस अति गर्मी महीनों के दौरान हरे धनिए की खेती के लिए उपयुक्त एवं किफायती पाया गया। यह लैट्यूस फसल को सामान्य मौसम से 40–45 दिन पहले बढ़ाने में भी उपयुक्त था। वर्षा काल और वर्षा उपरांत मौसम के दौरान कीट–रोधी नेटहाउस कद्दू के वायरस मुक्त फसल उत्पादन के लिए सर्वाधिक उपयुक्त पाया गया। टमाटर फसल के लिए वर्ष में लगभग 9 माह के लिए शून्य ऊर्जा वाला प्राकृतिक रूप से हवादार ग्रीन हाउस उपयुक्त पाया गया। लंबे दिनों की परिस्थिति के अन्तर्गत 100 $\mu$ mol/$m^2$/Sec की दर से लाल (80 प्रतिशत) एवं नीला (20 प्रतिशत) LEDs के मिश्रण के साथ प्रकाश सक्रिय विकिरण (PAR) द्वारा क्राइसेन्थियम (गुलदाउदी) (किस्म जेम्बला) में कृत्रिम पुष्पीकरण लाया गया।

चावल किस्म पूसा 44 पर तापमान प्रवणता सुरंग (TGTC) में पर्यावरणीय परीक्षणों से निम्न, मध्यम एवं उच्च उर्वरता स्तरों के तहत उन्नयित तापमान (+0.8 ls 3.5$^{o}$C) पर उगाई जाने वाली चावल पैदावार में कमी पाई गई। शाकीय, पुनर्जनन तथा समग्र बढ़वार चरणों के दौरान उन्नयित तापमान पर उगाई जाने वाली मूंगफली में पुनर्जनन बढ़वार चरण के दौरान कहीं अधिक तापीय संवेदनशीलता दिखाई दी। राजस्थान के लिए उद्भासन, संवेदनशीलता एवं अनुकूलन कार्यप्रणाली क्षमता वाले संवेदनशीलता सूचकांक का विकास किया गया तथा बड़े स्तर पर जलवायु भिन्नता का सामना कर रहे जिले नामतः राजसमंद, डूंगरपुर, धौलपुर, दौसा एवं करौली कहीं अधिक संवेदनशील पाए गए। मीथेन के वार्षिक उत्सर्जन स्तर को वर्ष 1994 के स्तर से अद्यतन किया गया जो कि 3.49 Tg आंका गया तथा वर्ष 2000 के लिए प्रबंधित मृदा से नाइट्रस ऑक्साइड का सीधा उत्सर्जन 132.3Gg आंका गया। भारत के विभिन्न कृषि जलवायवी क्षेत्रों में किए गए 26 दीर्घावधि परीक्षणों (LTEs) से प्राप्त आंकड़ों के विश्लेषण द्वारा भारतीय कृषि मे क्षमताशील एवं कार्बन अनुक्रमिक लागत के आंकलन किए गए। स्वच्छ

जैव–ऊर्जा के विकास के लिए अम्ल पूर्व उपचार के बाद प्रकिण्विक सेकेरीफिकेशन सर्वाधिक प्रभावी पाया गया। वायु प्रदूषण निगरानी कार्यक्रम के तहत विभिन्न $CO_2$ स्तरों के अन्तर्गत कृषि फसलों पर क्षोभमण्डल ओजोन के उन्नयित स्तरों के प्रभाव का मूल्यांकन भी किया गया।

संस्थान द्वारा अधिकतम फसल उत्पादन के लिए खेत से जुड़े अनेक उपकरण एवं प्रौद्योगिकियों का विकास किया गया। वर्ष के दौरान, एक लहसुन प्लांटर, एक प्याज बीज निष्कर्षक यंत्र तथा एक मोटर चालित सब्जी बीज निष्कर्षक यंत्र विकसित किए गए और उनका मूल्यांकन किया गया। प्याज को सुखाने के लिए एक सौर कैबिनेट ड्रायर (प्राकृतिक संवहन) का उपयोग किया गया। संस्थान के क्षेत्रीय केन्द्र करनाल में अरहर को छीलने तथा गहाई की प्रणाली विकसित की गई।

कटाई उपरांत प्रौद्योगिकी एवं प्रबंधन के तहत *स्टीविआ* के साथ बेल फल गूदे से विभिन्न मीठे स्तर वाले रेडी टू सर्व (RTS) पेय पदार्थों का विकास किया गया। स्ट्राबेरी खेती में फूल निकलने की स्थिति में 100 ml/l की दर से पॉलीएमाइन प्यूट्रेसीन के पर्णीय अनुप्रयोग द्वारा विरूपित पौधों में 18 प्रतिशत तक कमी लाई जा सकी। बेर (*जिजीफस मॉरीटेनिया* लम्क) जननद्रव्य के प्रकाश–रसायनिक विश्लेषण से पता चला कि ZG 3, सोनार 5, गोला, रश्मि, इलायची तथा कैथली किस्में प्रकाश–रसायनिक संयोजन तथा प्रति–ऑक्सीकारक सक्रियता में क्षमताशील उच्च जीनप्ररूप हैं। प्रसंस्करित बेर गूदे में ताजा फलों की अपेक्षा कहीं अधिक प्रति–ऑक्सीकारक (AOX) क्षमता थी। 1 प्रतिशत की दर से कैल्शियम क्लोराइड के छिड़काव से सेब में कडुआ, गड़ढ़ा रोग, सड़न और भार कमी में उल्लेखनीय कमी देखी गई तथा शीत भण्डारण में 6 माह की समाप्ति पर भी फलों में बड़ी मात्रा में चिकनाहट बनी रही। ब्लांच किए गए तथा असंतुलित टमाटर कतरन से टमाटर पाउडर बनाने की प्रक्रिया का विकास किया गया। इसको दोबारा बेहतर तरीके से बनाया जा सकेगा और इसका उपयोग अच्छे इन्द्रियग्राही गुणों के साथ टमाटर सूप, चटनी तथा पेस्ट बनाने में किया जा सकेगा। कटाई के पश्चात् दो घण्टे के भीतर पैकेज हिमन से शक्कर नुकसान की जांच की गई तथा कटे हुए स्वीट कॉर्न की बाजार गुणवत्ता को बनाए रखा गया। गौण संघटकों के रूप में चने के साथ बाजरा, मक्का, जौ तथा सोरघम से खाने के लिए तैयार बहिर्बेधित उत्पाद विकसित किए गए तथा उनके गुणवत्ता लक्षणों का प्रलेखन किया गया।

यादृच्छिक और विशिष्ट प्राइमरों का प्रयोग करते हुए *ऐस्पर्जिलस* (20), *फ़्यूज़ेरियम* (6), *राइज़ोकोटानिया बटाटीकोला* (6) और *सैन्थोमोनास कम्पेस्ट्रिस पीवी. प्यूनिका* (10) पृथकों की आण्विक टाइपिंग की गई। चने के मुरझान रोग के लिए उत्तरदायी *फ़्यूज़ेरियम ऑक्सीपोरम* एफ. प्रजाति सिसेरिस (FOC, Race 4) और गेहूं के स्पॉट ब्लॉच के लिए उत्तरदायी *बीपोलारिस सोरोकिनाना* के लिए आण्विक निदान सूचक विकसित किए गए। 1936 में बड़ी इलायची के फुरूकी रोग का पता लगाने के बाद इसके हेतु विज्ञान का वर्णन किया गया और इसके वायरस की पहचान लार्ज कार्डामॉम बुशी डवार्फ वायरस (एल सी बी डी वी) के रूप में की गई। पर्णाभता रोग के लिए *तोरिया* (*ब्रैसिका रापा.* सीवी. *तोरिया*) के साथ फाइटोप्लाज़्मा के 16 Sr IX ग्रुप के सदस्य के संबंध का पता लगाया गया।

गीले मूल विगलन के प्रबंधन के लिए थाइमोथॉक्सम 70 प्रतिशत डब्ल्यू एस (क्रूसर) और पूसा 5एस डी 4 ग्रा./कि.ग्रा की दर से बीज उपचार और बुवाई के 21 और 35 दिनों के बाद थाइमोथॉक्सम 25 प्रतिशत डब्ल्यू जी (एक्टारा 0.02 प्रतिशत) और कार्बनडेज़ियम (0.05 प्रतिशत) के मिश्रण के दो पर्णीय छिड़कावों की एकीकृत रोग प्रबंधन रणनीति को विकसित किया गया। खेत की परिस्थितियों के तहत आलू की पछेती अंगमारी (एल बी) और मूंग के *सेरकोस्पोरा* पर्ण चित्ती और पीत मोज़ेक के विरूद्ध *कीटोमियम* आधारित जैव–संरूपणों (Cg2 WP vkSj Cg2 SL) को वैधीकृत किया गया और रोग में 62 प्रतिशत तक कमी पाई गई। किसानों के खेतों में मूंगफली के काले मूल विगलन के विरूद्ध *ट्राइकोडर्मा* आधारित जैव संरूपण प्रभावी पाए गए और इनसे 65 प्रतिशत तक रोग में कमी हुई।

चावल, सोयाबीन, सरसों और सब्जियों पर कीट नाशीजीव प्रबंधन अध्ययन किए गए। स्पैक्ट्रोडायोमीटर का प्रयोग करते हुए सुदूर संवेदन के साथ चावल पर पर्ण फोल्डर *नाइफॉलोक्रोसिस मेडानॉलिस* क्षति के लिए स्पैक्ट्रमी चिन्हकों की स्थापना की गई। अन्य अध्ययनों में जैविक नियंत्रण, कीट शरीरक्रिया विज्ञान, और कीट आविषालुताविज्ञान शामिल थे। स्पैडोपेट्रा लिटूरा नवजात के विरूद्ध विभिन्न cry आविषों और *हैलीकोवर्पा आर्मीगेरा* के विरूद्ध पाइरीथ्रॉइडस (डेल्टामेथ्रिन, α–साइपरमेथ्रिन तथा β–सिसफ्लूथ्रिन) की आविशालुता का मूल्यांकन करने के लिए प्रयास किए गए। *हैलीकोवर्पा आर्मीगेरा* में *Cry*1 *Ac* पर वंशागति अध्ययनों से मुख्य प्रतिरोधी जीन या मजबूती से संबंधित स्थानिक जीनों के संबंध का पता चला। *बैक्ट्रोसेरा कुकरबिट* के बहुतायत में पालन के लिए उन्नत अर्ध संश्लिष्ट भोजन (मेरीडिक) विकसित किया गया। गेहूं और मूंग पर भण्डारण कीटों जैसे *ट्राइबोलियम केस्टानियम, सिटोफिलस ओरेज़े, राइज़ोपर्था डोमीनिका* तथा *कालोसोब्रचस मैक्यूलेटस* के विरूद्ध फलाई ऐश और डायटमी मृत्तिका की विषालुता खुराक आधारित पाई गई।

बैंगन (*पूसा उत्तम*) फलों के पुष्पन के समय 10,000 संक्रमित किशोर पौधों पर नेमाजेल संरूपण *स्टेनेरनेमा थर्मोफिलियम* और एस. *ग्लासेरी* के पर्णीय छिड़काव के परिणामस्वरूप बैंगन की संख्या और भार में महत्वपूर्ण रूप से वृद्धि हुई। मूंगफली को संक्रमित करने वाले

दो *स्टेनेरनेमा* प्रजातियों के द्रव्य संरूपण सफेद भृंगकों (*होलोट्रिचिया कोसानगुनिया*) के विरूद्ध प्रभावकारी पाए गए। समबंधन कारक (एस एफ) और इंटीग्रेस जीन के लिए RNAi निर्माणों के साथ रूपांतरित टमाटर में *मिलॉयडोजीन इनकॉगनिटा* के कुछ कमजोर मादा सूत्रकृमि वाले बहुत ही कम और छोटे गॉल थे। वाणिज्यिक निरूपण (कार्बोफ्यरेन 3G) 1–1.5 कि.ग्रा. ए.आई/हैक्टर की दर से अभिशंसित खुराकों की तुलना में जब मृदा ड्रेंच के रूप में कार्बोफ्यूरेन के नैनों–संरूपण को 5 पीपीएम की दर से डाला गया तो टमाटर की बेहतर प्ररोह वृद्धि तथा गॉलों की संख्या में पर्याप्त कमी पाई गई।

अपने प्राकृतिक रूप में उपलब्ध फेलकोन के ऑक्साइम व्युत्पन्नों के मूल्यांकन में आइसोवेलरेट ईस्टर को कीटों के लिए सबसे अधिक सक्रिय प्रति आहारी (एन्टीफीडेंट) और नोनानोएट ईस्टर को सबसे अधिक सक्रिय कीटनाशी के रूप में पहचाना गया। *आल्टर्नारिया पोरी* के विरूद्ध हैक्साकोनाज़ोल में पाई गई प्रतिकवकीय गतिविधि जो कि *एस. लिटूरा* के विरूद्ध मध्यम रूप से कीटनाशी है, की तुलना में, नालीडिक्सिक एसिड हाइड्राजाइड के हाइड्राज़ोनों में अधिकतम प्रति कवकीय गतिविधि पाई गई। लोबिया में कांच घर परीक्षण के तहत 10 शिफ् क्षारकों में से 4–बेंजीलीडेमिनों–3–मरकेप्टो–5–फिनाइल–4 एच–1,2,4– ट्राइज़ोज़ोल ने मिलॉयडोजीन *इनकॉगनिटा* के विरूद्ध उच्चतम सक्रियता का प्रदर्शन किया। *कैण्डिडा अंटार्कटिका* लिपेज़ के उपयोग द्वारा जैव–उत्प्रेरित रूप से उत्पन्न एन–प्रोपायल–व्यूटरामिड,–पेन्टेनामिड एवं हेक्सेनमिड में *मेल्बॉयडोगाइन इन्कागनिटा* सूत्रकृमि के विरूद्ध उल्लेखनीय सक्रियता पाई गई। सरसों तथा गेंदा पौधों के साथ किए गए पादप उपचार से पता चला कि सरसों पौधों से 15–18 प्रतिशत इमीडाक्लोप्रिड, 7–8 प्रतिशत क्लोरपायरीफॉस एवं डीडीटी तथा 6 प्रतिशत बाइफेन्थ्रिन हट सका जबकि गेंदा पौधे द्वारा 4–5 प्रतिशत तक की सीमा तक ही नाशकजीवनाशियों, DDT एवं बाइफेन्थ्रिन को हटाया जा सका। व्यावसायिक रूप से उपलब्ध विभिन्न हाइड्रोजेल का परीक्षण मोनोमर एक्राइलेमिड सांद्रता के लिए किया गया। पूसा हाइड्रोजेल में गैर–डिटेक्टेवल ($0.02\ mg\ g^{-1}$) एक्राइलेमिड था।

जैविक और अजैविक प्रतिबल सहिष्णुता के लिए पराजीनियों को विकसित करने के लिए पादप जैव प्रौद्योगिकीय अध्ययन किए गए। *Cry1 Jb* (1.35 kb) के डोमेन I और II और *Cry1A* के डोमेन III वाले काल्पनिक δ–एन्डोटॉक्सिन जीन की *हैलिकोवर्पा आर्मीगेरा* के प्रति बढ़ी हुई विषालुता के साथ बैक्टीरिया में अभिव्यंजना की गई। एक अन्य अध्ययन में, उच्च स्तर की अभिव्यंजना के लिए अन्तर्द्रव्यी जालिका के लिए *Cry* प्रोटीन को लक्षित किया गया। तंबाकू में मटर से *लेक्टिन* जीन की अति–अभिव्यंजना द्वारा कीटों के प्रति सहिष्णुता की शुरूआत की गई। मेटोलॉथियॉनिन प्रोटीन जिसे कि कवक की बढ़वार को प्रतिकूल रूप से प्रभावित करने के लिए जाना जाता है, उसके लिए जीन कोडिंग को क्लोनीकृत किया गया और उसे पादप स्थानांतरण वैक्टर में गतिशील किया गया।

पौधों में आधार प्रतिरक्षा में शामिल पूरी लंबाई के cDNA of *XAP-5* जीन को *बी.* जुन्सिया से क्लोनीकृत किया गया। इन जीनों का प्रयोग कवकीय रोगों जैसे कि *आल्टीर्नेरिया* अंगमारी और सफेद रतुए के विरूद्ध उनकी दक्षता का परीक्षण करने के लिए सरसों का रूपांतरण करने के लिए किया जाएगा। एक अन्य रोगजनक प्रतिरक्षात्मक जीन *NPRI* का वहन करने वाले पराजीनी सरसों के पौधों का जनन किया गया और उनकी पराजीनी स्थिति का सत्यापन किया गया। छह *अनैक्सिन* जीनों की अभिव्यंजना पद्धतियों की सूखा सहिष्णु चावल की किस्म नगीना–22 में RT-PCR के माध्यम से जांच की गई। *अनैक्सिन* जीन AnnOs11 और AnnOs14 के दो पूरी लंबाई के c-DNA क्लोनों को नगीना–22 से पृथक किया गया। फॉस्फोरस गतिशीलता के लिए उत्तरदायी *फाइटेस* जीन को पृथक किया गया और सोयाबीन में इसकी अति–अभिव्यंजना के लक्ष्य से इसके गुणधर्म लक्षणों का निर्धारण किया गया। छोटे उष्मा प्रघात प्रोटीन (HSP) के लिए एक अन्य जीन का क्लोन किया गया और उसका गेहूं में गुणधर्म लक्षण निर्धारण किया गया। β–कैरोटीन संश्लेषण में शामिल फाइटोन सिन्थेस (PSY) के लिए जीन कोडिंग को पृथक किया गया और केले की प्रजाति नेनड्रैन से इसका गुणधर्म लक्षण निर्धारण किया गया। *खीरे का मोज़ेक वायरस* (RNAI) (दिल्ली पृथक्कृत GU111227, 3358 nt.) *पपीते की वलय–चित्ती* (रोगजनक प्रकार W, EU475877, 10335 nt) और *सिट्रस ट्रिसटेज़ा वायरस* (Kpg3, 19253 nt) के सम्पूर्ण जीनोमों का अनुक्रमण किया गया। टमाटर के पर्ण–कुंचन के विरूद्ध प्रतिरोध प्रदान करने के लिए कृत्रिम सूक्ष्म RNA(miRNA) निर्माणों को डिज़ाइन किया गया।

शरीरक्रियाविज्ञानी अन्वेषणों से पता चला कि *ब्रैसिका जुन्सिया* जीन रूप CS 52 और CS 54 में लवणता सहिष्णुता लवण के प्रति अत्यधिक संवेदनशील (एस.ओ.एस.) जीन सोपानों से जुड़ी हुई थी। कटे हुए ग्लेडिओलस फूलों की नाइट्रिक ऑक्साइड प्रेरित निधानी आयु में वृद्धि, सिस्टेन प्रोटीज़ (*GgCyPl*) की अभिव्यंजना में कमी और *DADI* जीनों की अभिव्यंजना में वृद्धि से जुड़ी हुई पाई गई। *स्टेनिरनेमा* के rDNA के ITS क्षेत्र का अनुक्रमण किया गया, जिसने कि *एस. सियामकायी* के साथ 99 प्रतिशत समानता दिखाई। कीटरोगजनक सूत्रकृमियों के राइबोसोमीय DNA के ITS क्षेत्र के छह नए जीनों का अनुक्रमण किया गया और उन्हें प्रविष्टि संख्या क्रमशः GQ353373 और GU354216-354219 से जीन बैंक में पंजीकृत किया गया।

जीन रूप WR 95 में तने के रतुआ प्रतिरोध का आनुवांशिक विश्लेषण करने से रतुआ प्रतिरोध के लिए एकल अप्रभावी जीन का पता

चला। इस जीन प्रारूप की तना रतुआ प्रतिरोधी जीनों *Sr22*, *Sr24*, *Sr25*, *Sr26*, *Sr31*, *Sr36* तथा *Sr38* के आण्विक मार्करों के साथ स्क्रीनिंग की गई। इनमें से किसी भी जीन का WR 95 में पता नहीं लग पाया। गेहूं में आनुवंशिक अध्ययनों से अनेक ब्रैड गेहूं की किस्मों जिसमें कि प्रमुख किस्में जैसे कि पी बी डब्ल्यू 343, सी 273, राज 3765, यू पी 2338, नर्मदा 4, डी बी डब्ल्यू 16 और निगमयी आदि शामिल हैं, में हाइब्रिड बौनापन की जीन की उपस्थिति का पता चला। मार्कर सहायता प्राप्त प्रतीपसंकर प्रजनन के माध्यम से, दो जीवाण्विक अंगमारी प्रतिरोधी जीनों *xa13* और *xa21* को पूसा–6बी और पीआरआर–78, चावल हाइब्रिड पूसा–आरएच–10 के पैतृक वंशक्रमों में स्थानांतरित किया गया। चने में, 100 बीज भार और प्रति पौधा फलियों की संख्या के लिए कल्पित QTLs की पहचान की गई जिससे कि उच्च उपजशील किस्मों का चयन किया जा सके। विभिन्न प्रजातियों में सफेद रतुआ प्रतिरोध जीनों के लिए परिवर्तनीयता तथा युग्म विकल्पी संबंध का *ब्रैसिका* में प्रलेखन किया गया।

खाद्य सुरक्षा तथा कृषि विविधीकरण पर किए गए अनुसंधान से 4 प्रतिशत वार्षिक की लक्षित वृद्धि दर को हासिल करने के लिए कृषि में उच्च सार्वजनिक निवेश की आवश्यकता का पता चला। सिंचाई, किसानों को खेत उपकरणों एवं सेवाओं की बेहतर आपूर्ति तथा तकनीकी सहायता जैसे क्षेत्रों में सार्वजनिक निवेश की प्रभावशीलता हेतु किए गए संस्थागत सुधारों से पैदावार अंतराल को पाटना अन्य प्राथमिकता वाले क्षेत्र थे जिनमें तुरंत ध्यान दिए जाने की आवश्यकता है। शुष्क भूमि क्षेत्रों के लिए उत्पादकता संवर्धन प्रयास जल संरक्षण और दक्ष प्रयोग कार्यनीति के इर्द–गिर्द होने चाहिए। कृषि व्यापार पर किए गए अध्ययन से *बासमती* चावल और पुष्पीय उत्पादों के निर्यात में उल्लेखनीय वृद्धि का पता चला। हालांकि कृषि निर्यात में समग्र वृद्धि मध्यम और अस्थिर थी। परिनगरीय खेती पर किए गए अध्ययन से पता चला कि सब्जियों जैसी उच्च मूल्य वाली फसलों के कारण खेत लाभ प्रदता में सुधार हुआ जिसका योगदान खेत से होने वाली कुल आय का तीन चौथाई था। देश में प्रमुख सब्जी बाजारों में उत्कृष्ट एकीकरण स्तर देखा गया जिसमें वर्ष दर वर्ष सुधार हुआ है। हालांकि अभी छोटे बाजारो में एकीकरण की रफ्तार कमजोर थी।

भारत के गंगा–यमुना के मैदानों (IGP) में चावल की औसत उत्पादकता 3.66 टन प्रति हैक्टर थी। हालांकि जहां तक चावल उत्पादकता का संबंध है आई जी पी राज्यों के बीच व्यापक अंतर देखा गया। जहां पंजाब में यह 5.44 टन/हैक्टर तक उच्च थी वहीं बिहार में यह 2 टन/हैक्टर से कम स्तर पर थी। क्षेत्रीय विषमता और ऐसे गैर लाभान्वित राज्यों में चावल की कम पैदावार से आई जी पी क्षेत्र में कुल प्रदर्शन में कमी आई। आई जी पी में चावल उत्पादन में वृद्धि के स्रोतों के अपघटन से यह पता चला कि बिहार (114 प्रतिशत) और पश्चिम बंगाल (97 प्रतिशत) जैसे राज्यों में पैदावार प्रभाव कहीं ज्यादा था जबकि पंजाब (58 प्रतिशत) और हरियाणा (83 प्रतिशत) में क्षेत्र प्रभाव उल्लेखनीय था। आई जी पी क्षेत्र में चावल उत्पादन की वृद्धि दर में अभी हाल ही में आई कमी को रोकने के लिए प्रौद्योगिकियों को बढ़ाने एवं संस्थागत सुधार के लिए समुचित नीतियों को स्थान दिया जाना महत्वपूर्ण है।

किसानों के जानकारी व्यवहार पर किए गए अध्ययन से पता चला कि उत्तर प्रदेश में प्रगतिशील किसान, डीलर और इलेक्ट्रॉनिक मास–मीडिया (रेडियो व टेलीविजन) किसानों के लिए निरन्तर सूचना के महत्वपूर्ण स्रोत बने रहे। यह भी पाया गया कि किसान ऐसी गुणवत्ता सूचना जो कि उनकी खेत आमदनी में पर्याप्त वृद्धि कर सके, के लिए भुगतान करने के लिए भी तैयार थे। सबसे अधिक मांगी जाने वाली सूचना बाजार मूल्य और मौसम से संबंधित थी। किसानों के खेत स्कूलों ने जानकारी बढ़ाने विशेषकर जैव–नाशकजीवनाशी, जैव–उर्वरक तथा ट्रैप फसलों के रोपण और अन्य फसल प्रबंधन पद्धतियां जैसी नाशीजीव प्रबधन पद्धतियों को अपनाने पर उल्लेखनीय रूप से प्रभाव डाला। स्वतः सहायता समूह को प्रबंधन संचार और उद्यमशीलता दक्षता के क्षेत्र में प्रशिक्षण दिए जाने की आवश्यकता थी। सूक्ष्म वित्तीय गतिविधियों में स्वतः सहायतार्थ समूह की भागीदारी से परिवार की आमदनी बढ़ाने और ग्रामीण महिलाओं के सशक्तिकरण में मदद मिली। संस्थान ने विभिन्न व्यावसायिक प्रशिक्षण पाठ्यक्रमों में लगभग 500 महिलाओं को प्रशिक्षित किया।

राष्ट्रीय कृषि प्रसार कार्यक्रम के तहत संस्थान द्वारा विभिन्न फसलों के लिए विकसित नई किस्मों और प्रौद्योगिकियों के 1000 खेत पर ही प्रदर्शन किए गए। पैदावार अन्तराल 25 से 100 प्रतिशत के क्रम में था। संस्थान ने भा.कृ.अ.सं. प्रौद्योगिकियों के हस्तांतरण के लिए बड़ी संख्या में स्वैच्छिक संगठनों, एजेन्सियों को जोड़ते हुए एक नए रास्ते की स्थापना की और किसानों को सूचना उपलब्ध कराई गई। संस्थान द्वारा आयोजित *पूसा कृषि विज्ञान मेले* में बड़ी संख्या में अनुसंधान संस्थानों, स्वैच्छिक संगठनों, निजी कम्पनियों और अन्य संगठनों ने भाग लिया। देश के विभिन्न भागों से लगभग एक लाख आगन्तुक मेले में आए और इस दौरान लगभग 22 लाख रूपये के बीज और पौद सामग्री की बिक्री हुई। भा.कृ.अ.सं. प्रौद्योगिकियों के बारे में जानकारी हासिल करने के उद्देश्य से 22 राज्यों के लगभग 13 हजार किसानों ने संस्थान के एटिक केन्द्र का दौरा किया। संस्थान के कृषि विज्ञान केन्द्र ने बड़ी संख्या में किसानों को प्रशिक्षण प्रदान किया और हरियाणा में गुड़गांव जिले के किसानों को भा.कृ.अ.सं. प्रौद्योगिकी का हस्तांतरण करते हुए उनकी सहायता की।

भारतीय कृषि अनुसंधान संस्थान के स्नातकोत्तर विद्यालय के 48वें दीक्षांत समारोह का आयोजन 13 फरवरी, 2010 को किया गया।

भारत की महामहिम राष्ट्रपति श्रीमती प्रतिभा देवी सिंह पाटील, जो कि समारोह की मुख्य अतिथि थीं, ने दीक्षांत भाषण दिया गया। इस दीक्षांत समारोह में एम.एससी. के कुल 75 तथा पीएच.डी. के कुल 69 छात्रों को उपाधियां प्रदान की गईं।

संस्थान द्वारा बहुत से नियमित एवं अल्पावधि प्रशिक्षण पाठ्यक्रमों का आयोजन किया गया और छात्रों के लिए सुविधाओं का नवीनीकरण किया गया। जैवसूचना प्रणाली और कृषि सूचना प्रणाली पर संस्थान द्वारा विशेष रूप से ध्यान दिया जा रहा है। भा.कृ.अ.सं. पुस्तकालय संस्थान तथा देश के अन्य भागों के छात्रों, वैज्ञानिक समुदाय को निरन्तर अपनी सेवाएं प्रदान कर रहा है। संस्थान की अधिदेशित गतिविधियों के बारे में सूचना के प्रसार के उद्देश्य से संस्थान द्वारा हिन्दी तथा अंग्रेजी दोनों भाषाओं में वैज्ञानिकों द्वारा समीक्षात्मक अनुसंधान पेपर, संगोष्ठी पेपर, पुस्तकें/पुस्तकों में अध्याय, लोकप्रिय लेख, तकनीकी बुलेटिन, नियमित तथा तदर्थ प्रकाशनों के रूप में बहुत से गुणवत्तापूर्ण प्रकाशन जारी किए गए।

संस्थान को 'एग्रीकल्चर टुडे' के प्रकाशकों द्वारा स्थापित **एग्रीकल्चर लीडरशिप एवॉर्ड–2009** और भा.कृ.अ.प. का **सर्वश्रेष्ठ वार्षिक रिपोर्ट पुरस्कार–2008-09** प्राप्त हुए। संस्थान के अनेक वैज्ञानिकों, छात्रों तथा संकाय सदस्यों ने प्रतिष्ठित पुरस्कार और सम्मान प्राप्त किए।

# EXECUTIVE SUMMARY

The Indian Agricultural Research Institute accelerated its efforts to fast track basic, strategic and applied research along with development of improved technologies and human resources. During 2009-10, the Institute concluded the research programmes running for the last five years and initiated new projects in high priority areas. The Institute made impressive contributions by breeding 18 varieties of field, vegetable, ornamental and other horticultural crops along with development of various resource, crop and product management technologies. Eight patents of various processes and products were granted to the Institute and in turn the Institute licensed six technologies for commercialization. A total of 144 students were awarded degrees in the year 2010. A summary of salient achievements is given below:

The School of Crop Improvement made important contribution to varietal improvements. In wheat, a high yielding variety Pusa Sindhu Ganga (HD 2967) was identified for release for timely sown irrigated conditions of two diverse ecologies, viz., the plains of Northern and North Eastern regions, with an average yield of 5.04 t/ha and 4.54 t/ha, respectively. A variety Pusa Bahar (HD 2985) was released for commercial cultivation in the states of Uttar Pradesh, Bihar, Jharkhand, West Bengal and Assam under late sown conditions in the rice-wheat cropping system. It has a yield range of 3.5-4.0 t/ha and the lowest reduction in 1000-grain weight under very late sown condition. Another variety Pusa Basant (HD 2987) was released for commercial cultivation in the states of Maharashtra and Karnataka with an average yield of 2.0-2.2 t/ha under rainfed, and 3.0-3.2 t/ha under restricted irrigation conditions. Another high yielding variety Pusa Baker (HS 490) with superior biscuit making quality was released for cultivation under late sown, restricted irrigation conditions of the Northern Hills Zone (NHZ). Pusa Navagiri (HW 5207) with a yield potential of 5.96 t/ha under need-based irrigation was released for cultivation in Southern Hills Zone. The variety possesses resistance to all the three rusts and matures in 101-102 days. In rice, Pusa 1301, a *basmati* rice genotype superior to Pusa Basmati 1121 in tolerance to shattering and grain quality traits, particularly aroma and cooked grain quality, has been developed and is in advanced stage of testing.

In pearl millet, an early maturing and fast-growing composite variety Pusa Composite 612 with resistance to downy mildew disease was released and notified. In mungbean, a bold-seeded variety Pusa 672, with shining attractive seed and good cooking quality was released and notified for the Northern Hills Zone. It produces an average yield of 1-1.1 t/ha and matures in 80 days. In *Brassica*, a variety NPJ 112 suitable for multiple cropping system with an average seed yield of 1.47 t/ha and a maturity period of 107 days was released and notified for Zone II comprising the northern plains.

Among vegetables, DBL 02, a violet-purple coloured, round pistal-end fruited variety of brinjal was identified for release for cultivation in Zone I (Jammu & Kashmir, Himachal Pradesh and parts of Uttarakhand), Zone IV (Punjab, Delhi, Uttar Pradesh and Bihar) and Zone VI (Haryana, Rajasthan, Gujarat, Dadra & Nagar Haveli and Daman & Diu). It takes about 55 days to first harvest from transplanting with an average fruit weight of about 80-90 g and a yield of 38.2 t/ha. Pusa Asita, the country's first black carrot variety, was released and notified for Delhi state. It is a tropical carrot rich in anthocyanin with a yield of 25 t/ha in 90-100 days. In temperate carrot, the first public sector orange coloured hybrid Pusa Nayanjyoti containing 7.552 mg/100 g

β-carotene with a potential yield of 39.6 t/ha was released by Himachal Pradesh. Mosambi sweet orange collections, viz., MOS 1 and MOS 3 were identified as most promising under Delhi conditions. In grape, Hybrid 75-32 and Hybrid 76-1 were found to perform consistently well and three new hybrids, namely, Hybrid 205-6-17, Hybrid 2006-11-8 and Hybrid 2006-12-1 having quality berry and early ripening were selected. A semi-vigorous rootstock Pusa Seb Mulvrint-1 was identified in apple. *Prunus japonica*, when used as root stock, imparted dwarfness in apricot, peach, plum and cherry. In walnut, Pusa Khor was identified as superior clone with distinct precocity and lateral bearing.

In ornamental crops, two promising gladiolus hybrids, viz., Pusa Kiran (white coloured florets on long and sturdy spikes) and Pusa Shubham (cream/light yellow florets) with very good spikes well suited for vase decoration, bouquet preparation and floral arrangements were identified for release. A French marigold variety Pusa Arpita with a yield potential of 15-20 t/ha was identified for release by IARI Variety Identification Committee. A thermo- and photo-period insensitive floriferous bushy variety of chrysanthemum with yellowish pink flowers Pusa Anmol, which produces three flower flushes in a year in 85-100 days after transplanting, was identified for release. Another chrysanthemum variety Pusa Centenary, which blooms in 100-110 days, having vigorous growth and very big yellow flowers, was identified for release.

In seed science research, various seed treatments for improved field emergence, uniformity, and early seedling growth in soybean, onion and maize were standardized. The Institute produced a record 1092 tonnes of quality seeds, out of which 565 tonnes were breeder seeds and 527 tonnes were truthfully-labeled seeds including 496 tonnes under farmers' participatory programme.

Crop genetic resources research identified several accessions of different crops having useful traits. In wheat, HS 492 (INGR No. 09005) was registered as genetic stock for resistance against all the pathotypes of leaf rust by ICAR. In addition, several genetic stocks were identified for various parameters such as number of tillers/sq. metre (WR1702), 1000-grain weight (WR1617, RD1151, RD1152, RD1271), grains/spike (RD1151, RD1162), short duration and heat tolerance (WR1695, WR1743), protein content and grain size (RD1336). In maize, cultivars, Pusa Early Hybrid Makka-3, Pusa Extra Early Hybrid Makka-5, Pusa Composite-3 and Pusa Composite-4 were registered as extant varieties with the PPV&FRA.

As regards microbial genetic resources, 615 fungal specimens of Ascomycetes, Basidiomycetes and Deuteromycetes were accessioned in HCIO raising the total number of specimens to 48,837. The important new species added were *Asteridiella crotonis-caudati, Asterina gamsii, A. prataprajii, Bartalinia caeryaensis, B. psidii, Irenopsis pavoniae, I. xeromphidiss, Meliola mahamulkarii, M. manoharacharyi, M. rachammae, Phyllachora gymnemae, Schiffnerula catharanthi, S. flacourtiae, S. girijae* and *Uromyces terminalia.*

Under biosystematics and identification services, 615 diseased fungal specimens were accessioned in HCIO during 2009-10 raising the total number of specimens to 48,837. Besides, 270 fungal cultures were identified enriching the ITCC with 42 different cultures. Under nematode biosystematic services, 29 type specimens (21 type slides representing 12 new species and 3 genera) and 90 wet suspensions of nematodes were added to the national collection, thus bringing the total strength up to 2253 type accessions and 3302 wet accessions.

Crop and resource management research provided further insights into sustainability of production systems. Mulching (wheat straw 5 t/ha or *Sesbania* mulch) and iron fertilization (50 kg iron sulphate/ha+2 foliar sprays of iron sulphate at maximum tillering and pre-flowering stages) showed marked influence in enhancing the productivity of aerobic rice. Inoculation of puddled rice with plant growth promoting rhizobacteria, viz., *Azospirillum* and *Bacillus* under the system of rice intensification (SRI) was helpful in realizing higher rice yields. Sequential application of pendimethalin @ 0.75 kg/ha followed by pendimethalin @

0.75 kg/ha at 30 days after transplanting was promising for weed control in onion.

Crop evapotranspiration ($Et_c$) of major crops (rice, wheat, and maize) were estimated using *CROPWAT* model and compared with $Et_c$ estimated from normal values. Twenty Artificial Neural Network (ANN) models with different network architectures, transfer and learning functions for the prediction of crop evapotranspiration were developed, validated and tested for wheat crop grown in Delhi by using lysimetric data and meteorologic information with MATLAB. Another study in Mewat (Haryana) assessed the availability, harvesting potential and utilization of water after adjusting for water saving technologies and their impacts on the production and income of the farmers.

Major emphasis under microbiology, was on bioprospecting of microbes from extreme environments for novel genes and molecules, identification of genes responsible for mineral phosphate solubilization, and development of biofilms of inoculant strains by the use of fungal, bacterial and cyanobacterial matrix. Organic farming in rice based cropping (including wheat and vegetables) systems through microbial inputs; development of a concoction of "effective microorganisms" for sustainable crop growth; utilization of cyanobacteria for value added products, especially, pigments; biochemical profiling of *Azolla* extracts and their influence on plant growth; recycling of organic residue and development of microbial consortia, and phototrophic biofilms for biodegradation of plastics were other high priority research areas.

In soil management studies, application of NPK + farmyard manure was most effective in enhancing the biodiversity and resistance and resilience of soil biological functions against heat stress. As compared to maize, the SOC fractions improved in greater amount in wheat. Fifty per cent RDF could be substituted by the application of manures for crop production as well as for maintaining soil organic C, thus saving 50% of chemical fertilizers. Maximum improvement in carbon management index (CMI) was observed in plots that received 100% organic source of nutrients. Sewage sludge (SS) treatments resulted in greater increase in wheat yield as compared to that in the control. The highest yield was obtained in SS+RS (rice straw) in 1:9 +50% NPK, which was statistically on a par with that of the recommended dose of NPK. The soil samples after wheat recorded significant improvement due to application of sewage sludge along with rice straw and 50% NPK thereby saving 50% of NPK fertilizers.

The long-term experiment at IARI farm since 1971-72 under AICRP-LTFE recorded higher grain yields of maize and wheat with the application of 15 t FYM/ha along with the recommended NPK or super-optimal NPK (150% of recommended NPK) compared to the yields obtained under all other treatments. A low cost programmable colorimeter (LCPC) was fabricated which can be programmed to display fertilizer recommendation of selected crops (at present for wheat and maize) from soil test data and targeted yield.

For protected cultivation system, walk-in-tunnels were found suitable and economically viable for complete off-season summer squash cultivation during the peak winter months. Black shade net house of 60% shading intensity was found suitable and economical for green coriander cultivation during peak summer months. The same was also found suitable for advancing the lettuce crop by 40-45 days ahead of the normal season. Insect proof net house was fabricated and found highly suitable for virus-free crop production in pumpkin during rainy and post-rainy season. Zero energy naturally ventilated greenhouse was found suitable for tomato cultivation for about 9 months a year. Artificial flowering was induced in chrysanthemum (var. Zembla) by using photo active radiation (PAR) with a mixture of red (80%) and blue (20%) LEDs @ 100 µ mol/$m^2$/sec under long day conditions.

Environmental experiments in temperature gradient tunnels (TGTs) on rice variety Pusa 44 showed marked reduction in yield of rice exposed to elevated temperatures (+0.8 to 3.5$^0$C) under low, medium and high fertility levels. Groundnut exposed to elevated temperature during vegetative, reproductive and entire growth phases showed greater thermal sensitivity during reproductive growth

phase. Vulnerability index, a function of exposure, sensitivity and adaptive capacity was developed for Rajasthan, and the districts facing large climatic variations such as Rajasmand, Dungarpur, Dhaulpur, Dausa, and Karauli, were found to be more vulnerable. Annual emission of methane was updated from 1994 levels and estimated to be 3.49 Tg, and the direct emission of nitrous oxide from managed soils was estimated to be 132.3 Gg for the year 2000. Potential and cost of carbon sequestration in Indian agriculture were estimated by analyzing the data from 26 long-term experiments (LTEs) in different agro-climatic zones (ACZs) of India. Acid pretreatment followed by enzymatic saccharification was found to be most efficient for the development of clean biofuels. Impact of elevated levels of tropospheric ozone on agricultural crops under different $CO_2$ levels was also assessed under air pollution monitoring programme.

The Institute developed several farm related equipment and technology for optimizing crop production. During the year, a garlic planter, an onion seed extractor, and a motorized vegetable seed extractor were developed and evaluated. A solar cabinet dryer (natural convection) was used for drying onion. A system of pigeonpea stripping and threshing was developed at Regional Station, Karnal.

Under post-harvest technology and management, ready to serve **(**RTS) beverages of different degrees of sweetness were developed from *bael* fruit pulp with *Stevia*. Occurrence of deformed fruit in strawberry cultivation could be reduced up to 18% by foliar application of polyamine putrescine @100 ml/l at flower initiation. Phytochemical analysis of *ber* (*Zizyphus mauritiana* Lamk) germplasm indicated the cultivars, ZG 3, Sonaur 5, Gola, Rashmi, Elaichi and Kaithali to be potential genotypes high in phytochemical composition and antioxidant activity. Processed *ber* pulp had higher antioxidant (AOX) potential than fresh fruits. Calcium chloride spray @ 1% exhibited significant reduction of bitter pit, decay and weight loss in apple with high value of fruit firmness at the end of six months of cold storage. A process for the preparation of tomato powder from blanched and unbalanced tomato slices was developed. It could be reconstituted well and used to make tomato soup, sauces and paste with good organoleptic quality. Package icing within 2 hours after harvest was found to check the sugar loss and retain the marketable quality of harvested sweet corns. Ready-to-eat extruded products were developed from pearl millet, maize, barley and sorghum along with chickpea as minor ingredient and their quality characteristics were documented.

Molecular typing of *Aspergillus* (20), *Fusarium* (6), *Rhizoctonia bataticola* (6) and *Xanthomonas campestris* pv. *punicae* (10) isolates was performed using random and specific primers. Molecular diagnostics were developed for *Fusarium oxysporum* f. sp. *ciceris* (FOC, Race 4) causing wilt of chickpea and *Bipolaris sorokiniana* causing spot blotch of wheat, respectively. The etiology of foorkey disease of large cardamom was described after its detection in 1936 and the virus was identified as Large Cardamom Bushy Dwarf Virus (LCBDV). The association of a member of 16 Sr IX group of phytoplasma with *toria* (*Brassica rapa*. cv. *toria*) for phyllody disease was detected.

An integrated disease management strategy of seed treatment with thiamethoxam 70% WS (Cruiser) and Pusa 5SD @ 4 g/kg each followed by two foliar sprays of a mixture of thiamethoxam 25% WG (Actara, 0.02%) and carbendazim (0.05%) at 21 and 35 DAS, was developed to manage wet root rot, *Cercospora* leaf spot and yellow mosaic of mungbean. *Chaetomium* based bio-formulations (Cg2 WP and Cg2 SL) were validated against late blight (LB) of potato under field conditions and a disease reduction up to 62% was observed. *Trichoderma* based bio-formulations were found effective in farmers' fields against black root rot of groundnut with 65% disease reduction.

Insect pest management studies were conducted on rice, soybean, mustard, and vegetables. Spectral signatures were established for leaf folder *Cnaphalocrosis medinalis* damage on rice with remote sensing by the use of spectrodiometer. Other studies covered biological control, insect physiology and insect toxicology. Attempts were made

to evaluate the toxicity of different cry toxins against S*podoptera litura* neonates and pyrethroids (deltamethrin, α-cypermethrin and β-cycfluthrin) against *Helicoverpa armigera*. Inheritance studies on *cry1Ac* resistance in *Helicoverpa armigera* suggested the association of a major resistant gene or a set of tightly linked loci. Improved semi-synthetic (meridic) diet for mass rearing of *Bactrocera cucurbitae* was developed. Toxicity of fly ash and diatomaceous earth against storage insects such as *Tribolium castaneum*, *Sitophilus oryzae*, *Rhyzopertha dominica* and *Callosobruchus maculatus* on wheat and mungbean was found to be dose dependent.

Foliar application of NemaGel formulation *Steinernema thermophilum* and *S. glaseri* @ 10000 infective juveniles/ plant at the time of flowering resulted in significant increase in the number and weight of brinjal (*Pusa Uttam*) fruits. Liquid formulations of the two *Steinernema* species were found effective against white grubs (*Holotrichia cosanguina*) infesting groundnut. Tomato transformed with RNAi constructs for Splicing Factor (SF) and Integrase gene had very few and small galls containing a few weak nematode females of *Meloidogyne incognita.* Significant reduction in the number of galls and better shoot growth of tomato were observed when nano-formulation of carbofuran was applied @ 5 ppm as soil drench as compared to those observed under the recommended dosages of the commercial formulation (carbofuran 3G) @ 1-1.5 kg a.i./ha.

In the evaluation of oxime derivatives of naturally occurring felchone, isovalerate ester was identified as the most active insect antifeedant and nonanoate ester as the most active insecticide. Hydrazones of nalidixic acid hydrazide showed maximum antifungal activity comparable to that observed in hexaconazole against *Alternaria porii,* which is moderately insecticidal against *S. litura.* Among 10 schiff bases, 4-benzylidenamino-3-mercapto-5-phenyl-4H-1,2,4-triazole exhibited the highest activity against *Meloidogyne incognita* in cowpea under glass house test. Biocatalycally produced N-propyl-butyramide, -pentanamide and-hexanamide by the use of *Candida antarctica* lipase were found to possess significant activity against nematode *Meloidogyne incognita*. Phytoremediation studies with mustard and marigold plants revealed that mustard plants could remove 15-18% imidacloprid, 7-8% of chlorpyriphos and DDT and about 6% of bifenthrin while marigold plants could remove the pesticides, DDT and bifenthrin only to some extent (4-5%). Different commercially available hydrogels were tested for monomer acrylamide concentration. Pusa hydrogel contained non-detectable (0.02 mg $g^{-1}$) acrylamide.

Plant biotechnological studies were conducted to develop transgenics for biotic and abiotic stress tolerance. A chimeric δ-endotoxin gene comprising domains I and II of *cry1Jb* (1.35 kb) and domain III of *cry1A* was expressed in bacteria with increased toxicity to *Helicoverpa armigera*. In another study, *cry* protein was targeted to endoplasmic reticulum for high level of expression. Insect tolerance was introduced in tobacco by over-expressing *lectin* genes from pea. A gene coding for metallothionein protein known to adversely affect the growth of fungi was cloned and mobilized into plant transformation vector.

A full length cDNA of *XAP-5* gene involved in basal defense in plants was cloned from *B. juncea*. These genes will be used to transform mustard to test their efficacy against fungal diseases such as *Alternaria* blight and white rust. Transgenic mustard plants carrying another pathogen defense gene *NPRI* were generated and their transgenic status verified. Expression patterns of six *annexin* genes were examined in drought tolerant rice variety Nagina 22 through RT-PCR. Two full length c-DNA clones of the *annexin* genes, *AnnOsI1* and *AnnOsI4* were isolated from Nagina 22. A *phytase* gene responsible for phosphorus mobilization was isolated and characterized with the aim to over-express it in soybean. Another gene for small heat shock protein (hsp) was cloned and characterized in wheat. A gene coding for phytoene synthase (psy), involved in β-carotene synthesis, was isolated and characterized from banana cv. Nendran. Complete genomes of *Cucumber mosaic virus* (RNA1) (Delhi isolate, GU111227, 3358 nt), *Papaya ringspot*

*virus* (Pathotype W, EU475877, 10335 nt) and *Citrus tristeza virus* (Kpg3, 19253 nt) were sequenced. Artificial micro RNA (miRNA) constructs were designed to confer resistance against tomato leaf curl.

Physiological investigations revealed that salinity tolerance in *Brassica juncea* genotypes, CS 52 and CS 54 was associated with increased expression of salt overly sensitive (SOS) genes cascade. Nitric oxide induced increase in the shelf life of cut gladiolus flowers was found to be associated with decrease in the expression of *cysteine protease (GgCyP1*) and increase in the expression of *DAD1* genes. The ITS region of rDNA of *Steinernema* was sequenced, which showed 99% similarity with that of *S. siamkayai*. Six new genes of ITS region of ribosomal DNA of entomopathogenic nematodes were sequenced and registered in Genbank with accession numbers GQ353373 and GU354216 - 354219, respectively.

Genetic analysis of stem rust resistance in genotype WR 95 revealed a single recessive gene for rust resistance. This genotype was screened with molecular markers of stem rust resistance genes, *Sr22, Sr24, Sr25, Sr26, Sr31, Sr36,* and *Sr38*. None of these genes could be detected in WR 95. Genetic studies in wheat detected the presence of a hybrid dwarfness gene in many bread wheat varieties including prominent cultivars such as PBW 343, C 273, Raj 3765, UP 2338, Narmada 4, DBW 16, and Ningmai. Through marker assisted backcross breeding, two bacterial blight resistance genes *xa13* and *Xa21* were transferred to Pusa 6B and PRR78, the parental lines of the rice hybrid Pusa RH 10. In chickpea, putative QTLs for 100-seed weight and number of pods per plant were identified to enable selection of high yielding lines. Variability for white rust resistance genes in different species and allelic relationship was documented in *Brassica*.

The research on food security and agricultural diversification indicated the need for higher public investment in agriculture to achieve the growth target of 4% per annum. Institutional reforms for efficiency of public investment in areas like irrigation, and better delivery of farm inputs and services to farmers, and technical support to bridge the yield gap were the other priority areas needing immediate attention. For dryland areas, the productivity enhancement efforts should centre around water conservation and efficient use strategy. The study on agriculture trade showed that there has been an impressive growth in the export of *basmati* rice and floricultural products. The overall growth in agriculture exports, however, continued to be moderate and unstable. The study on peri-urban agriculture indicated improved farm profitability due to high value crops, e.g., vegetables, which contributed about three-fourths of the total farm income. The major vegetable markets in the country showed a high degree of integration which has improved over the years. However, small markets continued to be weakly integrated.

The average productivity of rice in the Indo-Gangetic Plains (IGP) of India was 3.66 t/ha. However, a wide variation was witnessed among the IGP states as far as rice productivity is concerned. It runs as high as 5.44 tonnes per hectare in Punjab and as low as 2 tonnes per hectare in Bihar. Regional disparity and low yield of rice in such disadvantaged states dampen the overall performance in the IGP region. Decomposition of sources of growth in rice production in IGP revealed that the yield effect was more in states like Bihar (114%) and West Bengal (97%) whereas the area effect was significant in Punjab (58%) and Haryana (83%). To arrest the recent deceleration in growth rate of rice production in the IGP region, it is important to put in place appropriate policies for technology push and institutional reforms.

Studies in information behavior of framers showed that progressive farmers, dealers and electronic mass media (radio and television) continue to be the important sources of information for farmers in Uttar Pradesh. It was also found that the farmers were willing to pay for quality information that would lead to substantial increase in farm income. The most sought information was related to market price and weather. The Farmers' Field Schools were found to have made significant impact on enhancing knowledge, especially in the adoption of IPM practices like bio-pesticides, bio-fertilizers and planting of trap crop and other crop

management practices. The Self Help Groups (SHGs) were found to be in need of training in the areas of management, communication and entrepreneurial skills. The participation of SHGs in micro-finance activities has helped in increasing the family income and empowering the rural women. The Institute trained about 500 women in various vocational training courses.

Under the National Agricultural Extension Programme, the Institute conducted about 1000 on-farm demonstrations of newly developed varieties and technologies of various crops. The yield gap was in the order of 25-100%. The Institute established an innovative way by linking a number of voluntary organizations (VOs)/agencies for transfer of IARI technologies and provided information to farmers through them. A large number of research institutes, VOs, private companies and other organizations participated in the *Pusa Krishi Vigyan Mela* organized by the Institute. About one lakh visitors from different parts of the country visited the *mela*, and seed and planting material worth Rs.22 lakhs were sold. Nearly 13,000 farmers from 22 states visited ATIC and exhibitions to get the information about IARI technologies. The KVK provided training to a large number of farmers and helped the farmers of Gurgaon district in Haryana by transferring IARI's technology.

The 48$^{th}$ convocation of the Post-Graduate School, IARI was held on February 13, 2010. Her Excellency the President of India, Smt. Pratibha Devisingh Patil, who was the chief guest, delivered the convocation address. At this convocation, a total of 75 M.Sc. and 69 Ph.D. students were awarded degrees.

The Institute also conducted several regular and short-term training courses and updated student amenities. Bioinformatics and agri-information continued to receive the Institute's attention. The IARI Library continued to provide services to the students and the scientific community of IARI and other institutions in the country. The Institute has brought out several quality publications in the form of scientific peer reviewed research papers, symposia papers, books/chapters in books, popular articles, technical bulletins, regular and *ad hoc* publications, both in English and Hindi, to disseminate information on the Institute's mandated activities.

The Institute won the **Agriculture Leadership Award 2009** instituted by the publishers of "Agriculture Today" and the **Best Annual Report Award 2008-09** of ICAR. Many scientists, students and faculty of the Institute received several prestigious awards and recognitions.

# 1. CROP IMPROVEMENT

## 1.1 CEREALS

### 1.1.1 Wheat

#### 1.1.1.1 Varieties identified/released

***Pusa Sindhu Ganga (HD 2967).*** A wheat genotype HD 2967 was identified by the 48th All India Wheat and Barley Research Workers Meet held at IARI for release in two zones, viz., North Western Plains Zone (NWPZ) and North Eastern Plains Zone (NEPZ) for timely sown irrigated conditions. This genotype developed from a cross ALD/COC//URESH/HD 2160m/HD 2278 produced an average grain yield of 5.04 t/ha in NWPZ and 4.54 t/ha in NEPZ in all India coordinated trials. The variety has amber coloured, hard textured, ovate grains with 40 g test weight and 12.7% protein content. It takes an average of 143 days and 129 days to mature in NWPZ and NEPZ, respectively. The variety possesses diversified genes other than 1B/1R and shows a high degree of resistance to leaf rust as well as to 78S84 and 46S119 races of yellow rust. The variety also shows lower incidence of leaf blight, Karnal bunt and flag smut compared to checks. It has high zinc, copper and manganese contents, sedimentation value and is suitable for bread as well as *chapati* making.


**Pusa Sindhu Ganga (HD 2967), the first wheat variety released for both NWPZ and NEPZ**

***Pusa Basant (HD 2985).*** A wheat variety Pusa Basant (HD 2985) was released for commercial cultivation in the states of Uttar Pradesh, Bihar, Jharkhand, West Bengal and Assam under late sown conditions in rice-wheat cropping system. It has a yield range of 3.5-4.0 t/ha and the lowest reduction in 1000-grain weight under very late sown condition.


**Pusa Basant (HD 2985), a wheat variety suited for late sown condition in rice-wheat cropping system**

***Pusa Bahar (HD 2987).*** A wheat variety Pusa Bahar (HD 2987) was released for commercial cultivation in the states of Maharashtra and Karnataka under rainfed and restricted irrigation conditions. This variety has yield ranges of 2.0-2.2 t/ha and 3.0-3.2 t/ha under rainfed and restricted irrigation conditions, respectively.


**Pusa Bahar (HD 2987), a wheat variety suitable for rainfed and restricted irrigation conditions**

***Pusa Baker (HS 490).*** A high yielding variety with superior biscuit making quality, Pusa Baker (HS 490) was released and notified by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops for commercial cultivation under late sown, restricted irrigation conditions of Northern Hills Zone (NHZ) comprising hills of Himachal Pradesh, Uttarakhand, Jammu & Kashmir and north eastern states. It was also recommended for cultivation in Himachal Pradesh by the State Variety Release Committee.

***Pusa Navagiri (HW 5207).*** Pusa Navagiri (HW 5207) developed at the Regional Station, Wellington was released for cultivation under conditions prevailing in Southern Hills Zone (SHZ) of India through All India Coordinated Wheat Improvement Programme. The variety HW 5207 has a yield potential of 5.96 t/ha under need-based/restricted irrigation (up to five irrigations) and exhibits remarkable resistance to all three rusts. Since it matures in 100-102 days, it could become a choice and an alternative crop to the resource poor farmers for grain as well as fodder in the areas where erratic and unpredictable north-east monsoon occurs. The variety has consistency in yield under varied levels of irrigation and gives nearly 32.5% yield advantage over the control varieties under two irrigation levels. It is a good variety for sustaining the livelihood of resource poor farmers.

**Pusa Navagiri (HW 5207), a wheat variety suitable for restricted irrigation condition of SHZ**

***HW 1095 (CoW(SW)2).*** HW 1095 (CoW(SW)2), a heat tolerant and high yielding *dicoccum* variety developed at the Regional Station, Wellington was released by the Tamil Nadu Agricultural University, Coimbatore as a state variety for cultivation under conditions prevailing in Southern Hills Zone (SHZ) of India. HW 1095 is a NP 200 mutant developed through *gamma* irradiation (200 Kr). It matures in 110 days and falls in early duration group. The culture HW 1095 recorded a mean grain yield of 4.04 t/ha, an increase of 26% grain yield over the NP 200 in different trials over the past five years.

**HW 1095 (CoW(SW)2), a heat tolerant and high yielding *dicoccum* variety for SHZ**

### 1.1.1.2 Promising entries

A large number of elite genotypes of wheat were tested in coordinated trials.

**Improved lines of wheat under testing in coordinated trials**

| Trials | Entry name/ numbers |
|---|---|
| Advance Varietal Trials (AVTs) | **AVT II:** HD 2997 (NEPZ), HD 3016 (NEPZ), HI 1563 (NEPZ)<br>***Durum wheat*** - HI 8691(CZ)<br><br>**AVT I:** HD 3043, HD 4722 (D) (NWPZ), HD 3045 (NWPZ & PZ), HD 3024 (NWPZ), HD 3027 (NWPZ), HD 3028 (NEPZ), HD3040 (PZ & SHZ), HD3053 (PZ & SHZ), HD 3037 (PZ), HD 3052 (SHZ), HI 1567 (CZ), HI 1568 (CZ), HI 1569 (PZ), HI 1571 (NWPZ & PZ), HI 1572 (CZ),<br>***Durum wheat*** - HI 8702 (PZ), HI 8703 (NWPZ & CZ), HI 8704 (CZ), HI 8708 (CZ), HI 8709 (CZ) |
| National Initial Evaluation Trials (NIVTs) | HD 3063, HD 3070, HD 3071, HD 3055, HD 3056, HD 3069, HD 3072, HD 3073, HD 3074, HD 4724,HD3057, HD3062, HI 8710, HI 8711, HI 8712, HI 8713, HI 8714, HI 8715, HI 8716, HI 8717, HI 8718, HI 8719, HI 8720, HI 8721, HI 8722, HI 1575, HI 1576, HI 1577, HI 1578, HI 1579, HI 1580, HI 1581 |

A *durum* wheat variety HI 8671 developed at Regional Station, Indore completed three years of testing under coordinated trials for Central Zone. It showed matching yield (4.98 t/ha) with the check HI 8498 (4.91 t/ha) under high fertility timely sown conditions, and had higher levels of iron (33.5%), zinc (32.7%) and copper (3.3%) compared to those of HI 8498, and hence can help in fighting malnutrition in the central belt of the country.

At Regional Station, Shimla two entries, HS 507 under timely sown rainfed & irrigated conditions and HS 513 under late sown restricted irrigation condition were promoted to the final year of testing in Northern Hills Zone (NHZ). Two genotypes, HS 514 under timely sown rainfed & irrigated conditions and HS 521 under early sown rainfed condition were promoted to the second year of testing in NHZ.

Two entries HS 531 in NIVT-1B and HS 527 in IVT-SHZ got placed in different zones while 11 genotypes, viz., HS 524, HS 525, HS 526, HS 527, HS 528, HS 529, HS 530, HS 531, HS 532, HS 533 and HS 534 were included in All India Coordinated Trials for further evaluation under different production conditions of Northern Hills Zone on the basis of their yield potential and high degree of rusts resistance.

A promising bread wheat entry HW 5207-1 possessing resistance to all rusts developed at Regional Station, Wellington is in the final year of testing under irrigated timely sown conditions in Central Zone.

#### 1.1.1.3 Evaluation of elite *Ug*99 resistant lines

Ninety-six wheat lines having resistance to stem rust race *Ug*99 in Africa were evaluated at Delhi under very high disease pressure condition for yellow and brown rusts. Sixty-six lines were selected on the basis of multiple resistance to yellow/ brown rust, spot blotch and powdery mildew and plant ideotype for further evaluation of yield and yield contributing traits. At Regional Station, Pusa, six cultures, HP 1929, HP 1930, HP 1931, HP 1932, HP 1933 and HP 1934 deriving resistance genes from diverse genetic backgrounds were found promising. These were under evaluation in different NIVTs of coordinated trials. Cultures with alien gene(s) and additional advantage of foliar blight resistance/ tolerance, viz., PS 976 - PS 986; PS 987 - PS 997; PS 998 - PS 1009; PS 1010 - PS 1015; PS 1016 - PS 1019; PS 1020; and PS 1021 and PS 1022 were tested in common varietals trials (CVTs). Forty-seven promising cultures (PS 976 - PS 1022) were tested in IPPSN. Seventy-five outstanding cultures developed at IARI Regional station, Pusa possessing dwarf stature, very good tillering efficiency, synchrony in maturity and resistance to brown rust and *Helminthosporium* leaf blight were tested in PDSN.

### 1.1.2 Rice

#### 1.1.2.1 Promising entries

***Pusa 1301 (IET 20830).*** A highly aromatic *basmati* rice line Pusa 1301 with grain and cooking quality par excellence, developed from the cross, Khalsa 7 x Improved Sabarmati, was tested in the Initial Varietal Trial-Basmati (IVT-BT) during *kharif* 2009. Its overall mean yield across 9 locations in the *basmati* growing regions was found to be 4.42 t/ha as against 4.49 t/ha of Pusa Basmati 1 and 3.2 t/ha of Taraori Basmati. Thus, it recorded a yield on a par with that of Pusa Basmati 1 and 37.85% higher than that of Taraori Basmati. In the state of Delhi, it ranked second recording a yield of 6.5 t/ha. In quality traits, this entry surpassed the checks in terms of the milled rice length (8.4 mm), cooked rice length (18.7 mm) and elongation ratio (2.2).

**Pusa 1301, a promising *basmati* rice line**

### 1.1.3 Barley

#### 1.1.3.1 Variety released

***Pusa Losar (BHS 380).*** A hulled barley variety Pusa Losar (BHS 380) developed by the Regional Station, Shimla was released and notified by the Central Sub-Committee on

Crop Standards, Notification and Release of Varieties for Agricultural Crops for commercial cultivation under rainfed condition of Northern Hills Zone comprising the hills of Himachal Pradesh, Uttarakhand, Jammu & Kashmir and north eastern states. This is the first dual purpose barley variety for meeting both food and fodder requirements of hill farmers. Fodder is a major problem in the hills under severe winter condition. This variety has an average fodder yield of 6.0 t/ha with a potential fodder yield of 13.5 t/ha and an average grain yield of 2.1 t/ha with a grain yield potential of 3.0 t/ha. It is superior to all the checks for fodder yield, and grain yield (20% to 35% under cut and 15% to 45% under no cut). This variety combines very high resistance against leaf and stripe rusts along with good resistance against blight and powdery mildew.

### 1.1.3.2 Entries in coordinated trials

BHS 387 was promoted to the second year of testing under rainfed condition of Northern Hills Zone while four genotypes, viz., BHS 392, BHS 393, BHS 394 and BHS 395 were included in the All India Coordinated Barley Trials for further evaluation under both grain as well as dual purpose trials.

## 1.1.4 Maize

### 1.1.4.1 Evaluation of baby corn hybrids

Three sets of maize hybrid combinations were evaluated leading to the identification of promising hybrid combinations for the baby corn trait.

Efforts were continued for developing and identifying elite hybrids for their exclusive use as baby corn by assessing 18 agro-morpho quality traits as well as texture/cutting pressure in 45 experimental hybrids. Four elite experimental hybrids were selected by comparative evaluation against the two checks, HM-4 and HQPM-1 on the basis of their heterosis for specific parameters.

**A comparison of elite experimental maize hybrids and checks**

| Elite hybrid | Baby corn parameters | Heterosis (%) over checks | |
|---|---|---|---|
| | | HM-4 | HQPM-1 |
| 8042 x 8046 | Cob length (mm) | 61 | 70 |
| 8049 x 8058 | Single de-husked cob weight (gm) | 130 | 113 |
| 8049 x 8058 | Hardness (newton) | -35 | -37 |
| 8049 x 8058 | Harvest index | 193 | 271 |

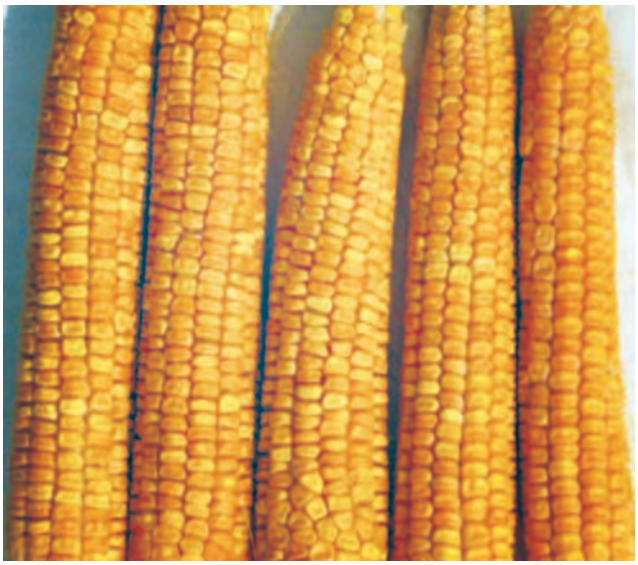
Many crosses involving elite maize inbred lines were found to be useful for baby corn purpose and one such cross (SKV 21×VL pop corn) was found promising.

In addition, promising crosses were identified for traits relating to baby corn usage: (i) MBD-08-8042 x MBD-08-8047 for single husked cob weight/plant, single de-husked cob weight/plant, husked cob yield/plant, de-husked cob yield/plant, fodder weight/plant and biological yield/plant; (ii) MBD-08-8041 x MBD-08-8045 for cream colour, fodder weight and biological yield/plant; and (iii) MBD-08-8041 x MBD-08-8043 for earliness and cob length.

**Tender ears of a promising baby corn cross SKV 21 × VL pop corn**

### 1.1.4.2 Development of sweet corn hybrids

Considering the rising demand for sweet corn hybrids, a total of 120 experimental hybrids were evaluated under *kharif* and *rabi* seasons for productivity as well as quality parameters for identifying elite hybrids. In addition, around fifteen field corn lines with introgression of sugary traits (*su, sh2*) were selected for detailed comparative evaluation. Twenty sweet corn inbred lines were subjected to finer biochemical characterization on the basis of phytoglucogen following glucanase assay using single kernels. Such differentiation on the basis of phytoglycogen content would complement the other approaches like allelic tests and molecular marker assisted differentiation among the sweet corn genotypes.



**A promising sweet corn hybrid under evaluation for higher productivity and quality**

### 1.1.4.3 Evaluation of maize land races under waterlogging stress

One hundred maize inbred lines and 37 landraces were evaluated under excess water stress using 'cup based screening' during *kharif* 2009. Based on this experiment, MAP 159, V 340, MGUD 1, MGUD 3 and MGUD 9 were identified to be highly tolerant to waterlogging stress while the landraces, IML 454, IML 478, IML 676 and IML 677 were found to be moderately tolerant.

## 1.2 MILLET

### 1.2.1 Pearl Millet

#### 1.2.1.1 Variety released

***Pusa Composite 612.*** An early maturing and fast growing pearl millet composite variety Pusa Composite 612, which is highly resistant to downy mildew disease and suitable for moisture stress condition was released and notified by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops in March 2010**.** This high yielding composite variety out yielded the popular checks ICMV 221 by 19.50%, ICTP 8203 by 11.63%, ICMV155 by 11.03% and Raj-171 by 15.96%.

**An early maturing pearl millet composite Pusa Composite 612**

#### 1.2.1.2 Hybrids and composites in coordinated trials

Two new hybrids, namely, MS 841 A x PPMI 479 and MS 576 A x PPMI 762 which out yielded the best check Pusa 605 by 15-20% during *kharif* 2008 were included in the Initial Hybrid Trial (IHT II) conducted by the AICPMIP during *kharif* 2009. The hybrid Pusa 804 (MS 431 A x PPMI 721) was promoted from IHT II to AHT II A for the second year of testing during *kharif* 2009.

## 1.3 GRAIN LEGUMES

### 1.3.1 Mungbean

#### 1.3.1.1 Variety released

***Pusa 0672.*** A bold seeded mung bean variety Pusa 0672, which matures in 80 days, was released and notified by the Central Sub-Committee on crop Standards, Notification and Release of Varieties for Agricultural Crops for cultivation in Northern Hills Zone comprising Jammu and Kashmir, Manipur and Tripura. It yields 1.0-1.1 t/ha and has a 100-seed weight of 3.8-5.3 g with shining attractive seed and good cooking quality. It is non-lodging, non-shattering, resistant to MYMV and has synchronous maturity.

**A bold seeded mungbean variety Pusa 0672**

#### 1.3.1.2 Entries in coordinated trials

In mungbean, two entries, namely, Pusa 0932 and Pusa 0831 was promoted to AVT-1 for spring and *kharif* season trials. Two entries, Pusa 1031 and Pusa 1032 were entered in the IVT-1.

### 1.3.2 Chickpea

#### 1.3.2.1 Promising entries

Seventeen new entries were contributed to coordinated trials. Bold seeded chickpea line BG 2085 was promoted to AVT-2 while BG 3000, BG 3001 and BG 3002 were promoted to AVT-1 trials.

**Chickpea genotypes in all India coordinated trials**

| Trial | Entry |
|---|---|
| IVT - *desi* | BG 3003, BG 3004, BGD 1053, BGD 1054 |
| IVT - Late | BG 3005, BG 3006, BGD 1055, BGD 1056 |
| IVT - Rainfed | BG 3007, BG 3008, BG 3009, BGD 1057, BGD 1058, BGD 1059 |
| IVT - *Kabuli* | BG 3010 |
| IVT - K (ELSK-I)* | BG 3011, BG 3012 |

***** Extra Large Seeded *Kabuli*

### 1.3.3 Lentil

#### 1.3.3.1 Entries in coordinated trials

In lentil, two entries (L 4586 and L 4587) belonging to small seeded group, two entries (L4701 and L4702) belonging to bold and extrabold seeded group, and one entry L 4503 belonging to extra early group were entered in IVT trials.

### 1.3.4 Fieldpea

#### 1.3.4.1 Entries in coordinated trials

Two dwarf genotypes (DDR 87 and DDR 88) and two tall genotypes (DMR 63 and DMR 64) of fieldpea were entered in All India Coordinated Trials.

### 1.3.5 Pigeonpea

#### 1.3.5.1 Entries in coordinated trial

Pusa 2008-2 with a zonal mean of 1.36 t/ha having a 12.2% increase over the check was promoted to AVT-1. It gives 50% flowers in 75 days and matures in 138 days with a test weight of 7.2 g. Two varieties, namely, Pusa 2009-05/1 and Pusa (PS) 2009-05/4 were entered in IVT- early trial for testing in NWPZ.

## 1.4 OILSEED CROPS

### 1.4.1 *Brassicas*

#### 1.4.1.1 Variety released

***Pusa Mustard 25 (NPJ 112).*** A mustard variety Pusa Mustard 25 (NPJ 112) suitable for multiple cropping system between September (after the harvest of *kharif* crops) and mid-December (up to the sowing of *rabi* crops, particularly, wheat and vegetables) was released and notified for Zone-II (Rajasthan, Haryana, Punjab, Delhi, plains of Jammu & Kashmir, Himachal Pradesh, and western UP). It is an additional crop and is a substitute of *B. rapa* cv. Toria (in toria's traditional belt). The average seed yield of this variety is 1.47 t/ ha in 107 days.

**Pusa Mustard 25, an early maturing mustard variety**

### 1.4.1.2 Elite entries in coordinated and common trials

Eighteen elite entries were contributed/promoted in All India Coordinated Trials.

**Advanced mustard entries at various stages of coordinated trials**

| Name of trial | Entry/entries | Zone |
|---|---|---|
| IVT-Toria/early mustard (Irrigated/rainfed) | EJ 22, NPJ 135 | Zones II, III, IV, V |
| AVT-1 Toria/early mustard (Irrigated) | NPJ 124, EJ 20 | Zone II |
| AVT-2 Toria/early mustard | EJ-17 | Zone III |
| IVT-Timely sown mustard (Irrigated/rainfed) | JS 29, NPJ 134 | All Zones |
| AVT-1 Timely sown irrigated | HYT 33 | Zone II |
| IVT - Late sown mustard | NPJ-140 | All Zones |
| AVT - Late sown mustard | NPJ 125 | Zone II |
| AVT-2 Late sown mustard | NPJ 113 | Zone II |
| IVT- Mustard quality | LET-40, LET-41 | Zone II, III |
| AVT-1 Quality mustard | LET-14-1, LET 36 | Zone II, III |
| IVT-Saline/alkaline conditions | NPJ-142 | All Zones |
| IVT-Karan rai (Rainfed) | NPC-18, NPC-19 | All India |

### 1.4.1.3 Conversion of CMS and restorers for hybrid development

The transfer of diverse CMS (*mori, can, bar, eru*) and restorer gene(s) from alien sources in cultivated *Brassica* was attempted. Good combiners such as Geeta, Pusa Tarak, EC-308575, EC 597318 (Double zero), Pusa Jai Kisan, IE 335399, Laxmi, SEJ-8, Pusa Agrani, and Bio-YSR were taken up for conversion and the materials are in different stages of backcrossing.

### 1.4.1.4 Breeding for low erucic Indian mustard

Based on the previous year's selections, the zero and double zero breeding material along with germplasm was grown for advancement and further selection on the basis of phenotypic data, erucic acid and glucosinolates content. In 869 samples analysed, the erucic acid content ranged from 0% to 30%. Zero erucic single plants were grown as single plant progenies under net/space isolation for nucleus seed production of released varieties and for sending seed of advance culture for testing in coordinated trials.

## 1.4.2 Soybean

### 1.4.2.1 Entries in coordinated trials

Soybean entry DS 2309 was tested in AVT-II in North Western Plains Zone, and the entry DS 2410 was tested in AVT-I in North Eastern Zone during *kharif* 2008 and were ranked first in respective zones.

# 1.5 FIBRE CROP

## 1.5.1 Cotton

### 1.5.1.1 Promising entry

***Pusa 72-9-37.*** A high yielding cotton variety Pusa 72-9-37 having 35% ginning out turn, 4.0 g boll weight, 28 mm fibre length, and 22.5 g per tex fibre strength was found suitable for Central Zone under irrigated condition. The seed cotton yield of the variety in the coordinated trial was 2.37 t/ha recording 25% and 17% increase in yield over that of the local and zonal checks, respectively.

**Pusa 72-9-37**

### 1.5.1.2 Entries in coordinated trials

P 57-6 was tested in Br 03(a) in North Zone, P 21-15 in Br03(b) in Central Zone, and P 403 and P 551 in national trials Br 02(a) and Br 02(b). P 1750, P 13-2 and P 23-1 were evaluated in TMC trial for machine picking.

## 1.6 VEGETABLE CROPS

### 1.6.1 Cole Crops

#### 1.6.1.1 Cauliflower

Thirty promising lines were advanced for further assessment and utilization in improvement programme. Sel 7 was found to be most promising with the highest average net curd weight of 680 g followed by DC 41-5 (590 g) and DC 23000 (510 g). Out of the 52 hybrid combinations attempted and evaluated in early maturity group, the highest net curd weight was observed in VV x Sel 7 (1000 g) followed by 351 x DC 23000 (850 g) and 327-14-8-3 x DC 23000 and XX x Sel 71(800 g). In mid-maturity group, the highest average net curd weight was observed in 8409 CMS (1155.33 g) followed by Pusa Shukti (1088.33 g) and Improved Japanese (1086.66 g).

Amongst self incompatible (SI) hybrids, CCm5 x DC 310-22 recorded maximum average net curd weight (1211.66 g) followed by CCm5 x DC 310 (1203.33 g) and CCm8 x SM (1183.33 g). In the case of CMS hybrids, out of 13 crosses evaluated, 8410 x 3-5-1-2 recorded the highest average net curd weight (1343.33 g) followed by 8410 x 309 (1312.66 g) and 8410 x Pusa Shukti (1240.66 g). In resistance breeding programme, 38 lines/advance generation populations evaluated for downy mildew and black rot disease resistance, were advanced for further evaluation and utilization as variety directly and/or in hybridization programme. Twenty-five $RIL_S$ and 8 $NIL_S$ were advanced to $F_5$ for further phenotyping and genotyping. Third backcross ($BC_3$) was attempted for introgression of sterile cytoplasm from *Erucastrum canariense* and *Brassica tournefortii* in Indian cauliflower using embryo rescue.

At Regional Station, Katrain, three CMS lines, *Ogu*1A, *Ogu*2A and *Ogu*3A were developed in cauliflower. These CMS lines along with their maintainers were characterized for horticultural, floral and seed setting related traits. Seed setting was satisfactory in all the lines and was the highest in *Ogu*1A (30.76 g/plant) and the lowest in *Ogu*2A (19.66 g/plant). Three CMS based hybrids KTH-51 (44.5 t/ha), KTH-52 (42.3 t/ha) and KTH-44 (39.6 t/ha) were found promising. For diversification of CMS system in snowball cauliflower, backcross ($BC_1$) was attempted to introgress sterile cytoplasm of *Trychoestoma ballii* and *Diplotaxis catholica* from *Brassica juncea* into cauliflower Pusa Snowball K-1 using embryo rescue. The cauliflower varieties Pusa Himjyoti, Pusa Snowball K-25 and DB-187-0 were found tolerant against DBM.

Two genotypes, DC 23 and DC 27 were promoted to AVT 1 in AICRP (VC) in early maturity group. Two snowball cauliflower hybrids, KTH-51 and KTH-52 were entered in IET for multi-location testing under the AICRP trial.

#### 1.6.1.2 Cabbage

Three SI hybrids, KGMR-5 (46.0 t/ha), KTCBH-51 (46.0 t/ha) and KCH-9836 (43.3 t/ha) and one CMS hybrid KTCBH-84 (39.3 t/ha) were found promising for yield and important horticultural traits. Transfer of CMS through back crossing programme to ten promising varieties/lines of cabbage was attempted in $BC_3$ stage after making selection for superior horticultural and reproductive traits. Source of CMS is being diversified by transferring cytoplasm of *Trachystoma balli* and *Diplotaxis catholica* through *Brassica juncea* into promising cabbage line by using embryo rescue technique. The cabbage genotypes Kinner Red, KIRC-9, KIRC-10 and MR-1 x C8 were found tolerant against DBM.

Two superior hybrids, KTCBH-51 and KTCBH-84 were entered in IET for multi-location testing under AICRP (VC) trial.

#### 1.6.1.3 Knol khol

The entry KS-1 gave the highest yield of 52.2 t/ha followed by KS-2 (49.2 t/ha) in the AVT-II at Katrain. Transfer of improved source of CMS from cabbage to 3 promising lines of knol khol was initiated.

### 1.6.2 Cucurbitaceous Crops

#### 1.6.2.1 Bitter gourd

Tissue culture protocol was developed for multiplication of gynoecious lines and their use in gynoecious ×

monoeciuos hybrid production. Twelve $F_1$ hybrids were developed through Line × Tester design by using 3 gynoecious lines derived from original gynoecious population (DBGY-201) and 4 monoeciuos testers were evaluated for yield and its related traits. The gynoecious hybrids showed significant positive heterosis for fruit girth and the hybrid DBGY-201-2 × 'Arka Harit' exhibited maximum fruit girth (5.0 cm). All hybrids gave greater number of fruits compared to those of the respective mid parent and the best combination was DBGY-201-1 × 'Arka Harit' (100%) followed by DBGY- 201 × 'Arka Harit' (97%). Bitter gourd genotypes were screened for resistance to soil salinity. The minimum defoliation and affected leaves per cent were recorded in WBBG-15 (52.19%) and WBBG-15 (44.22%), respectively. Among all genotypes, WBBG 15 and WBBG 18 were found to be the promising breeding lines which will be utilized for future breeding programme on salinity tolerance.

### 1.6.2.2 Cucumber

Seven novel genotypes of cucumber including gynoecious lines, carotene rich cucumber, *Cucumis hystivus*, disease resistant lines and gherkin types collected from USA through NBPGR were maintained and utilized in the crossing programme for broadening the genetic base of Indian cucumber. Selections DC 6 and DC 78 yielded 21.4 t/ha and 20.9 t/ha showing an increase of 28.1% and 25.1%, respectively over check Pusa Uday (16.6 t/ha). Gynoecious $F_1$ hybrid DCHG 10 and monoecious $F_1$ hybrid DCH 6 gave yields of 23.2 t/ha and 22.7 t/ha, which were 38.8% and 35.9%, respectively, higher than that of the check Pusa Uday. Parental polymorphism survey was done with the use of 14 SSR/SCAR markers and one gene based marker among two gynoecious lines and one monoecious line. Two SSR markers, CSWTAAA01 and CSWCTT14 and a PCR marker based on F locus linked to ACC synthase gene (CsACS1G) showed polymorphism between these lines.

A promising hybrid DC 6 was advanced to AVT-II of AICRP (VC) trial.

### 1.6.2.3 Luffa

Sponge gourd selections, DSG-43, DSG-6 and DSG-7 gave yields of 16.3 t/ha, 15.8 t/ha and 15.4 t/ha, which were 25.3%, 21.5% and 18.4%, respectively, higher than that of the check Pusa Sneha. Selections, DSG-6 and DSG-7 showed consistently high tolerant reaction to *Tomato leaf curl New Delhi virus* particularly during rainy season which was conducive for white fly multiplication and spread of the disease. Sponge gourd $F_1$ hybrids, DSGH-9 and DSGH-3 gave yields of 17.9 t/ha and 17.4 t/ha, which were 34.5% and 30.8%, respectively, higher than that of the check Pusa Sneha. Twenty-four $F_1$ hybrids of ridge gourd involving monoeciuos x monoeciuos inbred and monoeciuos x hermaphrodite inbred were developed. Five $F_1$ hybrids involving Satputia as one of the parents were advanced to $F_2$ to study the genetics of hermaphrodite sex form. Ridge gourd genotypes Sel DRG-61 and DRG-9 gave yields of 16.9 t/ha and 16.3 t/ha, which were 24.8% and 22.5%, respectively, higher than that of the check Pusa Nasdar.

A promising sponge gourd selection DSG-43 was advanced to AVT-II of AICRP (VC) trial.

### 1.6.2.4 Ash gourd

Two promising ash gourd selections, DAG-12 and DAG-13 developed earlier were evaluated and found to yield higher than the check both in summer and *kharif* seasons. They gave 51.40 t/ha and 56.00 t/ha yields, respectively, during *kharif* season. Both were earlier in maturity than Pusa Ujwal (check) with an average fruit weight of 10.5 kg (DAG-12) and 9.5 kg (DAG-13), respectively. Two promising hybrids (DAGH 16 and DAGH 46) were evaluated under large scale yield trial. The average yields were 55.00 t/ha and 58.50 t/ha, which were 26.0% and 42.0%, respectively, higher than that of the check Pusa Ujwal.

### 1.6.2.5 Minor cucurbits

Twenty-five germplasm of long melon, twenty-one germplasm of round melon, eight germplasm of summer squash and four germplasm of ivy gourd were collected, and their evaluation was in progress. Summer squash Sel-8 was found promising and showed a yield of 17.5 t/ha, an increase of 44% over that of the local check.

## 1.6.3 Solanaceous Crops

### 1.6.3.1 Brinjal

***Variety identified.*** A brinjal variety DBL-02 was identified for release for cultivation in Zone I (Jammu & Kashmir, Himachal Pradesh and parts of Uttarakhand), Zone IV (Punjab, Delhi, Uttar Pradesh and Bihar) and Zone VI


**A brinjal variety DBL-02 recommended for cultivation in Zones I, IV and VI**

(Haryana, Rajasthan, Gujarat, Dadra & Nagar Haveli and Daman & Diu) in the XXVIII AICRP (VC) group meeting during January, 2010. Its fruits are long, violet-purple with round pistal end, each fruit weighing 80-90 g. The maturity period (days to first fruit harvest) is about 55 days from transplanting. Its yield is 38.2 t/ha, which is 26.9% higher than that of the national check Punjab Sadabahar (30.1 t/ha).

In a trial comprising long fruited hybrids, DBHL 20 (54.7 t/ha), DBHL 115 (51.6 t/ha) and DBHL 150 (50.0 t/ha) were found promising with an increase of 16.8%, 10.3% and 6.8%, respectively, over that of the check Pusa Hybrid 5 (46.8 t/ha). Among round fruited varieties, DBR 190 gave the highest yield of 39.3 t/ha, which was 14.9% higher than that of the national check KS 224 (34.2 t/ha). Seventy-five genotypes and $F_1$ combinations were screened against *Phomopsis* blight. Three hybrids, DBHL 161, DBHL 147 and DBHL 33 were found tolerant. Fifty genotypes and $F_1$ combinations were screened against shoot and fruit borer. Two hybrids, DBHL 150 and DBHSR 20 were found tolerant. Five lines each of *Solanum aethiopicum* and *S. incanum*; three lines each of *S. gilo* and *S. insanum*; and two lines each of *S. indicum*, *S. torvum* and *S. integrifolium* were collected.

### 1.6.3.2 Tomato

Two tomato varieties, DT 5 and DT 6 and the tomato hybrids, DTH 5 and DTH 6 were entered in AVT-I stage of AICRP (VC) trial.

Genotypes, H 86-1, H 86-4, Sel-6-11-1, TH 348-1, and TH 348-3 and hybrid combinations, N 5 x H 36 and N 1 x H 88-1 were found resistant to *Tomato leaf curl virus* (TLCV) with a high fruit yield. Fifteen genotypes were evaluated for quality traits like lycopene content, total polyphenols, antioxidant activity, ascorbic acid content, acidity and TSS. Pusa Rohini recorded maximum lycopene content (92.66 ± 1.66 mg/100 g) and ascorbic acid (40.44 ± 0.48 mg/100 g) while Cherry tomato orange recorded maximum polyphenols (135.0 ± 3.51 mg GAE/100 g) and antioxidant activity (4.84 ± 0.09 µmol TROLOX/g). The variety Pusa Gaurav had maximum acidity (0.63 + 0.0% acidity) and Cherry tomato red had maximum TSS (9.23 ± 0.41$^{O}$ Brix). Thirty genotypes were screened under artificial conditions for biotic stress against root-knot nematode (*Meloidogyne incognita*). Genotypes Pusa 120 and Hisar Lalit were found resistant. The varieties, Pusa Sadabahar, Pusa Sheetal, and Booster, and the hybrids N 5 x 3, 1234 x 3, Pusa Sheetal x 3 were found superior for setting fruits under high temperature (28±2 °C) and the hybrids 3 x Pusa Sheetal, 3 x H86, and H83 x 83 were found superior under low temperature (8±2 °C) during December to January.

### 1.6.3.3 Chilli

Thirty chilli lines comprising CMS and restorer lines and virus resistant lines were collected from AVRDC, Taiwan and their seed multiplication was in progress. Ten indigenous collections with desirable horticultural traits were subjected to pure line selection. Cluster and pendent fruit bearing genotypes were identified from a segregating material of Pusa Sadabahar x Pusa Jwala. Forty genotypes were screened for leaf curl virus tolerance under natural epiphytotic conditions and 3 selections, DCL 301, DCL 201, and DCL 521 were identified as tolerant. Seed multiplication of these lines was done to carry out further study.

### 1.6.3.4 Capsicum

The bell pepper hybrid KTCPH 9 had an average yield of 1.3 kg/plant under open field conditions and the fruits were dark green in colour. Among paprika types, Katrain Paprika Hybrid 1 was the highest yielder with an average per plant yield of 1.6 kg.

The genetic male sterile line of sweet pepper YC 12 A was maintained with Yellow Capsicum. Other genetic male

sterile lines, viz., YW 12 A was maintained with Yolo Wonder. In an experiment to attempt the use of insect pollinators for hybrid seed production of paprika, it was found that with the use of pollinating insects like honey bees and other insects, found in wild fauna, a seed setting of 2662 seeds/plant in 25 fruits/plant was obtained suggesting thereby that the use of insect pollinator for hybrid seed production of capsicum (paprika) is a viable option. Another male sterile line of capsicum (KMS-1) was found to be cytoplasmic in nature and was maintained by using maintainer line KM-1.

## 1.6.4 Root and Bulbous Crops

### 1.6.4.1 Carrot

***Varieties released (Pusa Asita and Pusa Nayanjyoti).*** A tropical black carrot variety Pusa Asita (IPC 126) developed for the first time in the country was released and notified by Delhi State Seed Sub-Committee. It is suitable for main season sowing beginning September under north-Indian conditions. It is characterized by small purplish green foliage and long black coloured self core roots. It takes about 90-110 days to reach marketable stage for harvesting with an average root yield of 25 t/ha. It is also a rich source of anthocyanins (520 mg/100 g), Zn (8.45 µg/g), Fe (260.60 µg/g) and Ca (368.67 µg/g).

A temperate carrot hybrid, Pusa Nayanjyoti (KTCTH 7) developed at the Regional Station, Katrain (HP) was released by the HP State Seed Sub-Committee for cultivation in Himachal Pradesh. It is the first orange coloured temperate carrot hybrid developed by a public sector institution in India. It is also suitable for other regions of India, where temperate types of carrot are grown. The average yield potential of this hybrid is 39.6 t/ha with an increase of 73% over that of the commercial variety Pusa Yamdagni. Its roots are orange, uniform, attractive, smooth, cylindrical and stumpy with small indistinct self-coloured core. It possesses a higher β-carotene content (7.55 mg/100 g of fresh weight).

***Promising genotypes.*** Out of 46 open pollinated lines/varieties of tropical carrot sown, 35 were found promising and were assessed for quantitative and quality traits. The highest root weight was recorded in IPC 4 (178.33 g) followed by that in IPC 34 (175 g), IPC $Ht_1$ (171.66 g) and IPC 29 (170 g). The highest β-carotene was recorded in IPC 25 (5.54 mg/100 g) followed by that in IPC 132 (4.73 mg/100 g) and IPC 4 (4.73 mg/100 g). CMS system was established in 36 diverse improved genetic backgrounds of tropical carrots. The highest average root weight was recorded in CMS 98 background (300 g) followed by that in CMS 11 (280 g). One hundred and forty hybrid combinations were attempted using CMS system. On evaluation, 25 of them were found

**Pusa Asita, the first tropical black carrot variety released in India**

**A temperate carrot hybrid Pusa Nayanjyoti released for Himachal Pradesh**

promising for root characteristics and CMS 126 x IPC 96 and CMS 126 x IPC 39 (360 g) recorded the highest average root weight followed by CMS 98 x IPC 124 (350 g) and CMS 11 x IPC 120 (340 g). Ninety-six experimental hybrids of temperate carrot involving sixteen CMS (A) lines and six pollinator (C) lines were generated and evaluated in station trials. The hybrid Pusa Nayanjyoti maintained its superiority by yielding 45.8 t/ha followed by KCTH 1020 (44.2 t/ha) and KTCTH 8 (42.5 t/ha).

Two carrot hybrids, namely, KTCTH 7 (Pusa Nayanjyoti) and KTCTH 8 were evaluated in AICRP (VC) trials.

### 1.6.4.2 Onion

Three onion selections, Sel-383 with dark red (41.52 t/ha), Sel-106 with white (37.65 t/ha) and Sel-RO-6 with pink (37.29 t/ha) coloured bulbs performed better than the check Pusa Red (28.50 t/ha). Among CMS hybrids, new combinations, H-73 (43.21 t/ha), H-82 (40.0 t/ha) and H-83 (38.4 t/ha) were found promising and exhibited 51.6%, 40.3% and 31.7% increase in yield, respectively, over that of the variety Pusa Red (28.5 t/ha). In *kharif* onion trials (for abiotic stress tolerance), Sel-157, Sel-126, Sel-102-1 and Sel-106 were promising for yield. Selections Sel-126, Pusa Red and B-line were found superior for dehydration, high TSS and storage.

Sel-126 and Sel-153 were advanced to AVT-II and Sel-157 and Sel-397 to AVT-I under AICRP (VC) varietal trials.

### 1.6.4.3 Radish

Six newly developed genotypes of radish were evaluated along with three released varieties and one hybrid. Genotype DC (W-W) recorded the highest average root weight (296.66 g) followed by DC (G-S) (243.33 g). The highest average root girth was in Palam Hriday (20.93 cm) followed by that in DC (W-W) (21.06 cm), DC ($P_u$-$P_u$) (18.30 cm) and DC (G-S) (18.20 cm). The vitamin C contents were maximum in Palam Hriday (60.03 mg/100 g) followed by that in DC ($P_u$-$P_u$) (46.90 mg/100 g), DC (W-P) (40.06 mg/100 g) and DC ($P_i$-$P_i$) (40.02 mg/100 g).

## 1.6.5 Leguminous Crop

### 1.6.5.1 Garden pea

Selections GP-17, GP-207 and GP-473 were found to possess a high degree of resistance to *Fusarium* wilt under sick plot while Arkel was highly susceptible. In a station trial, GP 17 and GP 473 recorded the highest yield (9.63 and 10.0 t/ha, respectively) against the check Arkel (7.20 t/ha) and Pusa Pragati (5.63 t/ha). Out of 150 lines evaluated, 25 lines were found resistant under field condition against powdery mildew diseases. Under new strains development, 190 new $F_1$s were made to develop high yielding disease resistant varieties. Besides, segregating materials of 47 crosses ($F_2$-$F_6$ generation) were advanced for further selection/evaluation.

### 1.6.5.2 Minor legumes

In Faba bean, 25 new germplasm were collected and multiplied for further evaluation. Three promising selections of Dolichos bean, namely, Sel-4 (purple), Sel-5 (long white) and Sel-6 (small white) were multiplied for further evaluation.

## 1.6.6 Malvaceous Crop

### 1.6.6.1 Okra

One hundred and fifty okra genotypes, i.e., segregating generations ($F_2$ & $F_3$), and single plant selections (SPS) were evaluated and superior lines in terms of pod characters, yield and resistance against yellow vein mosaic virus (YVMV) were selected for their further generation advancement. Fifteen single plant selections were made from promising lines, DOV-1, DOV-2 and Sel-1 for further improvement and purification. Fifteen genotypes of different wild species of *Abelmoschus* were collected and evaluated against YVMV, mites, jassids, etc. *A. tetraphyllus* was found resistant against yellow vein mosaic virus; however, other species were moderately resistant.

## 1.6.7 Under-utilized Leafy Vegetable Crops

Five germplasm of beet leaf and spinach were collected and evaluated for further purification. Simultaneously crosses were made between Virginia Savoy and Spinach (PS-1) for creating variability. Seven genotypes of *bathua* (*Chenopodium*) were selected and selfed. Among them, one genotype was found promising for higher foliage yield. Fourteen *methi* genotypes were evaluated and 4 superior selections were made for their leaf yield and quality.

## 1.7 FRUIT CROPS

### 1.7.1 Mango

**Fruits of mango Hybrid 11-2**

#### 1.7.1.1 Hybridization in mango

Crosses were attempted during March 2010 using Amrapali as female parent and Sensation, Pusa Arunima, Tommy Atkins, H-11-2, Bhadauran and H-8-11 as male parents in six different cross combinations. In total, 343 panicles involving 1,963 flowers were pollinated.

#### 1.7.1.2 Evaluation of new mango hybrids

Sixteen potential mango hybrids were evaluated for different physico-chemical attributes. The hybrids, namely, H-1-1 (Amrapali x Sensation), H-1-6 (Amrapali x Sensation), H-2-6 (Amrapali x Lal sundari) and H-4-12 (Dashehari x Sensation) performed consistently better. These hybrids are regular bearers with high yield and suitable for close planting. Another potential hybrid H-11-2 had intense red colouration on peel, is a regular bearer, and had desirable canopy and bigger fruits (317.98 g) with a high pulp: stone ratio (11.31). This hybrid will be evaluated further for different desirable traits.

### 1.7.2 Citrus

Different collections of acid lime, mosambi and malta sweet orange were evaluated under Delhi conditions to identify less seeded better quality variants. In acid lime collections, ALC-6 bore the heaviest fruit (69.62 g) followed by ALC-2 (61.08 g) and ALC-4 (46.86 g). However, juice content was recorded the maximum in ALC-1 (55.54%) followed by that in ALC-2 (53.27%) and ALC-6 (51.26%). The number of seeds per fruit varied from 6.8 seeds in ALC-1 to 30.8 seeds per fruit in ALC-2. Acidity was found to be the highest in ALC-5 (6.86%) and minimum in ALC-4 (4.67%).

**Acid lime collection – ALC 1**

Three mosambi collections, viz., MOS-1, MOS-2 and MOS-3 were found promising. Collection MOS-1 had the heaviest fruit (229.97 g), with good fruit size (75.87 x 78.78 mm), low peel thickness (6.15 mm), low seed number (12.4 seeds/fruit) and good fruit quality, i.e., juice content (50.38%), TSS (9.92%) and acidity (0.52%). In Malta collection, fruit weight varied from 356.88 g in MS-3 to 172.00 g in MS-2. Juice recovery was found to be the highest in MS-2 (52.08%) followed by MS-7 (43.44%). Collection MS-2 had the highest TSS (11.58%).

Four grapefruit cultivars were evaluated for physico-chemical parameters to find out suitable cultivar(s) for north

**Acid lime collection – ALC 6**

Indian conditions. Imperial attained maximum fruit weight (429.11 g), whereas juice recovery (49.90%) was the highest in Marsh Seedless. The number of seeds varied from 4.4 in Red Blush to 47.4 seeds in Foster. The minimum peel thickness (5.23 mm) and the highest TSS (10.48%) were recorded in Marsh Seedless.

## 1.7.3 Kinnow

Roving survey was conducted in different blocks of Abohar (Punjab) and Sri Ganganagar (Rajasthan) during January 2010 for identifying less seeded Kinnow mandarin variants.

Out of the 30 orchards surveyed, two promising genotypes each from Abohar (KSBA-3, KSKA-4) and Ganganagar (KSLG-1, KSG-2) were identified.

The number of seeds in these genotypes varied between 9 and 14 as compared to 25 and 30 seeds per fruit in original genotype. Trees have been marked for collection of bud-wood, their multiplication and evaluation under Delhi conditions.

## 1.7.4 Grape

Seventeen $F_1$ hybrid seedlings were planted for evaluation. Two thousand five hundred twenty-one (2,521) $F_1$ hybrid and selfed seeds were produced using 10 different cross combinations and 107 panicles.

Thirty-two hybrids were assessed for their fruit and quality characters. Of these, Banqui Abyad x Perlette-75-32 and Hur x Cardinal-76-1 performed well on Head system of training with good quality fruits, early ripening and high yields. New hybrids, viz., Hybrid 2005-6-17, Hybrid 2006-11-8 and Hybrid 2006-12-1 were found early ripening with good berry quality. Forty germplasm were added during the year. Five grafted wine varieties were planted for evaluation under Delhi conditions.

**Yield and physico-chemical quality of grapefruit cultivars under Delhi conditions**

| Cultivar | Yield | Fruit weight (g) | Juice (%) | Seeds/fruit | Peel thickness (mm) | TSS (%) | Acidity (%) |
|---|---|---|---|---|---|---|---|
| Foster | 22.45 | 414.26 | 41.93 | 47.4 | 6.21 | 8.76 | 1.14 |
| Imperial | 28.40 | 429.11 | 38.80 | 46.4 | 5.78 | 9.56 | 0.81 |
| Marsh | 8.63 | 259.06 | 49.90 | 4.4 | 5.23 | 10.48 | 1.24 |
| Red Blush | 12.75 | 305.15 | 46.55 | 4.5 | 6.05 | 10.24 | 1.18 |

**Performance of some promising grape hybrids on head system of training**

| Hybrid | Ripening | Av. No. bunches/vine | Av. bunch wt. (g) | Av. berry wt. (g) | TSS (%) | Remarks |
|---|---|---|---|---|---|---|
| 2005-6-17 | 2nd wk June | 17.0 | 425.0 | 1.80 | 20.0 | Greenish-yellow seedless |
| 2006-11-8 | -do- | 19.0 | 450.0 | 1.90 | 20.0 | Yellowish-green seedless |
| 2006-12-1 | -do- | 12.0 | 425.0 | 1.80 | 18.0 | Yellowish-green seedless |

## 1.7.5 Papaya

### 1.7.5.1 Papaya improvement

At Regional Station, Pusa, 16 papaya germplsam lines were evaluated for different horticultural traits. Minimum height (39 cm) and nodes at first flowering (22) were observed in Pusa Nanha, whereas maximum height (110 cm), stem girth (17 cm), number of fruits (45), weight of fruit (1.80 kg) and TSS (13.4%) were observed in Red Lady. Selection PP-2-8 having pink flesh is under evaluation for various fruit physico-chemical properties.

## 1.7.6 Temperate Fruits

### 1.7.6.1 Apple

A semi-vigorous rootstock selection from *Malus baccata* Shillong was named Pusa Seb Mulvrint-1. Work was initiated in dwarfing, semi-dwarfing and vigorous categories on the basis of leaf stomata to identify suitable pollinizers by crossing *Malus* sp. with different cultivars. DNA fingerprinting by the use of RAPD and ISSR techniques was started to ascertain whether different *Malus baccata* accessions belong to a single species or are evolved as different species or natural hybrids.

**Bottom heated technique in apple**

Through Bottom Heated Technique standardized and designed by the Regional Station, Shimla hardwood cuttings as well as grafted cuttings were successfully rooted. Database for different indigenous and existing *Malus* sp. was prepared both as a searchable database in Microsoft Access and as hard copies. Variability in chilling units experienced under Shimla conditions is being evaluated to ascertain the extent of variability and its impact on the flowering physiology of temperate fruit crops.

### 1.7.6.2 Apricot

Survey and collection of wild and cultivated apricot germplasm was made in Himachal Pradesh. The cultivars, Charmagz, St. Ambriose, Suffaida Oblonga, Nari Kinnaur and Kaisha Kinnaur were rated the best in organoleptic tests and were suitable for drying purposes owing to their high TSS and dry matter contents. *Prunus japonica* was identified as a dwarfing rootstock for apricot, peach, plum and cherry.

**Dwarfing effect of *Prunus japonica***

### 1.7.6.3 Kiwifruit

Application of growth retardant CPPU (N-(2-chloro-4-pyridyl)-N-phenylurea) produced dark skin colour and slight changes in appearance and advancement in ripening by one week. There was reduced flesh firmness, increased soluble solids and decreased titrable acidity. The average fruit weight was further increased by light summer pruning in intervals along with CPPU application in addition to regular winter pruning. The “A” grade size of fruit increased from 10% to 45%. Through bottom heated technique, the hardwood cuttings of kiwi fruit cultivars were successfully rooted by dipping in 3000 ppm IBA for 30 seconds.

**Increased fruit size in kiwi**

### 1.7.6.4 Pear

*Pyrus pyrifolia (serotina), P. pashia* and *P. pashia* var *kumaonii* are vigorous rootstocks for pear. *P. calleryana* showing signs of delayed incompatibility in growth of scion on this rootstock is now on a par with other stocks though initially it appeared to be dwarfing. Their performance is under evaluation.

### 1.7.6.5 Walnut

"Pusa Khor" is a recently selected lateral bearing walnut clone which commences bearing fruit from the second year of planting as compared to 8-12 years taken by most other commercial cultivars. Besides precocity, the lateral bearer is also known to be a high yielder and suitable for high density planting. Pusa Khor has exhibited higher rate of photosynthesis and transpiration as compared to other grafted walnuts of comparable age. Bearing habit of Pusa Khor was noted 65.0% laterally and 35.0% terminally.

**Nuts of Pusa Khor**

## 1.8 ORNAMENTAL CROPS

### 1.8.1 Gladiolus

#### 1.8.1.1 Varieties identified

***Pusa Kiran (Ave Open).*** The gladious variety Pusa Kiran is a selection from the open pollinated population of the variety 'Ave'. The selection produces white coloured florets (16 – 18 in number) on long and sturdy spikes. It produces very good spikes well suited for vase decoration, bouquet preparation and for floral arrangements, which last for more than 10 days. The florets are white (155 B) in colour with ray like red colour (53 C) markings on throat. It has good spike length (>95.00 cm), rachis length (>55.00 cm) and number of florets per spike (>16). It is a very good multiplier producing more than two corms (on an average 2.53) and 20 cormels from each mother corm. This is an early variety flowering in about 75 days.

**Spikes of gladiolus variety Pusa Kiran**

***Pusa Shubham.*** Pusa Shubham is a selection from the cross between Lucky Shamrock and Green Lilac. The variety produces very good spikes well suited for vase decoration,

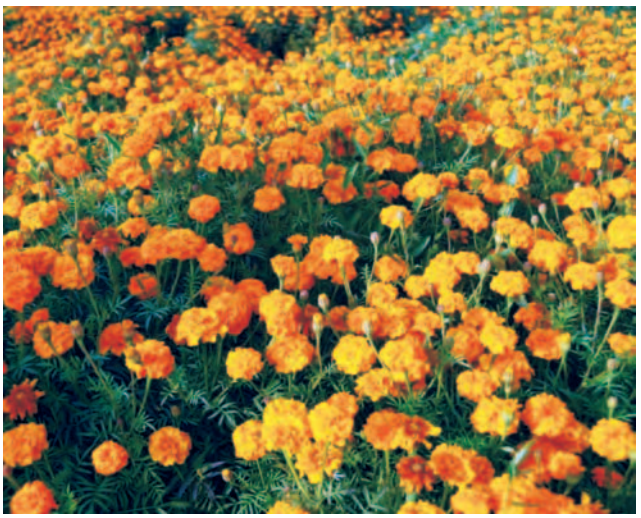
**Spikes of gladiolus variety Pusa Shubham**

bouquet preparation, floral arrangements, etc., which last for more than 10 days. It is an early variety flowering in about 72 days. The florets are cream or light yellow in colour (2 D) with red-purple (71 C) markings on yellow base of the throat. Spikes are more than 85 cm in length with good rachis length (>42.00 cm) and 14 numbers of florets per spike. The inter-floret length is less which results in compact arrangement of florets on one side of the spike. About 6-7 florets remain open at a time which makes it excellent for vase decoration or for making floral bouquets or arrangements. Further, it is a very good multiplier producing two corms and more than 23 cormels from each mother corm.

## 1.8.2 French Marigold

### 1.8.2.1 Variety identified

***Pusa Arpita.*** A French marigold variety Pusa Arpita was identified for release by IARI Variety Identification Committee. The variety is a selection from heterozygous material collected from farmers' field. The variety produces yellow coloured medium sized flowers suitable for loose flower production. The variety flowers during December-January. The potential yield of the variety is 15-20 t/ha.



**A French marigold variety Pusa Arpita**

## 1.8.3 Chrysanthemum

### 1.8.3.1 Varieties identified

***Pusa Anmol.*** A chrysanthemum variety Pusa Anmol was identified for release. It is a highly floriferous bushy variety with yellowish pink flowers, and is a *gamma* ray induced mutant of cv. Ajay. It is a thermo- and photo-insensitive variety and produces three flower flushes in a year (October-November, February-March and June-July) as against one in a majority of the cultivars. The variety flowers in 85-100 days after transplanting, and is ideal for loose flowers and whole plant cut flower. Its blooms remain fresh for 20-22 days in field conditions.

**Flowers of chrysanthemum variety Pusa Anmol**

***Pusa Centenary*.** Pusa Centenary, a vigorous growing chrysanthemum variety producing very big yellow flowers was identified for release This variety is a *gamma* ray induced mutant of cv. Thai Chen Queen. It blooms in 100-110 days after transplanting, and is ideal for cut flower production. The blooms remain fresh for 20-22 days in field conditions.

**Flower of chrysanthemum variety Pusa Centenary**

### 1.8.4 Lilium

#### 1.8.4.1 Production of allotriploid and diploid in Lilium

Seventy-two intersectional crosses were made between four LA hybrid selections and two Asiatic Lilium hybrids with the objective to produce more allotriploid and diploid for further introgression breeding. Maximum number of healthy seeds (254) were found in a cross combination of 'LA Sel.3 x Pollyanna'. Earlier epigeal (29 days) and maximum seed germination of 11% was recorded in 'LA- Sel-4 x Pollyanna'.

#### 1.8.4.2 Evaluation of Longiflorum Asiatic (LA) hybrids

Seven LA hybrid seed selections were evaluated under open field conditions. Early flowering (82 days) was recorded in LA Sel-I. The cultivar Samur took 114.3 days to flowering. Plant height was recorded to be maximum (65.6 cm) in Samur.

### 1.8.5 Alstromeria

Two cultivars of Alstroemeria, viz., Aladin and Pluto were evaluated under polyhouse for year-round flower production. The cultivar Pluto was found to be superior.

## 1.9 SEED SCIENCE AND TECHNOLOGY

### 1.9.1 Hybrid Vegetable Seed Production

#### 1.9.1.1 Tomato

A comparative evaluation was made on the efficacy of hybrid tomato seed production under temperature controlled polyhouse, ventilated polyhouse and nethouse conditions *vis-à-vis* that in the open field. It was found that the onset of flowering both in polyhouse and ventilated polyhouse conditions was 20-30 days earlier than that under nethouse and field conditions. Fruit setting was more under temperature controlled polyhouse ranging from 54% to 78% as against 54% to 72% and 47% to 65% under polyhouse and nethouse conditions, respectively, in the female parent of Pusa Hybrid 2 and Pusa Hybrid 4. However, overall hybrid seed yield was higher in the case of Pusa Hybrid 4. High viability of pollen of the male parents of these two hybrids was observed under controlled conditions. On an average, 60 crossed fruits could be retained per plant in the female parent of Pusa Hybrid 4 to achieve seed yield of >3.0 kg/100 sq. m. in temperature controlled polyhouse.

#### 1.9.1.2 Cauliflower

Seed production technology for cauliflower hybrid Pusa Kartik Sankar was standardized for north Indian condition. Following a planting ratio of 4:2 (female : male) and application of IAA @ 50 ppm or $GA_3$ @ 250 ppm at different growth stages to the female parent, an average yield of 30 g seed/plant of hybrid Pusa Kartik Sankar was achieved. Thus, an average production of 200-300 kg hybrid seed/ha can be obtained. For the multiplication of the self-incompatible line of the cauliflower hybrid Pusa Kartik Sankar, repeated application of NaCl (4-6 %) at 4 days interval was found appropriate.

#### 1.9.1.3 Brinjal

A comparative evaluation of hybrid seed production in insect proof nethouse and open field conditions revealed that seed production under insect proof net house condition is more profitable giving a seed yield of 2.0-2.3 kg/100 sq.m as against 1.6 kg under open field condition in female parents of Pusa Hybrid 5, 6 and 9 .The stigma receptivity was longer

**Brinjal hybrid seed production plot under open field (L) and insect proof nethouse (R) conditions**

(1-2 days ), fruit and seed setting was higher (10-22%) and seed quality was better under nethouse as compared to open field condition. On an average, 10 to 12 and 6 to 8 crossed fruits/plant could be retained in long and round genotypes, respectively, to achieve high seed yield and better quality under insect proof net house condition. The seed crop raised in the nethouse also required 5 to 6 less pesticidal sprays compared to those in open field, thus, further reducing the cost of seed production.

### 1.9.1.4 Bitter gourd

Hybrid seed production studies undertaken in open field and net house conditions in *kharif*, 2009 showed positive correlations of fruit weight with number of seeds/fruit, 100-seed weight and seed quality. Maximum fruit and seed setting was achieved in vines when crossed between 15$^{th}$ and 30$^{th}$ August (Mean Temp: 30.8 $^{o}$C; Mean RH: 78%) and 10$^{th}$ and 20$^{th}$ September (Mean Temp: 29.2 $^{o}$C; Mean RH: 70%), respectively, in nethouse and open field conditions. Hybrid seed production in the nethouse showed vigorous, healthy and insect free crop which produced more crossed fruits (2-4 fruits) with higher fruit weight (10-20 g/ fruit), higher seed yield/fruit (more filled seed) and better seed quality as compared to those in open field conditions.

### 1.9.1.5 Carrot

Studies on hybrid seed production technique conducted at Regional Station, Katrain revealed that Female:Male planting ratio of 8:2 was most suitable for economical production of hybrid seed of temperate carrot Pusa Nayanjyoti.

## 1.9.2 Characterization and Maintenance of Protogynous Lines in Indian Mustard

Studies on the characterization and maintenance of protogyny and self incompatibility system based parental lines in Indian mustard (reported in previous years) and evaluation of hybrids based on these were initiated. The duration of protogyny ranged from 3 to 13 days, depending on the genotype and mean temperature. Various pollination methods and application of inorganic salts, amino acids and growth promoting chemicals were attempted for maintenance of protogynous and self incompatible lines with varying success. Best results were obtained with kinetin, aspartic acid and lysine applications.

## 1.9.3 Characterization of Farmers' Rice Varieties for DUS Testing Purpose

Sixty farmers' varieties of rice collected from different states of the country were morphologically characterized based on national DUS test guidelines for plant variety protection. The data showed that while many of the characteristics of national DUS test guidelines did not show much variations, some of the new characteristics were prominent in these varieties which need to be included as additional characteristics in the national DUS test guidelines. A number of farmers' varieties, which were presumed to be variants of a released variety Patel 3, were examined on morphological as well as molecular characteristics and showed a high level of similarity.

## 1.9.4 Seed Quality Evaluation and Enhancement

Based on three years' study, seed vigour standards were determined in onion and soybean. It was found that in onion, germination count of about 80% in the standard germination test corresponded to about 50% field emergence and more than 60% first count in standard germination test after accelerated ageing (AA) test predicted more than 70% germination after 9 months of storage. Solid matrix priming and halo priming with 0.3% $KNO_3$ or coating with Royalflo was most effective in enhancing the field emergence as well as maintaining above 75% germination in onion up to 9 months of storage.

In soybean, more than 80% germination after dual stress vigour test, which is based on low oxygen and volatile aldehyde stress, corresponded to more than 50% field emergence. Similarly, more than 50% first count in germination test after accelerated ageing predicted 70% germination or more after 9 months of storage.

For predicting the planting value of maize seed in terms of high field emergence, cold test was found most reliable with a correlation co-efficient of r = 0.745**. This was followed by electrical conductance of seed leachate (-0.725**) and accelerated ageing test (0.670**).

Seed enhancement treatments in maize, namely, hydropriming (17 h/20 °C) + thiram (3 g/kg) , halopriming ($KNO_3$ : 0.3%), biopriming with coelomic fluid and fulvic acid (0.1%), and electromagnetic stimulation significantly improved field emergence of maize by 1-3 days (3% - 15%) , its uniformity , speed of emergence (11% - 22%) , early seedling growth (11% - 50%), early vegetative growth and plant height, over those of the control under field conditions.

Seed enhancement treatments with Royal flo @ 5 ml/kg of seed or thiram @ 2 g/kg of seed + imidachloroprid @ 2 7.5 ml/kg improved the field emergence, seedling vigour and growth in chickpea and also maintained higher seed quality during storage.

Seed treatment with various botanicals and bio-control agents for controlling loose smut in wheat varieties revealed significant varietal and treatment differences. In untreated seeds, it ranged from 2.41% to 6.61% in different genotype, while it was nil in seeds treated with turmeric powder. Several bacterial and fungal bio-control agents were tested against seed borne pathogen *B. oryzae* on paddy seed. It was observed that *Trichoderma* isolate, i.e., CIAH 10 could suppress up to 60% pathogen incidence.

Significant diversity was observed with respect to morphogenesis of rice false smut (*Ustiloginoidea virens*) in seed samples collected from different agro climatic regions of India.

## 1.9.5 Seed Testing Protocols for Medicinal Plant Species

Seed testing protocols were standardized for two commercially important medicinal plant species, i.e., *Cassia angustifolia* (Senna) and *Abelmoschus moschatus* (Muskdana). Quick viability test, following topographical tetrazolium staining, was also standardized for muskdana. Physical purity and seed germination standards were also suggested in Ashwagandha.

Germination for both the species could be tested following 'Between Paper Method' at 25 °C taking first and final count after $6^{th}$ and $12^{th}$ days, respectively. Both the species exhibited physical dormancy and required pre-treatment with concentrated $H_2SO_4$ for 15-30 minutes followed by thorough washing in running water.

## 1.9.6 Efficacy of Seed Treatment against *Fusarium moniliforme*, the Causal Organism of Bakanae Disease in Paddy Variety Pusa Basmati 1121

At the Regional Station, Karnal, paddy seed of cv. Pusa Basmati 1121 was inoculated with *Fusarium moniliforme*, the causal organism of bakanae disease in paddy (Titer of inoculant = 3.9x $10^8$ cfu/ml). After 5 days of inoculation, the seeds were treated by soaking overnight in solutions of Bavistin @ 0.25%, *Trichoderma viride* @ 0.4%, Captan @ 0.2% + streptocycline @ 1 ppm and in plain water which served as control. The excess water was drained out and the seeds were assayed for fungal infection by blotter technique. The results revealed that seed treatment with Bavistin @ 0.25% and Captan @ 0.2% + Streptocycline @ 1 ppm was effective in the control of the pathogen on seed followed by *Trichoderma viride* @ 0.4% as against control.

**Per cent infection of *Fusarium moniliforme* in different seed treatments**

| Seed treatment | Dose | Per cent infection |
|---|---|---|
| Bavistin | 0.25% | $0.0^c$ |
| Captan + Streptocycline | 0.2% + 1ppm | $0.0^c$ |
| *Trichoderma viride* | 0.4% | $23.5^b$ |
| Plain water | - | $45.5^a$ |
| $LSD_{0.01}$ | | 6.0*** |

## 1.9.7 Efficacy of Seed Treatment and Foliar Application of Different Fungicides in the Control of Sheath Blight Disease in Paddy cv. Pusa Sugandh 2

The efficacy of different seed treatments in combination with foliar application (one and two sprays) of fungicides was assessed in the control of Sheath blight disease in paddy cv. Sugandh 2.

The results indicated that seed treatment should be followed by foliar spraying for effective control of the disease. Seed treatment with Captan @ 0.2% + streptocycline 100 ppm was more effective than the treatment with streptocycline 100 ppm alone. Two foliar sprayings with Contaf @ 0.2% effectively controlled the disease.

## 1.9.8 Foliar Efficacy of Different Fungicides in the Control of Karnal Bunt Disease in Wheat

Different fungicides and bio-fungicides were assessed as foliar application in wheat variety HD 2687 in the field for the control of Karnal bunt disease and related parameters. Spraying was done at booting stage of the crop. The results revealed that spraying with Tilt/vitavax gave best results with regard to disease control, seed yield, 1000-seed weight, seed germination and vigour. These results were also comparable with half dose of Tilt and Tilt (half dose) + *Trichoderma viride*.

**Effect of different fungicides on the incidence of Karnal bunt disease and seed yield**

| Treatment | % Infection* | Seed yield (t/ha) |
|---|---|---|
| Untreated | $0.28^{a}$ | $3.97^{ab}$ |
| Tilt (0.1%) | $0.06^{d}$ | $3.65^{b}$ |
| Vitavax Power (0.25%) | $0.06^{d}$ | $4.63^{a}$ |
| Bavistin (0.25%) | $0.25^{ab}$ | $3.98^{ab}$ |
| TV (0.4%) | $0.22^{b}$ | $3.85^{ab}$ |
| *P. fluorescence* (0.4%) | $0.25^{ab}$ | $4.15^{ab}$ |
| Tilt + TV (0.05+0.4%) | $0.07^{d}$ | $3.98^{ab}$ |
| Bavistin + TV (0.125+0.4%) | $0.08^{d}$ | $3.68^{b}$ |
| Vitavax + TV (0.125+0.4%) | $0.24^{ab}$ | $4.03^{ab}$ |
| P.f + TV (0.4+0.4%) | $0.14^{c}$ | $3.93^{ab}$ |
| Tilt (0.05%) | $0.07^{d}$ | $4.00^{ab}$ |
| $LSD_{0.05}$ | 0.04*** | NS |

*based on seed infection

## 1.9.9 Seed Agronomy of Pusa Basmati 6 (Pusa 1401)

A field experiment was conducted at Karnal during *kharif* 2009 to study the effect of transplanting dates on seed yield and quality in *basmati* rice variety Pusa 1401. The crop was transplanted on 25th June, 5th July, 15th July and 25th July. Considerable reduction in seed yield (16.6% and 32.0%), respectively, was recorded when transplanting was done on 15th and 25th July compared to that on 25th June. Seed germination was significantly reduced when transplanting was delayed up to 25th July compared to that in 25th June transplanting though it was above seed certification standard of 80%.

## 1.9.10 Effect of Sowing Dates on Forage and Seed Yield of Berseem cv. BL 42

A field experiment was conducted in the *rabi* season of 2008-09 at Karnal to study the effect of different sowing dates on forage and seed yield of berseem. Sowing was done on 25th October, 5th November, 15th November and 25th November. Both green and dry forage yields were significantly reduced when sowing was delayed to 15th and 25th November. Reductions in green and dry forage yields were 32.2% and 57.7% and 38.3% and 57.7% in 15th and 25th November sowings respectively, compared to those in 25th October sowing. However, seed yield was not significantly affected owing to different sowing dates.

**Effect of sowing dates on forage and seed yield of berseem cv. BL 42 at Regional Station, Karnal**

| Sowing date | Green fodder yield (t/ha) | Dry fodder yield (t/ha) | Seed yield (t/ha) |
|---|---|---|---|
| 25th October | 110.00 | 14.70 | 0.437 |
| 5th November | 106.20 | 13.78 | 0.425 |
| 15th November | 74.50 | 9.06 | 0.435 |
| 25th November | 46.50 | 6.21 | 0.390 |
| CD (P = 0.05) | 14.78 | 0.954 | NS |

## 1.9.11 Effect of Growing System (Trailing vs Traditional) on Seed Yield Contributing Character in Hybrid Seed Production of Bottle Gourd cv. Pusa Hybrid 3

An experiment was carried out to investigate the effect of growing system on seed yield and seed quality attributes in hybrid seed production of bottle gourd cv Pusa Hybrid 3 during *kharif* 2009 at the Centre for Protected Cultivation Technology (CPCT). The result indicated that there is a significant effect of trailing on the number of fruit/vine (6.25), fruit length (49.40 cm.), number of filled seed/fruit (607.60), seed yield/fruit (95.54 g), and seed yield/plant (597.12 g) in comparison to that of traditional system.

## 1.9.12 Studies on Method of Seed Extraction in Brinjal cv. Pusa Uttam

Three methods (hand beating, tractor treading and machine extraction) were employed to study the seed recovery (from mature fruit to seed) and seed processing recovery in brinjal variety Pusa Uttam with the objectives to economize the cost of seed extraction. The results presented indicated that the recovery of seed from the mature fruit was higher in hand beating and tractor treading in comparison to that in machine extraction. However, the recovery of processed seed was higher in seed lot extracted by the machine than that by tractor treading and hand beating.

**A comparison of methods of seed extraction in brinjal cv. Pusa Uttam**

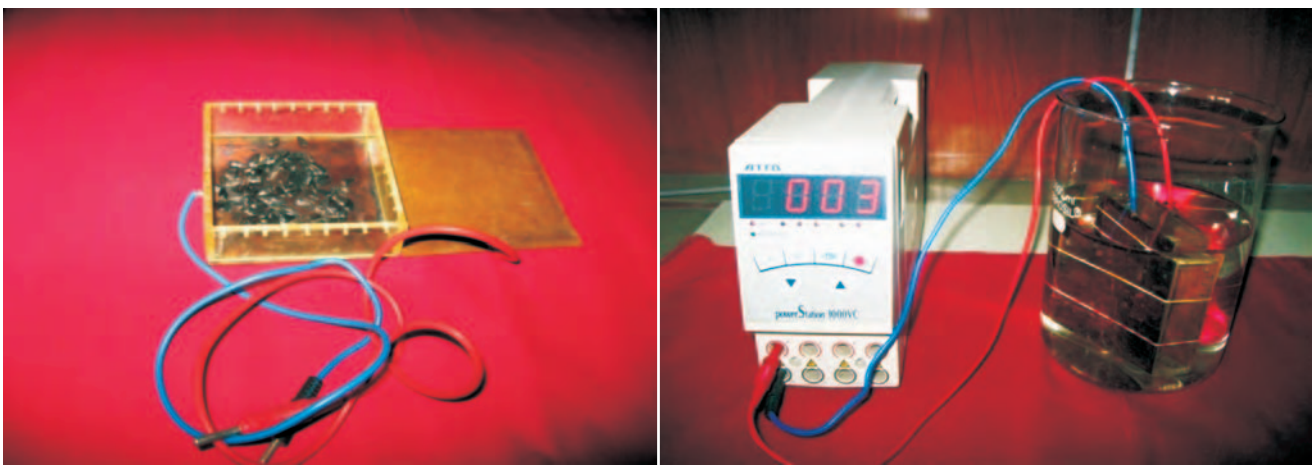
| Character | Methods | | |
|---|---|---|---|
| | Hand | Tractor | Machine |
| Seed recovery (fruit to seed per 10 kg of fruits) | 138 g | 138 g | 101 g |
| Recovery in seed processing (%) | 89.61 | 90.78 | 92.66 |
| 1000-seed weight (g) | 6.12 | 6.16 | 6.16 |

## 1.9.13 Electrical Seed Treatment on Seed Germination Characteristics of Sunflower

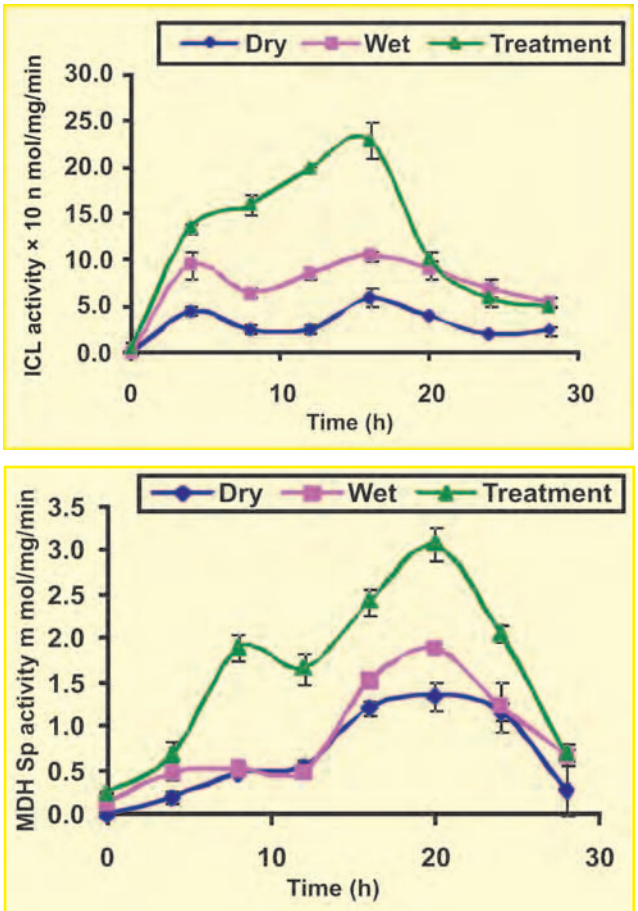
Electric field treatment of seeds of sunflower (Var. DRSF-113) by passing 200 mA current between copper electrodes (Plate 1) reduced the number of abnormal seedlings in the seeds treated for 3 and 5 min. Also the speed of germination improved by 2.9 folds compared to that in the control, and the root growth was enhanced more than shoot growth (13-32%) compared to that in the control. Among the enzymes involved in germination, the activities of isocitrate lyase and malate dehydrogenase increased significantly over those of the untreated controls.

## 1.9.14 Comparison of Microwave Treatment with other Conventional Methods for Reducing Seed Hardness in Stylo

The efficacy of microwave treatment in breaking hard seed coat dormancy imposed in *Stylosanthes seabrana* was compared with that of conventional methods, viz., scarification, hot water treatment (10 min) and sulphuric acid treatment (10 min). Imposed dormancy was comparable with



**Set up for electric field treatment of sunflower seeds**



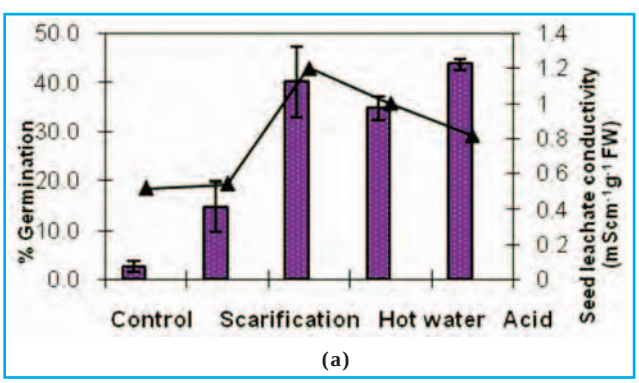

**Activities of isocitrate lyase and malate dehydrogenase with imbibitions time in seeds of sunflower exposed to electric field along with wet and dry controls**

that of hot water and acid treatment. The rankings of the treatments were in the following order: Microwave > hot water > acid > scarification > control. Relative low electrical conductivity of the seed leachate in microwave treatment showed that seeds maintained membrane integrity facilitating better imbibition followed by germination. Seedling vigour based on seedling length was similar for all the treatments. Seed respiration rate showed that microwave treated seeds respired faster than the seeds in other treatments.

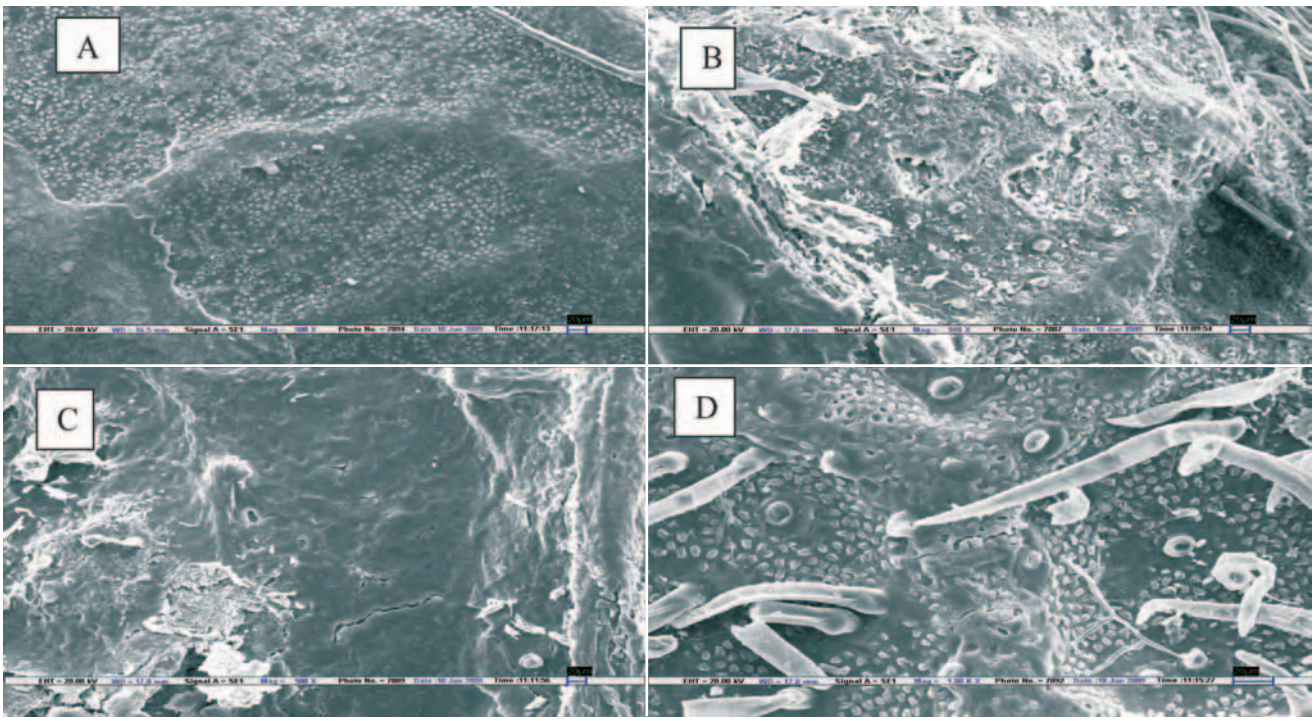
The steep increase in respiration rate at 48 h in microwave treated seeds suggests that metabolic processes associated with germination process are hastened in these seeds. Scanning electron micrographs of the seeds from all the treatments showed that in microwave treated seeds, the seed coat ruptured and many pores opened that would have resulted in increased rate of water uptake in the seeds. The results show that microwave treatment is an eco-friendly, easy to handle pre-sowing treatment which can be substituted because of its added advantages over the other conventional treatments for breaking hard seed coat imposed dormancy in *Stylosanthes*.

## 1.9.15 Effect of *Gamma* Irradiation on the Quality Parameters of Four Varieties of *G. hirsutum* Cotton

Seeds of four varieties (P 8-6, P 57-6, P 1752 and P 56-4) of *G. hirsutum* L. were irradiated with *Gamma* rays at 200,300 and 400 Gy doses in a $^{60}$Co at NRL to study the impact of radiation on the productivity and various important qualitative characters of cotton. In general, the treatment at 200 Gy on the seeds improved the yield per plant, boll weight and GOT% in P 8-6, P 57-6 and P 1752. P 57-6 showed improvement in quantity even at 300 Gy treatments. The




**A comparison of micro-wave treatment with other conventional dormancy breaking treatments: (a) germination and seed leachate electrical conductivity, and (b) respiration rate during imbibition**




**Scanning electron micrographs (500X) of *S. seabrana* seed coat after different treatments: (A) untreated control, (B) scarification, (C) acid, and (D) microwave**

quality parameters such as 2.5% span length (mm), strength (g/tex) and micronaire also showed slight improvement in the varieties P 8-6, P 57-6 and P 56-4. Higher doses of 300 and 400 Gray, in general, decreased the yield, reduced the boll weight and increased the seed index. The plants producing seed cotton reduced in number, especially in 400 Gy treatments in P 56-4 while per plant yield was better at these doses. There was a reduction in the boll weight at 300 and 400 Gy treatments in most cases.

### 1.9.16 Effect of Magnetic Energy Treatment on Cotton Seeds before Sowing and its Impact on Cotton Quality Parameters

Seeds of four varieties (P 56-4, P 57-6, P 1752 and P 875) of *G. hirsutum* L. cotton were treated with 500 and 2500 Guass energy for 1h. 2500 Guass treatment showed improvement in cotton yield and improvement in GOT% in P 57-6 and P 8-6 while maintaining the boll size. P 57-6 and P 1752 showed improvement at 500 Guass treatment.

### 1.9.17 Seed Production

At the Institute's Farms in Delhi and at the Institute's regional stations at Karnal, Indore, Pusa, Katrain, Dharwad and Wellington, nucleus, breeder and IARI seeds of different varieties of cereals, pulses, oil seeds, and vegetables were produced during the year under strict quality control. Apart from seed production, 1246 and 6010 saplings of fruit plants were produced at the Seed Production Unit, Delhi and at the Regional Station, Karnal, respectively.

**Seed production (tonnes)**

| Crop | Nucleus seed | Breeder seed | IARI seed | Total seed |
|---|---|---|---|---|
| **Seed Production Unit, Delhi** | | | | |
| Cereals | - | 17.015 | 91.359 | 108.374 |
| Pulses | 4.203 | - | 3.220 | 7.423 |
| Oilseeds (mustard) | 0.051 | - | 8.372 | 8.423 |
| Vegetables & flowers | 0.005 | 0.761 | 1.085 | 1.851 |
| **Division of Genetics** | | | | |
| Pulses (chickpea) | 3.739 | 51.01 | - | 54.749 |
| Millets (pearl millet) | 0.601 | - | - | 0.601 |
| **Division of Vegetable Science** | | | | |
| Vegetables | - | 0.0567 | 1.212 | 1.2687 |
| **Regional Station, Karnal** | | | | |
| Cereals | 3.647 | 96.779 | 318.631 | 419.057 |
| Pulses | 0.009 | 15.642 | 8.275 | 24.016 |
| Oilseeds (mustard) | 0.021 | 1.023 | 1.503 | 2.547 |
| Forage | 0.101 | 1.422 | 1.406 | 2.929 |
| Vegetables | 0.005 | 10.886 | 3.104 | 13.995 |
| **Regional Station, Indore** | | | | |
| Cereals | - | 271.9 | - | 271.9 |
| Soybean | - | 2.6 | - | 2.6 |
| Papaya | - | 0.009 | - | 0.009 |
| **Regional Station, Pusa** | | | | |
| Cereals | 3.32 | 71.55 | 82.51 | 157.38 |
| Pulses | 0.10 | 0.80 | 0.837 | 1.737 |
| Oil seed (*toria*) | - | - | 0.42 | 0.42 |
| Tobacco | - | - | 1.33 | 1.33 |
| Papaya | - | - | 0.031 | 0.031 |
| **Regional Station, Katrain** | | | | |
| Vegetables | 0.0997 | 0.0925 | 3.923 | 4.1152 |
| **IARI Centre for Pulses Improvement, Dharwad** | | | | |
| Pulses (chick pea) | 1.08 | - | - | 1.08 |
| **Regional Station, Wellington** | | | | |
| Cereals (wheat) | - | 6.0 | - | 6.0 |

# 2. GENETIC RESOURCES

## 2.1 CROP GENETIC RESOURCES

### 2.1.1 Wheat

#### 2.1.1.1 Rejuvenation of germplasm

Four hundred germplasm lines were rejuvenated, which include released varieties, advanced breeding material of HD series, CL series, AVT 1 lines for specific traits, lines from international trials and nurseries, registered genetic stocks, resistant sources against yellow, brown and black rusts, Karnal bunt, leaf blight, and drought as well as donors for quality traits such as *chapati* and biscuit making.

#### 2.1.1.2 Germplasm evaluation

At IARI Regional Station, Shimla, twenty-two genotypes of wheat were evaluated for resistance against two virulent pathotypes (46S119 and 78S84) of stripe rust and the most virulent pathotype 77-5 of leaf rust, of which 20 were observed as resistant. Three varieties, viz., HS 365, HPW 155 and VL 892 and one elite genotype HS 484 were scored as adult plant resistant against the most virulent pathotype 77-5 of leaf rust.

#### 2.1.1.3 Donors and genetic stocks

The various donors being maintained and used in the breeding programmes are as follows:

**Donor stock for different traits in wheat**

| Traits | Genotypes |
|---|---|
| Resistant to all rust | HD 2833, PBW 503, HW 3077, UP 2565, VL 824, PBW 498, HD 2819 |
| Leaf rust | HW 2045, DBW 14, FLW 1, FLW 2, FLW 3, FLW 4, FLW 5, FLW 6, and FLW 8, FLW 9, FLW 10, FLW 11, FLW 13, RKB 1002 |
| Stripe rust | CBW 09, DBW 14, HD 2865, CBW 23, CBW 24, CBW 25, DBW 17 |
| Stem rust (*Ug*99) | HW 1085, FLW 2, FLW 6, FLW 8, FLW 9, FLW 11, FLW 13, RNB 1001 |
| Leaf blight | BS 85, BS 105, BS 110, Nepal 5, Ning 8201, Ning 8319, Chiriya 3, Chiriya 7 NL 835, BL 1704, Yang Mai 6, Mon's/Ald's, Vee's/Myna, Shenghai 7, Quan Feng 2, Shenghai 4-158, Harit 1 |
| Heat tolerance | Kauz/AA//Kauz, BPW 893, Bavicora, NIAW 34, Tepoca/Rabe, WR 704, Bacanora 88, CBW 12, DBW 14, DBW 16, AKW 651, PBW 435, NL 6230, 8th HTWYT-9, PBW 510, WH 730, NIAW 845 |
| Good agronomic base | DBW 16, CBW 38, PBW 550, HD 2932, HD 2967, DBW 17, DBW 30, DBW 31, RP 1 and RP 2 |
| 1000-kernel weight | Lok Bold, Lok 1, UP 2425 |
| Quality traits | GW 322, K 9107, HI 1500 (*chapati*), DBW 16 (*Glu*1), PBW 343, MP 4010 (ER), GW 322, NW 2036 (Zn), HI 977 (bread), NIAW 34, HW 2044 (Fe) |
| Moisture stress | C 306, HI 1500, HI 1531, HD 2987, K 8027, HD 2815, HD 2781, HD 2833 |

Genetic stocks identified from four years of multi location testing include WR1702 for the number of tillers/meter; WR 1617, RD 1151, RD 1152 and RD 1271 for thousand-grain weight; RD 1151 and RD 1162 for grains/spike; WR 1695 and WR 1743 for short duration and heat tolerance; and RD 1336 for protein content and grain size.

#### 2.1.1.4 Novel genetic stocks

One new wheat genetic stock HS 492 (INGR No. 09005) resistant against all the pathotypes of leaf rust was developed by IARI Regional Station, Shimla and registered through Plant Registration Committee of ICAR.

### 2.1.1.5 Pre-breeding and germplasm enhancement

***Introgression of rust resistance from Aegilops markgrafii.*** Introgression of rust resistance from *Ae. markgrafii* (2n=14, CC) into wheat was attempted and the $F_1$ (ER9× NI5439) plants showed 2n=42 chromosomes with 21 bivalents in most cells. In some cells, a tendency towards desynapsis was observed. $F_1$ plants were selfed to produce $F_2$ seed.

***Transfer of novel leaf rust resistance genes through interspecific hybridization between T.aestivum and T.militinae (2n=28,AAGG).*** Interspecific hybridization between *T.aestivum* and *T.militinae* for the transfer of leaf rust resistance from *T.militinae* was taken up. $BC_1$ plants showed the presence of multivalent and thus the possibility of introgression.

In another attempt, the interspecific hybrid between *T. aestivum* and *Ae.geniculata*, a good source of leaf rust resistance, was successfully backcrossed with *T. aestivum.*

### 2.1.1.6 New genetic stocks created for rust resistance

At IARI Regional Station, Wellington, *Ug*99 effective combinations of stem rust resistance genes, viz., *Sr*24+*Sr*25, *Sr*25+*Sr*26, *Sr*25+*Sr*27, *Sr*25+*Sr*36, *Sr*25+*Sr*38, *Sr*24+*Sr*26, *Sr*24+*Sr*27, and *Sr*24+*Sr*36 were pyramided with *Yr*10 in 20 adapted Indian bread wheat cultivars, which are available to the national wheat breeding programme. Other category of stocks carrying *Lr*19+*Sr*25+*Sr*36+*Pm*6 and *Yr*15 showing multiple resistance to leaf, stem, stripe rusts and powdery mildew were also been developed, which were confirmed to carry these genes through molecular markers. As many as 20 popular Indian bread wheat cultivars carrying *Lr*24 + *Sr*24 and *Lr*19+*Sr*25 were incorporated with *Sr36*+*Pm*6, *Lr*28, *Lr*37 and thereby resistance base to rusts and powdery mildew diseases was broadened in Indian wheat germplasm. Incorporation of new leaf rust genes *Lr*35 (+*Sr*39 for *Ug* 99 resistance), *Lr*39, *Lr*42, *Lr*44, *Lr*45, *Lr*47 was accomplished in 28 popular Indian bread wheat cultivars and the progenies were in advanced stage ($BC_3F_5$). Incorporation and pyramiding of APR genes *Lr*34, and *Lr*46 to develop durable rust resistance in 30 popular cultivars was in progress and advanced to $BC_1$ stage. Pyramiding of *Sr*24 with *Sr*31, *Lr*19+*Sr*25 with *Sr*31, *Lr*19+*Sr*25 with *Lr*24+ *Sr*24 and *Lr*28 + *Lr*32 +*Lr*37 with Sr36+Pm6 was completed in 20 popular high yielding Indian wheat cultivars. The CMS trait transferred from *T.timopheevi* was incorporated in 10 elite cultivars to develop 'A' lines for the development of hybrid wheat.

### 2.1.1.7 Maintenance breeding of varieties

Maintenance seed production was taken up for all the released varieties, viz., HD 2781, HD 2985, HD 2987, and HDR 77 and the entries in AVT, NIVT CVT trials.

## 2.1.2 Rice

### 2.1.2.1 Evaluation of diversity in rice germplasm

Six hundred four (604) rice genotypes including mega varieties and varieties grown in specific agro-ecologies collected from different breeding centres were evaluated during *kharif 2009* at IARI, New Delhi. After eliminating the duplicates and photo-sensitive genotypes based on phenotypic characters, 472 genotypes were evaluated for nine different agro-morphological traits. A wide range of variability was observed for different yield contributing traits.

**Variability observed in rice germplasm**

| Trait | Mean | Range |
|---|---|---|
| No. of tillers | 22.1 | 6.0-62 |
| Panicle length (cm) | 26.1 | 9.5-37.5 |
| Grains/panicle | 140.4 | 10.7-352.0 |
| 1000-gr. wt. (g) | 21.9 | 8.7-32.1 |

Among these germplasm lines, 256 genotypes were genotyped using STMS marker RM6100 linked to fertility restorer gene to ascertain their restoration ability. A total of 150 genotypes were found to be positive for restorer gene linked marker allele and 106 were found to produce maintainer line specific allele.

## 2.1.3 Maize

### 2.1.3.1 Maize for diversified end-uses

***Pop corn.*** Four pop corn populations were evaluated for yield and quality parameters against the check amber pop corn composite for identifying the potential source for deriving pop corn inbred lines. More than 50 potential pop corn inbred lines were assessed for quality parameters in

comparison to those of the check, for popping by the use of micro-oven to identify and further advance the elite inbred lines.

#### 2.1.3.2 Registration of extant hybrids and varieties

Two single cross hybrids, namely, Pusa Early Hybrid Makka 3 (Registration No.128 of 2009), Pusa Extra Early Hybrid Makka 5 (Registration No.129 of 2009) and two maize composites, namely, Pusa Composite 3 (Registration No.146 of 2009), and Pusa Composite 4 (Registration No.126 of 2009) were registered as extant varieties with PVP&FRA, New Delhi.

### 2.1.4 Pearl Millet

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

During *kharif* 2009, 154 pairs of A and B lines of forty-six male sterile lines were grown along with three checks MS 841A, MS 5141A and MS 576A. Twenty-three pairs of MS lines, which belonged to A2, A3, A4, A5 sources of cytoplasm were grown and maintained for the purpose of cytoplasmic diversification of existing male sterile lines. Six crosses were made in each pair to maintain these male sterile lines. One hundred eleven inbred lines suitable for moisture stress condition and resistant to downy mildew, which were derived from multiple crosses of diverse lines of Indian elite inbreds, African materials and downy mildew resistant sources, were maintained. One hundred seven $F_6$ lines were grown (involving 9 elite inbreds, namely, D 23, PPMI 69, PPMI 85, PPMI 301, PPMI 295, PPMI 834, PPMI 605, PPMI 666 and IPC 1664 crossed in a diallel mating system) to create genetic variability, and selections were made in these lines for yield attributing traits. Fifty-six $F_6$ lines with good agronomic traits and resistance to downy mildew disease were selected for utilization in breeding programme.

### 2.1.5 Chickpea

#### 2.1.5.1 Evaluation of germplasm for drought tolerance

Twenty-four chickpea genotypes were evaluated for drought tolerance traits, viz., root traits, RWC and MSI. The varieties, Pusa 362, BGD 72 and Pusa 1103 were identified as the most tolerant among all the varieties tested. A new entry Gokcee, which has high degree of drought tolerance was indented from ICARDA.

### 2.1.6 Mungbean

#### 2.1.6.1 Maintenance of released varieties

Five mungbean varieties released earlier, namely, Pusa Vishal, Pusa 953, PS 16, Pusa 9971 and Pusa Ratna were maintained.

#### 2.1.6.2 Evaluation and maintenance of germplasm

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

### 2.1.7 Pea and Lentil

#### 2.1.7.1 Germplasm evaluation and maintenance

***Evaluation for Fe and Zn contents*.** One hundred lines of lentil were evaluated for Fe and Zn contents. The Fe content in the germplasm ranged from 26.5 to 172.2 mg/kg), and the Zn content from15.1 to 73.9 mg/kg.

#### 2.1.7.2 Maintenance of released varieties

Four varieties of lentil, namely, L 4076, L 4147, Pusa Masoor 5, and Pusa Masoor 6 and six varieties of pea, namely, DMR 7, P 1542, DDR 23, DDR 27, DDR 44, and DDR 55 were maintained.

### 2.1.8 Pigeonpea

#### 2.1.8.1 Germplasm resources

One hundred forty-one germplasm lines belonging to late maturity group comprising ICRISAT material and IARI (New Delhi) selections were evaluated and maintianed.

### 2.1.9 *Brassicas*

#### 2.1.9.1 Maintenance of germplasm

In all, 639 germplasm lines of *Brassica* (*juncea*, *napus*, *carinata*, *compestris*, *nigra*, *oleracea*, *tournifortii*, *caudatus*), *Raphanus* (*sativa*, *caudatus*), *S. alba*, *E. sativa*, *Crambe*, *Camellina and*, *Lepidium* were selfed and

**A highly branched and early dwarf plant type in pigeonpea**

maintained and promising accessions were used in hybridization programme.

### 2.1.9.2 Maintenance of released varieties

Genetically pure seed of twenty-one pipeline entries were produced by selfing/isolation growing. As per DAC indent, breeder and nucleus seeds of ten released varieties, viz., Pusa Jagannath, Pusa Agrani, Pusa Vijay, Pusa Bahar, Pusa Bold, Pusa Jaikisan, Pusa Mustard 25, Pusa Mahak, Pusa Tarak and Pusa Aditya were produced.

## 2.1.10 Soybean

### 2.1.10.1 Maintenance and evaluation of germplasm

Two hundred and forty-five lines were evaluated in spring summer for photo-thermo sensitivity.

## 2.1.11 Cotton

### 2.1.11.1 Evaluation of *Cotton leaf curl virus* (CLCuV) resistant genotypes

Three CLcuV resistant progenies (P 16-6, P 40-3 and P 67-3) and five CLCuV tolerant progenies (P 22-3, P 34-3, P 40-1, P 40-5 and P 55-1) of Pusa 8-6 were evaluated.

### 2.1.11.2 Germplasm evaluation

One hundred twenty germplasm lines of cotton were evaluated for important economic traits.

## 2.1.12 Vegetables

### 2.1.12.1 Cabbage

Fifty germplasm lines of cabbage including 6 self incompatible lines, 10 CMS lines and their maintainer lines were purified and maintained.

### 2.1.12.2 Capsicum

Nine new germplasm lines of sweet pepper were evaluated and added to the repository. A collection, named, Sphynx was a very high yielder (1.45 kg/plant) under open conditions. Some of them like Bang-14, which turns yellow on ripening, would be particularly useful for developing coloured capsicum varieties/hybrids.

Ten new germplasm lines of paprika with varying levels of pungency were collected from different sources and evaluated for their performance. Some are good for pickling (Piquilo, Jammu) while others are good for table purpose (679) and powder making (Siddhi). One collection (Ornamental Red) is suitable for ornamental purpose for its attractive dark red pendant fruits.

### 2.1.12.3 Carrot

Sixty-four germplasm lines and 23 CMS lines along with their respective maintainers were maintained. Three more CMS lines are in advanced stages of development.

## 2.1.13 Ornamental Crops

### 2.1.13.1 Tulip

Four tulip germplasm, viz., Apeldoorn, Apeldoorn's Elite, Tulip Hb and Golden Melody were collected from Srinagar. Another five varieties of tulip were collected from Chandigarh under AICRP, of which Strong Gold, Pretty Woman and Ganders Rhapsody were found promising for cut flower production under Kullu valley conditions. The variety Christmas Dream showed poor sprouting and did not flower.

### 2.1.13.2 Lilium

In order to enrich the germplasm, 25 genotypes of lilium, 8 of alstroemeria, 20 of narcissus/daffodils, 6 of iris, 13 of dahlia, 35 of gladiolus, 15 of carnation, and 5 of *Ranuncuclus* were maintained.

## 2.2 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

### 2.2.1 *Herbarium Cryptogamae Indiae Orientalis* (HCIO)

***Enrichment of repository of fungal biodiversity.*** Six hundred fifteen (615) diseased fungal specimens of Ascomycetes, Basidiomycetes and Deuteromycetes were accessioned in HCIO raising the total number of specimens to 48, 837.

***New species accessioned.*** Some of the new species added towards fungal biodiversity include: *Asteridiella crotonis-caudati, Asterina gamsii, A. pratapraji, Bartalinia caeryaensis, B. psidii, Irenopsis pavoniae, I. xeromphidiss, Meliola mahamulkarii, M. manoharacharyi, M. rachammae, Phyllachora gymnemae, Schiffnerula catharanthi, S. flacourtiae, S. girijae,* and *Uromyces terminalia.*

### 2.2.2 Indian Type Culture Collection (ITCC)

***Maintenance and new additions***. About 3705 fungal cultures belonging to Mastigomycotina, Zygomycotina, Ascomycotina and Deuteromycotina were maintained at ITCC. The culture collection was further enriched with 42 different fungal cultures including *Alternaria alternata, Bauveria bassiana, Curvularia affinis, Diplodoa seriata, Pestalotia anacardii, P. termitarii* and *Talaromyces trachyspermus.*

***Culture supply and identification services.*** Four hundred sixty-seven authentic fungal cultures belonging to Zygomycetes (62), Hyphomycetes (130), Ascomycetes (38), Penicilli (32), Aspergilli (43), Coelomycetes (54) and Fusaria (108) were supplied. Besides, 270 cultures belonging to Hyphomycetes, Coelomycetes and Zygomycetes were identified and two new genera *Copialongicollus grevillea* (ITCC-6523) and *Priliferosphaera capsici* (ITCC6494) belonging to Sphaeropsidaceae were described.

***Characterization of Aspergillus and Fusarium spp.*** Twenty isolates of *Aspergillus flavus, A. ochraceus, A. parasiticus* and *A. terreus* were characterized through PCR-RAPD technique. Of the various primers screened, primers OPB exhibited 100% reproducible and stable bands in *A. flavus*. PCR amplification with primers derived from ITS region yielded approximately 580 bp product from six isolates of *Fusarium solani* (2), *F. oxysporum* (2) and *F. moniliforme* (2).

### 2.2.3 Insect Biosystematics

Taxonomic studies on the genus *Episomus* (Coleoptera: Curculionidae) was conducted. An annotated checklist of the 106 species known from the world was compiled. Twenty species of the genus *Episomus* (Curculionidae) from India and nearby countries were redescribed. Two varieties were raised to subspecific status. All the descriptions were supplemented with the characters of elytral vestiture and female and male genitalic structures. A key was prepared for all the 20 species known from this region.

The erstwhile *Sympiezomias* weevil genus group with its three genera from India, Myanmar and adjoining Oriental region was reviewed leading to the description of a new species *Sympiezomias subserratipes*.

Studies on the genera of Curculionoidea involved in plant galls were continued. The genera *Hypolixus truncatulus* and *Xanthochelus faunus* were further pursued in terms of life history traits, seasonal incidence, infestation%, mating behaviour, egg, larval, and pupal periods, adult longevity and fecundity.

An annotated checklist of the weevil genera *Phytoscaphus* and *Pseudphytoscaphus* was prepared along with their up to date nomenclature, synonyms and distribution. The zoogeographical analysis indicates that these are exclusively tropical with 57 species known, and of these, 46 species occur in India and Myanmar.

Taxonomic studies were initiated on sub-family Aphidiinae (Hymenoptera: Braconidae). Members of this sub-family are exclusively parasitoids of aphids. A perusal of all the available literature reveals a basic lack of information on the faunal composition, distribution and biology of this important group of natural enemies of aphids. Around 400 species under 60 genera of Aphidiinae were described worldwide. The Indian fauna is currently represented by

125 species under 22 genera which constitute around 31% of the world fauna, belonging to all the four tribes – Ephederini with 4 genera, Praini with 3 genera, Aphidiini with 12 genera and Trioxini with 4 genera. In India, this subfamily is represented by twenty-two genera, viz., *Adialytus, Aphidius, Archaphidus, Areopraon, Betuloxys, Binodoxys, Cristicaudus, Diaeretiella, Diaeretus, Ephedrus, Indaphidius, Indoephedrus, Kashmiria, Lipolexis, Lysiphlebia, Lysiphlebus, Monoctonus, Neoephedrus, Pauesia, Praon, Toxares,* and *Trioxys* with 125 species occurring from the plains to very high altitudes. The maximum number of species, i.e., 83 were reported from north India from the states of Delhi, Himachal Pradesh, Jammu and Kashmir, Punjab and Uttar Pradesh followed by 55 species from eastern India from the states of Assam, Bihar, Manipur, Meghalaya, Nagaland, Sikkim, Tripura and West Bengal and 13 species from South India from the states of Karnataka and Tamil Nadu. The genus *Aphidius* is the most abundant with maximum number of species on record followed by genus *Binodoxys*. The only aphidiine with a truly cosmopolitan distribution is *Diaeretiella rapae.*

Field surveys were made to determine the hymenopterous natural enemies associated with *P. brassicae* in and around Delhi during 2007-10. Altogether, hymenopterous parasitoids and predators belonging to five families could be recorded on various stages of *P. brassicae*. *Cotesia glomerata* (Braconidae) on the caterpillars; and *Pteromalus puparum* (Pteromalidae) and *Brachymeria lasus* (Chalcididae) on the pupae, were recorded as parasitoids exerting natural control on this important pest. As high as 38% parasitism was recorded during 2008-09 owing to the various parasitoids, among which *C. glomerata* was the most predominant accounting for 33% parasitism in spite of its activity being severely affected by a hyperparasitoid, *Tetrastichus* sp. The hymenopterous predators could be identified as *Polistes* hebraeus and *Vespa cincta* (Vespidae), and *Eumenes dimidiatipennis* (Eumenidae). Further, *Tetrastichus* sp. (Eulophidae) is being reported as a hyperparasitoid of *C. glomerata*. *P. puparum, P. hebraeus, V. cincta,* and *E. dimidiatipennis* as natural enemies of *P. brassicae and Tetrastichus as a hyperparasitoid* of *C. glomerata* are all first records for India.

Exploration and survey of leafhoppers of agricultural importance were carried out from different agro ecosystems, i.e., rice, mustard, wheat and mango in New Delhi. The collected material was sorted and processed for further studies. A total of 240 specimens belonging to 2 super families, viz., Membracoidea and Fulgoroidea were collected. Illustrations of diagnostic morphological characters were prepared for four superfamilies of Homoptera, i.e., Membracoidea, Cicadoidea, Fulgoroidea and Cercopoidea. Preparation of illustrated key for identification of families of Membracoidea and sub-families of Cicadellidae is in progress.

### 2.2.4 Nematode Biosystematics and Identification Services

***New isolates of Steinernema.*** Eight new strains of *Steinernema* were isolated from 3 districts (Jaipur, Jodhpur and Udaipur) of Rajasthan. The frequency of occurrence of EPNs was 20%, 15.4% and 13.8% in the samples from Udaipur, Jodhpur and Jaipur, respectively. Morphological studies of infective juveniles of these strains placed them in 2 groups of *Steinernema*: one strain from Jodhpur in *Bicornutum* group and the other 7 strains in *Carpocapsae*-group. Their niche soil temperature was 29-32 °C and pH 7.3-7.9.

***Molecular characterization of Steinernema species from Orissa.*** The ITS region of rDNA of *Steinernema* from Orissa was amplified and sequenced, and its phylogenetic relationships with other known species were deduced. It showed its close affinity with *S. siamkayai* by having 99 % similarity.

Molecular characterization of rice root-knot nematode *Meloidogyne graminicola* by the use of ITS sequencing of rDNA shows 99% similarity to that of Nepal population. There is about 89% similarity between full length sequences of *M.graminicola* to that of *M.nasasi*.

***NCBI GenBank depositions.*** The Institute submitted 5 new gene sequences of the ITS region of ribosomal DNA of entomopathogenic nematodes: 2 of *Steinernema* – one each from Bhubaneswar (Orissa) and Mathura (UP), and 3 strains of *Heterorhabditis* from Mathura vide accession nos. GQ353373 and GU354216 - 354219, respectively.

***National Nematode Collection of India (NNCI).*** The National Nematode Collection was maintained and augmented by the addition of 29 type specimens on 21 type slides representing 12 new species and 3 genera, thus bringing the total strength up to 2253 type accessions. It was also enriched by adding 90 wet suspensions from surveys (34 from Rajasthan, 26 from Allahabad, UP and 30 from Coimbatore) upgraded to 3302 wet accessions. The database of wet collections was updated from 1831 to 3200 records. Physical verification of type and wet collections was done, and 157 type slides were remounted, and 4% formalin was added, wherever found necessary.

***Nematode Identification Service.*** Plant parasitic and free-living nematode communities were analysed in samples received from IRRI-India, Chhattisgarh, Jammu & Kashmir, and the College of Agriculture, Hyderabad. The predominant species identified were: *Meloidogyne incognita*, *M. graminicola*, *M. Javanica*, *Xiphinema basiri*, *X. elongatum* and *Longidorus elongatus*.

**Comparison of ITS region of rDNA of Orissa isolate of *Steinernema* (IARI-EPN-SG*or*1) with its closely related species**

| Species | Sequence length (bp) | % Identity with IARI-EPN-SG*or*1 | A% | T% | G% | C% | AT% | GC% |
|---|---|---|---|---|---|---|---|---|
| *Steinernema* isolate IARI-EPN-SG*or*1 | 972 | - | 23.46 | 36.01 | 23.05 | 17.49 | 59.47 | 40.53 |
| *S.siamkayai* | 745 | 99 | 22.68 | 39.60 | 22.01 | 15.30 | 62.28 | 37.32 |
| *S. carpocapsae* | 987 | 90 | 24.42 | 34.95 | 23.20 | 17.43 | 59.37 | 40.63 |
| *S. scapterisci* | 899 | 84 | 25.70 | 34.82 | 22.91 | 16.57 | 60.51 | 39.49 |
| *S. tami* | 739 | 95 | 22.60 | 38.43 | 22.19 | 16.78 | 61.03 | 38.97 |

# 3. CROP AND RESOURCE MANAGEMENT AND ENVIRONMENT

## 3.1 AGRONOMY

### 3.1.1 Effect of Mulching and Iron Nutrition on Aerobic Rice

A field experiment was conducted during the rainy season of 2009 on a sandy clay-loam soil to study the effect of four mulching and iron nutrition treatments on the productivity and iron concentrations and their uptake by aerobic rice (Pusa 44). The study revealed higher grain and biological yield of aerobic rice under puddled and flooded conditions than under bare soil (no mulch), wheat straw mulch (5 t/ha) and *dhaincha* (*Sesbania aculeata*) mulch treatments. Growing of rice with *Sesbania* mulch and wheat straw mulch recorded 1.35 tonnes and 1.13 tonnes more biological yields, respectively, compared to that grown under bare soil (no mulch). The iron nutrition, irrespective of the method of its application, had a significant effect on the grain and biological yields of aerobic rice. Application of iron sulphate 50 kg/ha + two foliar sprays of 2.0% iron sulphate (at maximum tillering and pre-flowering stages) recorded significantly higher rough rice grain yield (5.10 t/ha) compared to control and remained statistically on a par with the application of iron sulphate 50 kg/ha and 100 kg/ha and three foliar sprays of 2.0% iron sulphate (heptahydrate) at maximum tillering, pre-flowering and flowering stages.

Methods of rice production had significant effect on Fe concentration in rough rice grain and their uptake under aerobic rice condition. Among the different methods of rice production, paddy grown under puddled and flooded conditions recorded significantly higher Fe concentration in rough rice grain and their uptake. Among the mulching treatments, rice grown with *Sesbania* mulch recorded significantly higher Fe concentration in rough rice grain as compared to other mulching treatments. Iron nutrition had also significant effect on the Fe concentration in rough rice grain and their uptake under aerobic rice condition. The significantly higher Fe concentrations in rough rice grain, straw and their uptake was recorded with iron sulphate 50 kg/ha + two foliar sprays of 2.0% iron sulphate compared to control, iron sulphate 50 kg/ha and 100 kg/ha, however, remained statistically on a par with 3 foliar sprays of 2.0% iron sulphate (heptahydrate) at maximum tillering, pre-flowering and flowering stages.

### 3.1.2 Performance of Rice Hybrids Grown by System of Rice Intensification (SRI) with Plant Growth Promoting Rhizobacteria (PGPR)

A field experiment was conducted in a sandy clay-loam soil during *kharif* season of 2009 to evaluate the performance of six rice hybrids grown by system of rice intensification (SRI) when inoculated with 3 kinds of plant growth promoting rhizobacteria (non-inoculated control, *Azospirillum brasilense*, CD4 and *Bacillus subtilis* RP24). Grain yield of PHB 71, being on a par with Arize 6444, PRH 10 and Indam 100-003, was significantly higher than that of Indam 100-001 and KRH 2. Inoculation of rice with *Azospirillum brasilense* and *Bacillus subtilis* increased the grain yield significantly over uninoculated control. However, both the PGPRs were equally effective in increasing the grain yield of rice grown by SRI.

### 3.1.3 Agronomic Evaluation of New Nitrification Inhibitor(s) Coated Prilled Urea at Varying N Rates in Rice-Wheat Cropping System

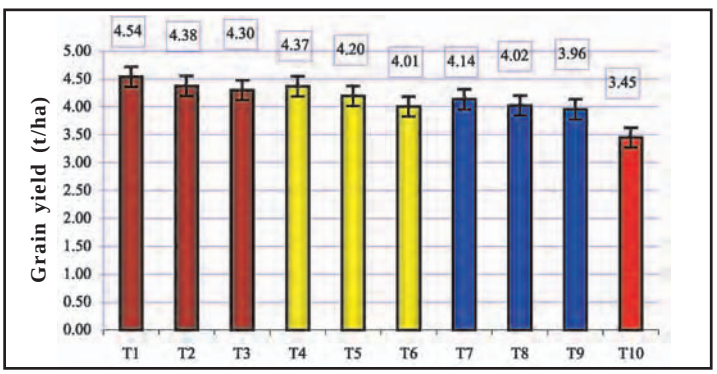
A field experiment was conducted during *kharif* 2009 to find out the best nitrification inhibitor (s) for coating of prilled urea to be used in lowland irrigated rice. The treatments (22) comprised of combinations of 3 N rates and 7 nitrification inhibitors coated prilled urea at a thickness of 1000 mg/kg prilled urea, and an absolute control. Rice responded significantly to the highest level of N, i.e., 150 kg/ha. All the oil coated prilled urea, except palmarosa oil coated urea,

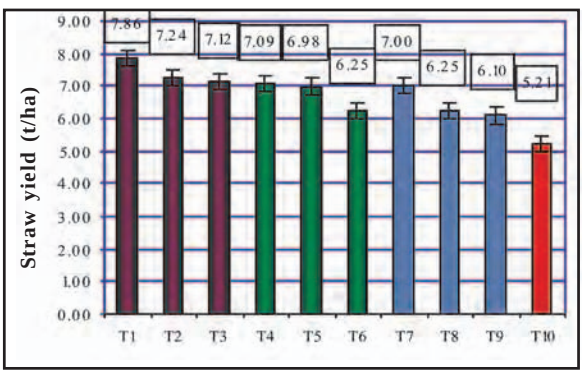
produced significantly higher grain yield of rice compared to that of uncoated prilled urea. Citronella oil coated prilled urea being on a par with karanj oil and cottonseed oil coated urea, was better than other coated urea. The values of highest nitrogen use efficiency and economic returns (Rs./Re. invested in N) were also recorded with citronella coated prilled urea.

### 3.1.4 Performance of Wheat under Organic and Inorganic Fertilization

An experiment was conducted to evaluate the effect of organic sources on wheat productivity and soil fertility. The treatments consisted of nine organic sources (T1-125% RDN, T2-100% RDN and T3-75% RDN through FYM; T4-125% RDN, T5-100 % RDN and T6-75% RDN through vermicompost; and T7-125% RDN, T8-100% RDN and T9-75% RDN through compost) applied to supply recommended dose of nitrogen (RDN), i.e., 120 kg N/ha and one T10-100% RDF through fertilizers (120-26.4-33.2 kg N-P-K/ha).

The RDN through FYM, vermicompost and compost performed significantly better than recommended dose of fertilizer (RDF) with respect to grain and straw yields during the fourth cycle of cropping. Application of 100% RDN through FYM produced almost equal grain yield as obtained from 75% RDN through FYM and 125% RDN through vermicompost but it was superior to the remaining doses of N equivalent through vermicompost and compost.




**Grain and straw yields (t/ha) of wheat under organic and inorganic fertilization**

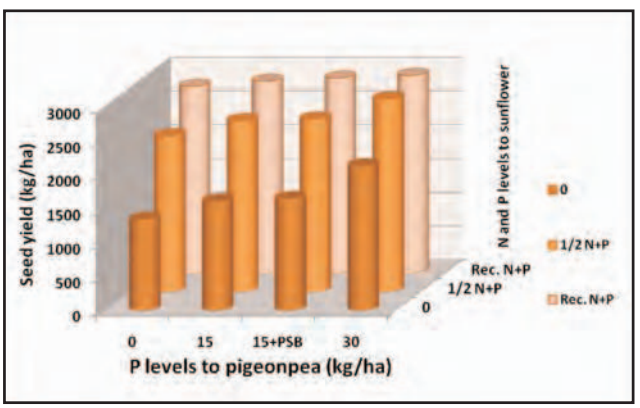
**Soil nutrient status under organic and inorganic fertilization after wheat harvest**

| | N (kg/ha) | | P (kg/ha) | | K (kg/ha) | |
|---|---|---|---|---|---|---|
| | 0-15 cm | 15-30 cm | 0-15 cm | 15-30 cm | 0-15 cm | 15-30 cm |
| 125% RDN through FYM | 326.5 | 270.8 | 33.9 | 21.5 | 256.0 | 217.8 |
| 100% RDN through FYM | 320.9 | 224.3 | 28.6 | 18.8 | 240.6 | 208.2 |
| 75% RDN through FYM | 300.7 | 192.9 | 22.8 | 14.7 | 200.1 | 148.6 |
| 125% RDN through vermicompost | 291.6 | 269.0 | 29.1 | 19.3 | 226.8 | 199.9 |
| 100% RDN through vermicompost | 253.7 | 218.4 | 24.7 | 16.3 | 213.0 | 192.3 |
| 75% RDN through vermicompost | 216.5 | 178.6 | 16.1 | 12.7 | 182.3 | 131.7 |
| 125% RDN through compost | 298.5 | 220.9 | 29.7 | 19.7 | 241.3 | 206.3 |
| 100% RDN through compost | 273.0 | 218.5 | 27.8 | 16.4 | 224.1 | 197.6 |
| 75% RDN through compost | 222.5 | 161.3 | 19.8 | 13.2 | 190.0 | 130.2 |
| 100% RDF | 152.5 | 109.5 | 14.5 | 10.2 | 124.9 | 95.7 |
| CD (P=0.05) | 10.5 | 8.0 | 4.2 | 2.1 | 18.2 | 19.8 |

### 3.1.5 Recycling of Sunflower Stover for Nutrient Economy in Pigeonpea-Sunflower System

Spring sunflower produces 6-8 tonnes stover/ha. Due to very limited uses, it can be recycled for improving the soil productivity and nutrient economy. A field experiment was, therefore, conducted during 2008-09 to evaluate the effect of sunflower stover incorporation on pigeonpea and sunflower and N and P management in this system. Eight combinations of two levels of stover incorporation and four levels of P applied to pigeonpea were tried. Succeeding crop of sunflower received three levels recommended dose of N and P (RDNP).

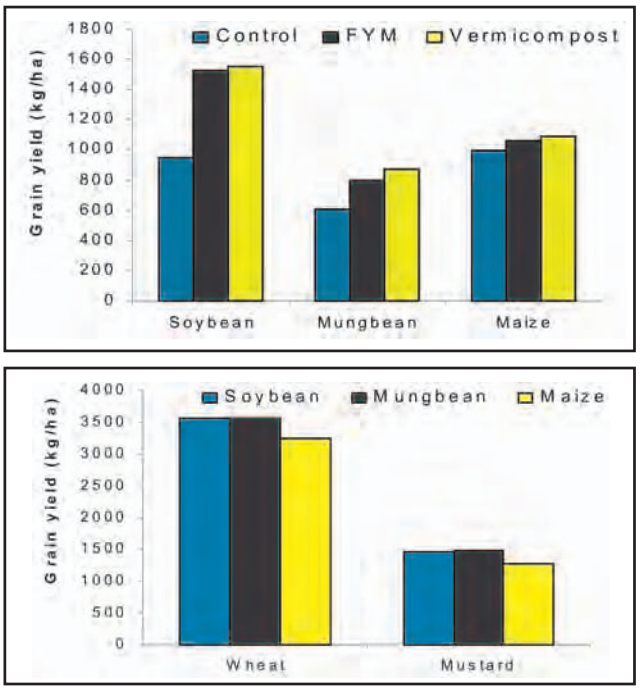
Sunflower stover incorporation (SSI) @ 8 t/ha caused marginal reduction in pigeonpea yield as compared to that of control. Residual effect of stover incorporation was found significant on the succeeding spring sunflower and resulted in marked increase in seed yield over control. System productivity and net returns also revealed improvement due to stover incorporation. Phosphorus application in pigeonpea caused significant increase in grain yield up to 30 kg P/ha. Residual effect of both 15 and 30 kg P was found significant on the yield of succeeding sunflower. System productivity and net returns recorded marked increase due to subsequent increase in P levels. Sunflower seed yield recorded improvement up to RDNP. Residual effect of stover incorporation was significant with direct application of N and P to sunflower and resulted in a saving of 50% of N and P as compared to no stover incorporation. Similarly, the residual effect of 30 kg P applied to pigeonpea, and legume effect of pigeonpea reduced N and P requirement of succeeding sunflower by 50%.




**Interaction effect between the residue of P given to pigeonpea and direct application of N and P to sunflower on the seed yield of sunflower**

### 3.1.6 Performance of Soybean, Mungbean and Maize Based Cropping Systems under Organic Production Systems

A two- year field study concluded during *rabi* 2008-09 on organic production system in soybean-wheat, soybean-mustard, mungbean-wheat, mungbean-mustard, maize-wheat and maize-mustard revealed that during *kharif* season, soybean and mungbean responded positively to FYM and vermicompost based organic management practices than control but maize was not influenced by the organic production system. Among the organic sources, vermicompost was marginally better than FYM based system. The succeeding crops of wheat and mustard raised with organic production system recorded significantly higher yield as compared to control. However, these crops after maize recorded significantly lower yield as compared to soybean and mungbean as preceding crops. It is inferred that the organic production system may be less favourable




**Yield performance of crops as influenced by organic production system (Mean of 2 years)**

to the heavy nutrient demanding crops like maize and more suitable for legumes. The inclusion of these crops in cropping systems would enhance the total productivity of the system.

### 3.1.7 Studies on Planting System and Phosphorus Management in Sole and Intercropped Pigeonpea under Rainfed Conditions

A field experiment was conducted on sandy loam soil during *kharif* 2008. The treatments consisted of a combination of 2 cropping systems, 3 planting systems and 4 phosphorus levels. Among the cropping systems, pigeonpea + mungbean provided significantly higher pigeonpea equivalent yield compared to that of the sole pigeonpea. Broad bed and furrow planting systems proved to be superior to uniform row and paired row planting systems. Among the fertility levels, 17.6 kg P/ha+ PSB + VAM was found on a par with 35.2 kg P/ha indicating an economy of 17.6 kg P with interacted P nutrition.

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

A field experiment was conducted during *rabi* 2008 with eighteen treatment combinations. The soil of the experimental site was sandy loam with pH 7.4 and analyzing low in organic carbon (0.4%) and medium in available P (14.0 kg/ha) and K (221 kg/ha). Sowing on 25$^{th}$ October gave significantly higher seed yield of mustard compared to that of 5th November sowing. Among aqua-fertilization treatments, 15,000 litres of water/ha proved a superior yielder. Recommended doses of fertilizer gave significantly higher seed yield compared to that of control and 50% RDF. Water use efficiency (WUE) was the highest in 25th October sowing, aqua-fertilization with 15,000 litres of water/ha and RDF.

### 3.1.9 Performance of New Wheat Genotypes at Different Dates of Sowing under Irrigated Conditions

Five genotypes, namely, HD 2967, HUW 612, HUW 616, DBW 39 and K 607 were tested against five checks at two different dates, i.e., normal and late sowings at Pusa (Bihar). At both dates of sowing, genotype HD 2967 preformed the best in terms of grain yield. This variety yielded significantly higher than new genotypes HUW 612, HUW 616 and K 607 but was on a par with DBW 39, PBW 343 and K 307 in normal sown condition, whereas in late sown conditions, it yielded significantly higher than the new genotypes and K 307 (C).

**Effect of planting systems and phosphorus management on yield and economics of sole and intercropped pigeonpea**

| Treatment | Pigeonpea yield (t/ha) | Mungbean yield (t/ha) | Pigeonpea equivalent (t/ha) | Net returns (Rs/ha) |
|---|---|---|---|---|
| **Cropping system** | | | | |
| Pigeonpea sole (50 cm) | 1.49 | | 1.49 | 28,400 |
| Pigeonpea + mungbean | 1.44 | 0.24 | 1.71 | 32,642 |
| CD (P=0.05) | NS | - | 0.66 | |
| **Planting System** | | | | |
| Uniform row planting system | 1.31 | 0.19 | 1.45 | 27,076 |
| Broad & Furrow (BBF) | 1.56 | 0.24 | 1.70 | 32,554 |
| Paired row planting | 1.51 | 0.23 | 1.64 | 31,256 |
| CD (P=0.05) | 0.08 | 0.02 | 0.08 | |
| **P level (kg/ha)** | | | | |
| Control | 1.18 | 0.15 | 1.27 | 24,984 |
| 17.6 | 1.42 | 0.21 | 1.55 | 30,726 |
| 17.6+PSB+VAM | 1.60 | 0.26 | 1.75 | 33,676 |
| 35.2 | 1.67 | 0.27 | 1.83 | 35,348 |
| CD (P=0.05) | 0.08 | 0.02 | 0.08 | - |

**Yield and water use in mustard as influenced by sowing dates and aqua-fertilization under rainfed conditions**

| Treatments | Seed yield (t/ha) | Consumptive use (mm) | WUE (kg/ha/mm) |
|---|---|---|---|
| **Date of sowing** | | | |
| 25th October | 1.98 | 220.4 | 8.69 |
| 5th November | 1.69 | 212.3 | 7.80 |
| CD (P=0.05) | 0.06 | - | - |
| **Aqua-fertilization (water litres/ha)** | | | |
| Normal sowing | 1.68 | 207.5 | 8.09 |
| 5,000 | 1.78 | 215.4 | 8.10 |
| 10,000 | 1.81 | 221.4 | 8.12 |
| 15, 000 | 1.94 | 224.3 | 8.55 |
| CD (P=0.05) | 0.08 | - | - |
| **Fertility levels** | | | |
| Control | 1.61 | 208.1 | 7.61 |
| 50% RDF | 1.82 | 220.1 | 8.19 |
| 100% RDF | 1.99 | 223.5 | 8.79 |
| CD (P=0.05) | 0.09 | - | - |

### 3.1.10 Performance of New Wheat Genotypes at Different Dates of Sowing under Irrigated Late and Very Late Sown Conditions

Four genotypes, namely, HD 2982, HD 2983, HD 2985 and MP 3224 were tested against four checks both under irrigated late and very late sown conditions at Pusa (Bihar). Performance of the genotype HD 2985 was the best followed by MP 3224 in terms of yield both under late (5.51 t/ha and 5.40 t/ha, respectively) and very late sown conditions (3.27 t/ha and 2.84 t/ha, respectively).

### 3.1.11 Evaluation of Wheat Varieties under Conventional Tillage and Zero Tillage Conditions

Twelve recommended varieties for NEPZ, seven for normal sown and five for late sown conditions were evaluated under conventional as well as zero tillage systems separately to know their suitability and yield performance at Pusa (Bihar). Under conventional tillage, HD 2733 was found to be the highest yielder (4.77 t/ha), followed by HP 1761 (4.22 t/ha.), NW 2036 (3.74 t/ha), HD 2824 (3.47 t/ha), K 9107 (3.40 t/ha) and PBW 373 (3.34 t/ha). Under zero tillage, the performance of varieties was almost similar to that under conventional tillage. The best performing variety was HP 1761 (4.68 t/ha), followed by HD 2733 (4.62 t/ha), NW 3036 (4.06 t/ha), K 9107 (4.02 t/ha), PBW 373 (3.91 t/ha) and HD 2824 (3.73 t/ha). Normally high tillering varieties performed better under zero tillage system.

### 3.1.12 Effect of Spacing on Yield in August Planted Pigeonpea

The performance of two varieties of pigeonpea under pre- *rabi* conditions at three row-to-row distance, i.e., 30, 40 and 50 cm, was evaluated at Pusa (Bihar). The results of the trial showed that 50 cm row spacing yielded highest and there was a gradual reduction in yield when row distance was reduced to 30 cm.

### 3.1.13 Tillage and Wheat Genotypes Interaction under Early Sown Condition in Central India

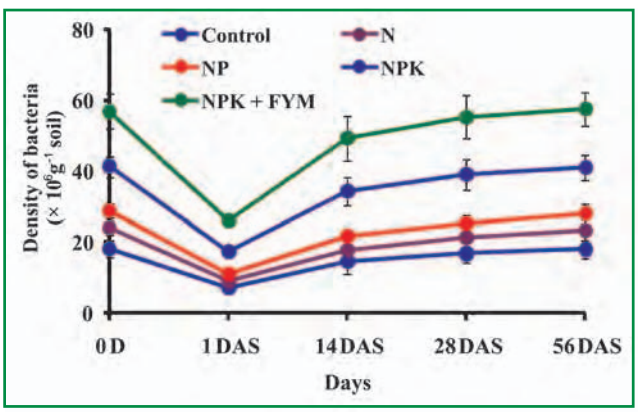
Conventional tillage recorded significantly higher grain (4.44 t/ha) and biomass (10.56 t/ha) yields compared to those under minimum (4.28 t/ha and 10.29 t/ha, respectively) and zero tillage (4.01 t/ha and 9.73 t/ha, respectively) at Indore (MP). Minimum tillage, being on a par with conventional tillage (Rs. 34031/ha), fetched higher net returns (Rs. 33548/ha) compared to those of zero tillage (Rs. 31801/ha). However, the benefit: cost ratio was the highest in zero tillage followed by that in minimum (1.99) and conventional tillage (1.84).

## 3.2 SOIL MANAGEMENT

### 3.2.1 Impact of Abiotic Stress on Microbial Abundance, Resistance and Resilience of Soil under Long-term Application of Fertilizers and Farmyard Manure

In the scenario of impending climate change, increasing soil temperature is inevitable. An experiment on soil biodiversity against abiotic stress was conducted in a field at IARI, New Delhi, under long-term (36 years) application of fertilizers with and without farmyard manure. Abundance of microbial groups (bacteria, fungi, *Actinomycetes*, *Pseudomonas*, *Azotobacter* and ammonia oxidising bacteria) was assessed for resistance and resilience against abiotic stress.

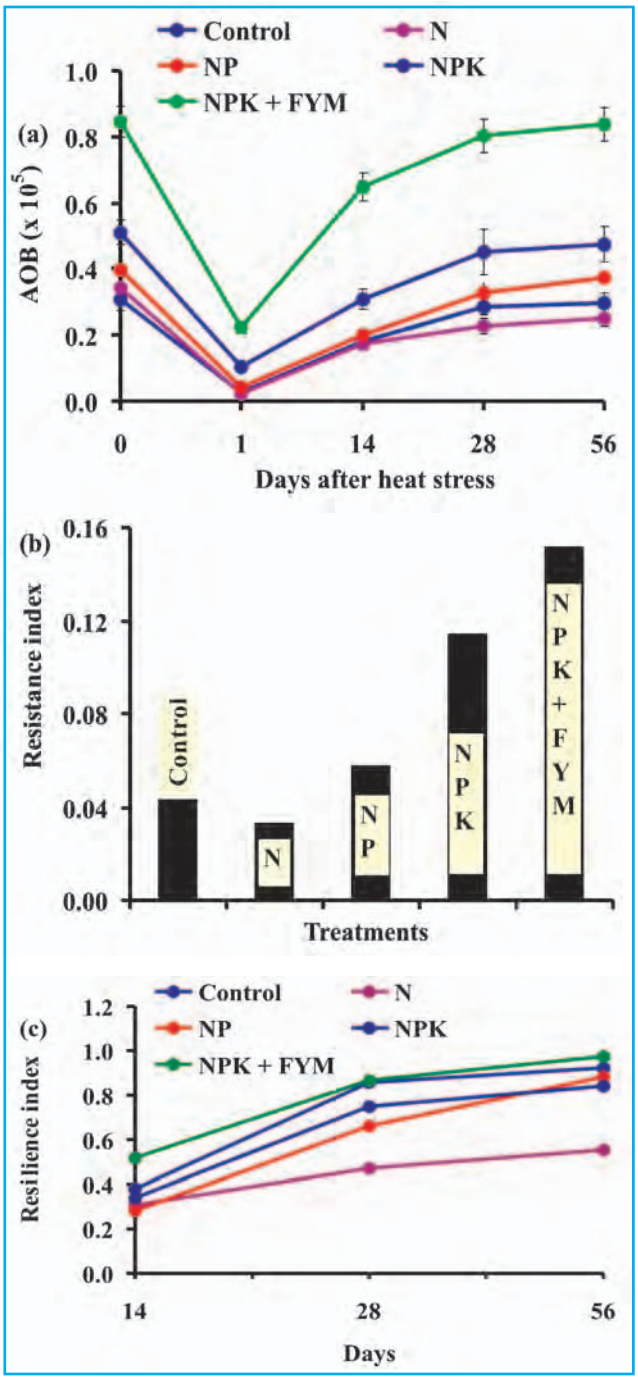
It was noticed that abiotic stress (heat at 48 °C for 24 h) significantly reduced the microbial activities and different microbial groups. The amplitude of reduction varied from 20% to 80%. The negative impact of heat stress on microbial groups was the highest in soil treated with only N (100% N). Recovery of 60% to almost 100% was recorded in about 2 months in most of the parameters studied. Among the soil organisms, resistance and resilience of fungi and *Actinomycetes* were higher than those of bacteria, *Pseudomonas*, *Azotobacter* and ammonia oxidising bacteria. Ammonia oxidising bacteria were found to be most sensitive with minimum resistance index (0.03-0.16) against heat stress. It was clear that among the treatments, application of NPK + farmyard manure was the most effective in enhancing the biodiversity and resistance and the resilience of soil biological functions against heat stress. This study also gave an indication that prolonged heat stress might affect the abundance of nitrifying organism leading to low nitrification activity, which is undesirable in an intensive production system.




**Population of bacteria in soil after heat stress. Bars indicate standard errors of mean. 0D and DAS indicate 'fresh soil' after sampling and 'days after stress,' respectively**

## 3.2.2 Enhancing Carbon Sequestration Potential of Soil for Mitigating Climate Change

After eight cropping cycles in rice-wheat system, it was observed that soil organic C (SOC) after harvest of wheat was more under non-puddled soil than under puddled soil (rice grown before wheat). Two irrigations in wheat (W3) significantly showed higher SOC contents than those in




**Abundance (a), resistance (b) and resilience (c) of ammonia oxidizing bacteria (AOB) against heat stress**

either three or five irrigations. The SOC contents were higher under no-tillage (NT) than under conventional tillage in wheat. No tillage improved SOC content significantly over CT in most of the nutrient treatments though some treatments

showed non-significant variation between CT and NT. The nutrient management treatments with organic supplementation (viz., crop residues, green manures, sewage-sludge) showed increased SOC contents over the treatments without organic substitution. The highest SOC was observed in 100% NPK (25% N substituted by crop residues).

### 3.2.3 Potassium Dynamics in Wheat Based Cropping Systems with Varying Tillage and Crop Residue Management Practices

Potassium dynamics has been studied in a long-term on-going field experiment started during *kharif* 2004 on a sandy loam soil (Typic Haplustept) at IARI farm, New Delhi. Tillage and crop residue management caused significant change in water soluble, exchangeable, available, hot $HNO_3$, non-exchangeable, lattice and total potassium fractions of soil. Inclusion of crop residue with tillage treatments significantly increased all the fractions of potassium irrespective of nature of tillage. Water soluble, exchangeable and available potassium contents in conventional tillage without residue (CT–R) and conventional tillage with residue (CT+R) plots were statistically on a par with those of zero tillage without residue (ZT–R) and zero tillage with residue (ZT+R). Significant increase in hot $HNO_3$, non-exchangeable, lattice and total potassium contents were observed under CT+R over CT–R and ZT+R over ZT–R except for lattice and total potassium under zero tillage where crop residue applied plots were on a par with plots without crop residue application. The effect of crops was significant on all the fractions of potassium except on water soluble potassium content of soil. Available and exchangeable K contents were significantly higher under cotton (151.4 mg/kg) over all the crops except groundnut. Findings of this investigation indicated that soil potassium management decisions might differ according to the nature of cropping system and tillage and crop residue management practices.

### 3.2.4 Radio-Cesium ($^{134}Cs$) Sorption-Desorption on Soil Clays and Waste Mica

The present investigation is the continuation of the on-going studies on control of radio-cesium sorption-desorption processes on soils and clay minerals. The information on behavior of radionuclides in soils and its uptake by plants is warranted for devising effective strategies and developing agricultural counter measures to minimize their transfer from soil to human beings. In the present study, clay-organic complexes from fourteen soils representing seven soil orders was studied for $^{134}Cs$ sorption-desorption. The data indicated that sorption of radio-cesium on soil clays was instantaneous and nearly more than 92% of $^{134}Cs$ adsorbed tenaciously at the end of 24 h equilibration time and the variations were attributed to nature and amount of clay minerals. The removal of soil organic matter from clay-organic complexes substantially lowered the affinity of cesium sorption on complexes. However, the effect of sesquioxides was not significant. The desorption studies using ammonium oxalate, sodium oxalate, calcium chloride and ammonium chlorides extracting solutions showed that, in general, with an increase in concentration of the extractants, the total Cs desorbed from clay-organic complexes also increased. Radio-cesium sorption was significantly increased with the lowering of the size fractions of mica. About 9% of the sorbed radionuclide from mica could be removed using different extractants. Pot culture experiments using waste mica as amendment to check the radionuclide transfer factors showed that the addition of waste mica significantly lowered the transfer of radio-cesium from soils to leafy vegetables like spinach and lettuce.

### 3.2.5 Biogeochemical Aspects of Soil Profile Development in Relation to Mineralogy, Organic Matter and Trace Metals

Four representative profile soil samples of a topo-sequence of Almora District were studied. The soils were rich in organic carbon ranging from 2.1% in the hill top to 0.57% in the valley terrace and acidic in nature with pH ranging from 5.84 to 6.39 in the surface soils with slight increase in the sub-surface soils. The bulk density was observed to increase down the profile on the hill top (1.33 to 1.65 $Mg/m^3$) and on the side slope of hills (1.23 to 1.86 $Mg/m^3$) indicating some soil compaction down the profile. Soils in hill top and side slopes showed good correlation with soil depth and bulk density ($r^2$ =0.84), but the same was not observed in the valley terrace and piedmont plains.

Cation exchange capacity (CEC) of the soils along the topo-sequence varied from 16.6 to 8.5 c mol ($p^+$)/ kg with the highest on the hill top and piedmont plains and the lowest in the valley terraces indicating more weathering on the valley terraces. Exchangeable $Ca^{2+}$ and $Mg^{2+}$ also followed a similar trend. Exchangeable $Ca^{2+}$ was found to be highly correlated with CEC of the soils ($r^2$ =0.88) while exchangeable $Mg^{2+}$ was poorly correlated with CEC ($r^2$ =0.37). The exchangeable $Na^+$(0.55-0.16 c mol ($p^+$)/ kg ) and exchangeable $K^+$ concentration (0.99 to 0.69 c mol ($p^+$)/ kg ) were low in these soils with a low base saturation (73 to 65%).

The mineralizable N contents of these soils were high in the order of 650 kg/ha on the hill tops, piedmont plain and valley terraces and around 550 kg/ha on the side slopes. Mineralizable N was found to be highly correlated with organic C ($r^2$=0.51). The soils are also medium in available phosphorous ranging from 12.5 kg/ha on the hill top to 14.7 kg/ha on the piedmont plains. The soils were found to be deficient in available P in the valley terraces. Organic carbon and P content of the soils in different topo-sequence showed good correlation ($r^2$ =0.82).

Total surface area of the clay fraction of soils from different topo-sequences ranged from 233 $m^2$/g in the side slopes to 484 $m^2$/g on the valley terraces. There was general increase in surface area of clays down the profile in all the soils of the topo-sequence. There is also an indication of formation of expanding clay minerals in the valley terraces and piedmont plains.

### 3.2.6 Effect of Organic Manures and Mineral Fertilizers on Yield, Nutrient Uptake and Changes in Soil Organic Carbon Fractions in Maize-Wheat Cropping System

A field experiment was carried out to study the effect of three organic manures, namely, vermicompost, NADEP compost and FYM and mineral fertilizers either alone or in combination with a maize-wheat crop rotation. Results revealed that yield and nutrient uptake by maize and wheat due to integrated use of organic and mineral fertilizers increased significantly over application of manures alone and comparable with the recommended dose of NPK fertilizers (100% RDF). Soils amended with value added manures as well as 100% RDF significantly improved Walkley Black carbon (WBC) over control during different physiological growth stages of both the crops. Much more pronounced effect in improving WBC was observed under 50% RDF+5 t/ha of manures than under control as well as sole application of organic manures and 100% RDF. Among the organic sources, vermicompost performed better, followed by FYM and NADEP compost. It was also observed that organic C fractions decreased with the advancement of crop growth. Similar trend also observed in the case of labile organic C as well as microbial biomass C with treatment receiving 50% RDF+5 t/ha of manures. Among the different pools, microbial biomass C was more influenced by physiological growth stages of crops. Carbon mineralization ($CO_2$ evolution) also followed the same trend as in the case of microbial biomass C indicating that soil respiration was higher in the active growth stages of crops. As compared to maize, the SOC fractions improved in greater amount in wheat. It may be concluded that 50% RDF could be substituted by the application of manures for crop production as well as for maintaining soil organic C, thereby saving 50% of chemical fertilizers.

### 3.2.7 Effect of Tillage, Water and Nutrient Management Practices on Soil Organic Carbon Pools and Available Nutrients under Rice-Wheat Cropping System

Interactive effects of tillage, water and nutrient management practices on soil organic carbon pools and available nutrients under rice-wheat cropping system were evaluated in a long-term field experiment, which was initiated in 2001 at IARI-farm. The experiments consisted of two tillage, three water and seven nutrient management practices. The results indicated that total (TOC) and Walkley and Black organic carbon (WBC) were not significantly affected by tillage after completion of seven cropping cycles. Moisture had positive impact on TOC and WBC content of soil. Improvement in TOC and WBC was directly proportional to the amount of organic matter added. On an average, puddled soil showed significantly higher labile carbon (LBC) than non-puddled ones whereas, reverse trend was observed in the case of microbial biomass carbon (MBC). As the duration of drainage increased from continuous submergence to

irrigation after three days of drainage, LBC and MBC increased. Soil treated with FYM and green manure along with mineral fertilizers or organic sources of nutrients, showed significantly higher LBC than soil receiving only inorganic fertilizers whereas, soil receiving crop residue along with mineral fertilizers and organic source of nutrients showed significantly higher MBC than other treatments. Green manure in rice-wheat was more effective than crop residues in increasing the LBC content of soil. Inorganic, integrated and organic sources of nutrients showed significant improvement in carbon management index (CMI) over control, and maximum improvement in CMI was observed in plots that received 100% organic source of nutrients. Mineral N and available P content were higher in puddled soil as compared to those in non-puddled soil. As the moisture content in soil decreased, P content in soil also decreased, whereas available S increased. Organic source of nutrients could not maintain the level of mineral N in soil even as that recorded in control, whereas plots that received FYM and crop residue along with mineral fertilizers showed significantly higher mineral N content compared to the plots where nutrients were supplied through chemical fertilizers. Use of crop residues along with mineral fertilizers had a beneficial effect on the available P.

### 3.2.8 Effect of Sewage Sludge and Cowpea Residue Incorporation on Yield and Soil Properties after Wheat

Sewage sludge (SS) alone and mixed with rice straw (RS) in the ratio of 1:3, 1:6, and 1:9 along with 50% NPK was applied to cowpea. Untreated control and plot receiving recommended dose of NPK were kept for comparison. The entire biomass of cowpea was turned in the field as green manure after harvest of pods of cowpea. The soil samples were collected after 90 days from the date of sowing of the cowpea. The results revealed that the highest content of organic carbon (OC) and mineral N ($NH_4^+$-N + $NO_3^-$-N) were found in sewage sludge + rice straw (1:9) + 50% NPK treatment. Succeeding wheat (HD 2687) crop was grown with the same set of treatments. Significant increase in wheat yield was observed because of sewage sludge treatments over that of control. The highest yield was obtained in SS+RS (1:9) +50% NPK, which was statistically on a par with recommended dose of NPK. The soil samples after wheat recorded significant improvement due to application of sewage sludge along with rice straw and 50% NPK, thereby saving 50% of NPK fertilizers.

### 3.2.9 Effect of Enriched Rice Straw Compost on Nutrition of Wheat and Soil Properties

Four enriched composts were prepared from rice straw alone and by mixing 2% N, 2% N + 2% P and 2% N + 2% P+ 2% K. These composts were evaluated in a field experiment to study their effect on yield and nutrient uptake by wheat (var. HD 2285). The highest grain yield (5.76 t/ha) was observed in treatment where 50% RDF was applied through inorganic fertilizer along with application of 5 t/ha NPK enriched compost and it was statically on a par with the treatment of 100% RDF. Application of ordinary compost at the rate of 5 t/ha along with 50% RDF gave 20-45% lower grain yield as compared to that given by the treatments which received N, NP and NPK enriched composts. The application of enriched composts resulted in higher uptake of N (7-26%) and P (21.8-60.6%) in comparison to the applications of ordinary composts. Maximum uptake of Zn, Cu, Mn and Fe was observed under the treatment of NPK enriched compost. Enriched composts were associated with enhanced availability of major as well as micro nutrients in soil. Higher organic N and P were observed under the treatment of N, NP and NPK enriched composts whereas higher amino acid N, amino sugar N and non-hydrolysable N were observed in treatment 100% RDF. A positive effect of N substitution through compost was observed in terms of improved ammoniacal N and nitrate N contents of soil.

## 3.3 WATER MANAGEMENT

### 3.3.1 Water Resources Conservation and Management

#### 3.3.1.1 Criteria developed for choice of sink for conservation of excess water

Investigations have been carried at Najafgarh block in West Delhi, a semi arid, peri-urban area, getting an average annual rainfall of 451 mm. The block is currently facing water shortage due to lowering of water table and deterioration in ground water quality. Past studies in this region revealed an

average natural recharge of 13% indicating vast possibilities of conserving part of the remaining 392 mm (average), which is lost either as run-off or as evaporation. Qualitative conservation is based on the quality of both the available surplus and that of the ground water of the area under study. Attempts were made to work out strategies for deciding the choice of sink for the purpose of conserving any excess water available on the basis of water quality divided in two groups.

The first group corresponded to the villages with ground water up to 4.62 dS/m EC and 18 SAR ( the limits obtained by merging acceptable and the tolerable values of both, in relation to irrigation). The second group corresponded to all other villages having ground water of very poor quality, i.e., exceeding 4.62 dS/m EC and 18 SAR (limits of both) beyond which it is unfit for irrigation for most of the crops. The ground water of the first group was designated as fit for both irrigation as well as for artificially recharging of the aquifer, provided available surplus for conservation also belonged to the first group. Similarly, if the ground water or the available surplus was of the second group, i.e., of rejection level, the conservation was suggested only by storing the water at the surface.

### 3.3.1.2 Watershed management planning for augmenting groundwater recharge through remote sensing and GIS approach in Manesar Nala Watershed in Arawali foot hills of Gurgaon (Haryana)

A pilot study was conducted to analyze the potential site suitability for constructing soil and water conservation structures in Manesar Nala Watershed, Gurgaon, Haryana by using space technology integrated Remote Sensing (RS) and Geographical Information System (GIS) as per Integrated Mission for Sustainable Development (IMSD) guidelines. Sites highly suitable for constructing water harvesting structures for augmenting groundwater recharge were identified through an analytical approach by fixing the appropriate criterion through the application of RS and GIS technologies. False Colour Composite (FCC) of remotely sensed images in LISS-III band onboard Indian Remote Sensing Satellite (IRS-I C LISS III imagery (FCC)) along with the Survey of India toposheets on scale 1: 50,000 and 1: 25,000 were used and analyzed in Window based GIS software ILWIS Ver. 3.4 and ERDAS Imagine Ver. 9.1 Digital Image Processing Software (raster based) for data analysis and drawing inferences. Appropriate decision rules were framed for each structure and with the help of GIS, the most appropriate locations for construction of structures were identified. Various structures such as check dams, groundwater recharge structures (percolation tanks), rain water harvesting ponds and check dams were suggested. The area coverages of these structures were found to be 449531 $m^2$, 449531 $m^2$ and 36448 $m^2$, respectively, with minimum loss of area for cultivation (1.27 per cent of the total geographical area of the watershed). The methodology developed in this study can be replicated elsewhere for similar purposes. It was concluded that if the structures could be created as per suggestions, it would not only be possible to harvest maximum amount of runoff water from the catchment but also would result in substantial amount of ground water recharge. A watershed management plan was formulated for land and water resources development in the maps for Watershed Development Plan showing the proposed land use, soil and water conservation structures, etc.

### 3.3.1.3 Artificial neural network model for prediction of crop evapotranspiration

Twenty Artificial Neural Network (ANN) models with different network architectures, transfer and learning functions for prediction of crop evapotranspiration were developed, validated and tested for wheat crop grown at Delhi by using lysimetric data and meteorologic information with MATLAB. The networks were developed by using feed forward back propagation (FFBP) and Elman back propagation (EBP) architectures with log sigmoid and tan sigmoid transfer functions. The modeling strategy of ANN model having back propagation learning algorithm, log sigmoid transfer function and model input strategy 1 (ANN-BP-L-1) was rated the best. This model exhibited better results with Nash-Sutcliffe Coefficient (E), i.e., efficiency coefficient and Root Mean Square Error (RMSE) of 0.972 and 0.498 for development data set and 0.776 and 1.334 mm for evaluation data set, respectively. When ANN predicted ET was compared with Penman-Monteith estimated ET, the results

showed that the ANN predicted ET was more close to the lysimeter values than Penman-Monteith estimated ET.

### 3.3.1.4 Modelling of evapotranspiration from bare soil

Field and laboratory simulation experiments were conducted to measure the bare soil evaporation from silty clay loam soil of *Jagat series* (SCl) and sandy loam soil of *Mehrauli series* (Sl) of IARI farm, New Delhi during the months of March and April 2009. Bare soil evaporation was estimated following a water balance approach from the measured soil moisture contents. Linear Multiple Regression (LMR) models were developed for predicting bare soil evaporation by using the predominant meteorological parameters affecting the evaporation phenomenon. The developed models (MLRE) were validated with the field observations for 0-15 and 15-30 cm soil depth with observed values and the result showed very close agreement with the predicted. Results obtained from the study indicated that the bare soil evaporation from 0 to 15 cm soil layer in SCl soil varied between 2.0 and 3.0 mm per day in the first phase which rose to 4.5 mm per day in the drying stage. For Sl soil, the bare soil evaporation varied from a minimum of 2.0 to a maximum of 3.2 mm per day in uppermost layer. In both soils the changes in soil moisture in other two layers were large though the same cannot be referred to as evaporation.

### 3.3.1.5 Modeling evapotranspiration and root-zone soil water balance for cropping system analysis in the trans-Gangetic plains region of India

A regional water balance model, namely, the Modified Thorntwaite-Mather Model (T-M model), was validated and tested for 19 districts of Haryana State falling in the trans-Gangetic plains region by the use of Remote Sensing and GIS Techniques. The T-M root-zone water balance model was used to generate the daily soil moisture in the root-zones based on the monthly rainfall and monthly potential evapotranspiration. Almost all the districts of Haryana showed negative water balance meaning that there was a severe water resources crunch in the area, and available water was inadequate to meet the crop irrigation requirements. Spatial variations of some of these parameters established that there was high uniformity at large in soil moisture deficit patterns among various districts in the region except in some localized pockets.

### 3.3.1.6 Supply and demand management constraints in a watershed area in Mewat district, Haryana

A study was undertaken in Mewat district, Haryana to assess the available water, water harvesting potential and water utilization after adjusting for water saving technologies and its impact on production and income of the farmers. Primary data on input use and other cultural practices were collected from farmers in six villages in Nuh block of the district. A linear programming model demonstrated the various scenarios of water availability and use as well as corresponding cropping pattern and income. The study showed that it was possible to increase the water availability, and changes in cropping pattern and water use could help farmers realize up to 217 per cent higher income levels. But under the existing circumstances, a micro level planning and management to remove supply constraints and managing the utilization of available water in the most optimal manner was found to be essential. The study also indentified the operational problems in the implementation of watershed programmes faced by various stakeholders, namely, User's Groups, Panchayats and the government departments. People's participation index in watershed planning, maintenance and monitoring was found to be 0.16.

## 3.3.2 Irrigation Water Management

### 3.3.2.1 Effect of planting method and intercropping on yield of maize and groundnut under maize based cropping system

Maize and groundnut were grown as sole and intercrops with each other to determine the effects of different planting methods under rainfed and limited irrigation on the productivity. Significantly higher grain yield of maize and groundnut was found with ridge planting compared to flat planting, irrespective of the cropping system under both rainfed and irrigated conditions. Similarly, the crop given irrigation at grain formation and dough stages produced higher yield as compared to rainfed crop. However, the

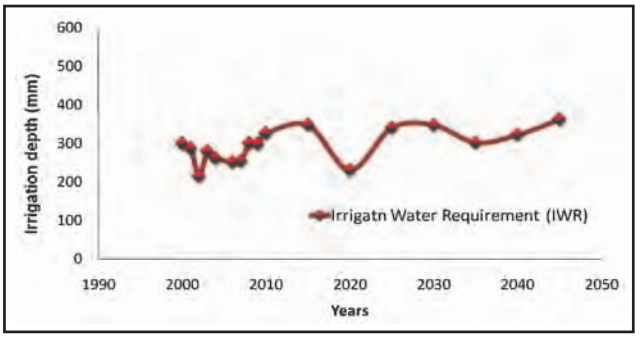
response of irrigation was more pronounced in groundnut compared to maize. Maize equivalent yields were higher under intercropping treatment compared to sole cropping under both irrigated and rainfed systems. However, it was higher under irrigated condition compared to rainfed irrespective of planting methods and cropping patterns. Water use efficiency (WUE) was higher with ridge planting compared to that of flat planting irrespective of the cropping system and irrigation level. The WUE was higher with maize + groundnut but in comparison to sole groundnut, it was significantly higher than that of sole maize.

### 3.3.2.2 Water use efficiency of maize crop under rainfed conditions

Field experiments was undertaken to estimate the water utilization of *kharif* maize under rainfed conditions. Experiment with four different levels of N, viz,. 0%, 50%, 100%, and 150% recommended nitrogen dose (RDN) (i.e. 150 kg/ha to rainfed maize) were carried out. There was a variation in the yield with a minimum of 1.42 t/ha in the plot with no nitrogen to a maximum of 2.83 t/ha in 150% RDN, i.e. 225 kg/ ha of nitrogen treatment. The increase in yield due to higher dose of nitrogen and water was observed to be non-significant. However, under rainfed condition, there was an increase in the yield of about 85% with RDN and 100% increase in the yield with 150% RDN as compared to no nitrogen application. The total rainfall during the crop growth period was 435 mm and the effective rainfall was 313.5 mm. Subsequently, the water use efficiency was estimated to be varying from a minimum of 0.4 kg/$m^3$ in the plot with no nitrogen to a maximum of 0.8 kg/ $m^3$ for the plot with 225 kg/ ha of nitrogen. The treatment combination of 100% soil moisture deficit and 150% RDN resulted in the highest water use efficiency of 1.1 kg/ $m^3$ with a yield of 6 t/ha and it consumed 567 mm of water.

### 3.3.2.3 Impact of climate change on sustainable yield of maize

In an investigation to study the impact of climate change on irrigation water requirement (IWR) for the *kharif* maize, the ClimGen weather model was used to generate the meteorological data of future years (2009-2050) by utilizing




**CROPWAT generated IWR using the observed and ClimGen generated climatic parameter of the study region for *kharif* maize crop**

37 years of historical data (1972-2008) of WTC observatory, IARI farm, New Delhi. The generated data were used as an input to FAO CROPWAT model to estimate the IWR of maize. The analysis were undertaken for the preceding and succeeding years of 1972-2008 and 2008-2043 as mentioned earlier. The CROPWAT estimated values of $ET_0$ (reference evapo-transpiration), ETc (Crop evapo-transpiration) and irrigation water requirement (IWR) for the *kharif* maize crop with a sustainable yield of 5 t/ha in the study region. It was observed that both the $ET_0$ and ETc values varied for different years and the projected IWR for a period from 2009 to 2045 ranged from 8% to 21% in comparison to the minimum and maximum values of IWR for a period from 2000 to 2008 to attain sustainable yield of maize crop in the northern India. This could be attributable to the changes in the climatic parameters, viz., temperature, solar radiation, wind speed, etc., as generated by the ClimGen model. Also, it was observed that the increase in the IWR values for future years was due to the occurrence of less rainfall during the monsoon months as estimated by the ClimGen model.

## 3.3.3 Surface Irrigation Studies

### 3.3.3.1 Hydraulics of surface irrigation

A study was carried out to analyse the hydraulics of overland flow into a border being irrigated in rotational running by a watercourse. The time-variable function of water infiltration rate was represented by its average value during the water-front advance. It was found that the ratio of average irrigation depth to the hydraulic depth of overland flow played a key role in affecting the hydraulics of overland flow.

### 3.3.3.2 Field evaluation of surface fertigation in wheat crop

A field experiment was conducted to study the nitrogen distribution pattern under surface fertigation in wheat crop in border irrigation layouts as compared to broadcasting method of fertilizer application. It was observed that $NO_3^-N$ was similar under both the treatments. However, in upper two depths, i.e.,0-30 and 30-60 cm depths, higher $NO_3^-N$ was found in surface fertigation. It was also observed that $NH_4^-N$ pattern was unaffected by the fertilizer application methodology.

## 3.3.4 Pressurized Irrigation Studies

### 3.3.4.1 Yield, water use efficiency and modeling of nitrate transport in garlic under micro irrigation fertigation with varying levels of N

Two different irrigation systems, namely, drip and micro-sprinkler systems were tested on garlic variety Yamuna Safed planted at 10 cm x 15 cm. The lateral spacing of 60 cm and emitter spacing of 50 cm were used in the drip irrigation system. In micro irrigation system, micro sprinkler spacing was kept as 2 m. The N levels were control, 40%, 80% and 120% of recommended dose of nitrogen (RDN), i.e., 100 kg/ha.

The bulb yield of garlic was significantly higher under drip irrigation system (7.22 t/ha) compared to that under micro sprinkler system (2.87 t/ha). The maximum yield was obtained with drip irrigation along with the application of 80% of RDN, which was significantly higher than that of all other treatment combinations. Water use efficiency was significantly higher with drip irrigation system compared to micro sprinkler system. Similarly, WUE obtained with 80% of RDN under both irrigation methods was higher than that obtained with other levels of N application. RDN application of 120% resulted in reduction in the bulb yield as well as WUE under both drip and micro sprinkler systems.

In drip irrigation, soil water content was relatively higher in shallow profiles (15-30 cm). Water content in all the soil layers decreased as the distance from the emitter increased in the horizontal direction. In micro sprinkler irrigation system, soil water content in the upper layer was higher in the periphery of the micro sprinkler. However, under drip irrigation plots, majority of nitrogen content was observed in the upper soil layers. However, in micro sprinkler system, nitrogen content was higher in the periphery of sprinkler system.

### 3.3.4.2 Crop geometry and water requirement of lettuce (*Lactuca sativa L.*) crop under trickle irrigation

An experiment to study the optimal crop geometry and to estimate the water requirement of lettuce under trickle irrigation was conducted. The impact of three crop geometry (45 cm x 30 cm, 30 cm x 30 cm and 17.5 cm x 30 cm), two different fertigation strategies (60 kg/ha and 100 kg/ha) and two irrigation levels (2 & 4 days irrigation intervals) were assessed. It was found that the seasonal crop water requirement for lettuce plant was 162 mm for 2 and 4 days' irrigation intervals and 183 mm for 7 days' irrigation interval. An event of hail storm followed by rainfall of 11.8 mm led to yield loss of 9%. Besides the quantitative loss, there was qualitative damage of the crop too. Increased irrigation interval did not help much because the water requirement increased by 14%. The reasons are that lettuce crop is shallow rooted and have a limited capacity to use water storages at depth and 85% of the water used by lettuce is extracted from the top 20 cm of soil. In the case of longer irrigation interval, the depth of irrigation was more and led to percolation losses beyond the root zone depth.

### 3.3.4.3 Study of moisture distribution pattern of inline lateral lines under two irrigation schedules for onion crop

An experiment was conducted to study the effect of moisture distribution on root development and yield of onion crop under trickle irrigation. There was two irrigation schedules, viz., two-day irrigation interval and four-day irrigation interval. The distribution uniformity of the trickle irrigation was improved to 87% as compared to the 78% reported earlier. The result showed that simultaneous root development of the crop near to lateral was comparatively better than the crop away from the lateral. This development was responsible for more uptake of the nutrient and bigger bulb formation leading to improvement in yield. Yield

variability related to water distribution was also observed in the crop. The yield was better in two-day irrigation interval than in four-day irrigation interval.

### 3.3.4.4 Application of saline water through drip irrigation in garlic and cotton

Field experiment was conducted on a sandy loam soil at the experimental farm of the Institute to assess the salt tolerance of garlic (*Allium sativum L.)* by using different salinity waters (EC 1.5-7.5 dS/m in garlic and 1.5 -11 dS/m in cotton). Three types of drip systems, e.g., surface drip, subsurface drip (depth of placement at 15 cm and 30 cm) were also tested in cotton. Saline treatments were imposed by irrigating with water that was salinized with NaCl and $CaCl_2$. Increasing soil salinity from 1.5 to 7.5 dS/m reduced the yield of garlic significantly. Similarly, increasing soil salinity from 1.5 to 11.0 dS/m reduced the yield of cotton significantly.

## 3.3.5 Ground Water Studies

### 3.3.5.1 Variation in climatic parameters and their effect on crop water requirements of major crops

About 3 decades' data of average annual rainfall, annual minimum and maximum temperatures and annual relative humidity were collected from IARI and analyzed to examine the changes in these parameters. Trend analysis revealed that average annual rainfall, average annual maximum temperature and RH exhibited a declining trend. However, the average annual minimum temperature, and average annual temperature showed marginally increasing trend. Crop evapotranspiration ($Et_c$) of major crops (rice, wheat, and maize) was estimated using *CROPWAT* model and compared with $Et_c$ estimated from normal values. When the average monthly temperature was increased by 0.5 $^0$C above normal, $Et_c$ of rice, wheat and maize increased by 8.3 mm, 3.5 mm and 2.8 mm, respectively. Increases in Etc of rice-wheat and maize-wheat cropping systems were 11.8 mm and 7.0 mm, respectively. If converted into volume, $Et_c$ for 1.0 ha area under rice-wheat and maize-wheat cropping system would be 118.0 $m^3$ and 70.0 $m^3$, respectively. This would mean that if a farmer has 1 ha of area under rice-wheat system, he would have to arrange 118 $m^3$ of additional water. Similarly, for maize-wheat system, the additional water requirement would be 70.0 $m^3$. This volume would be considerable in rainfed region. In the event of climate change, without increase in water supply, the farmers may shift to maize-based cropping system with pulse or oilseed as alternate crops in *rabi*. In case the relative humidity decreased by 3%, crop water requirement would increase slightly.

### 3.3.5.2 Study on groundwater situation and modeling of groundwater recharge

An analysis of groundwater table data was done to investigate the groundwater behaviour in IARI campus. The average decline in water table in the farm area during May 2008 and May 2009 was 1.27 m. The average rise in water table during 2009 due to rainfall in monsoon was 0.58 m. This indicated that recharge in monsoon season was not adequate to compensate the annual decline.

Monsoon rainfall is the major source of groundwater recharge. Part of the rainfall flows away as surface runoff, part of it is lost as ET, considerable portion is stored in vadose zone particularly in deep water table area, and the remaining portion reaches water table which is termed as groundwater recharge. In an earlier study, soil moisture storage was approximated and crop evapotranspiration was not considered in the estimation of groundwater recharge. A study was conducted to assess the groundwater recharge in IARI campus by giving due consideration to these processes. Recharge flux (recharge rate) estimated by variably saturated flow model HYDRUS at the water table was considered as input in the ground water flow model MODFLOW to estimate the groundwater recharge under varying groundwater recharge and pumping scenarios in terms of rise of water table. Several scenarios were considered for simulation. MODFLOW is a modular 3-D finite difference model for simulating the groundwater behavior under varying hydrological stresses. The study area was divided into a number of cells of 60 m x 60 m each. Simulated rise in water table under various scenarios varied from 0.49 m to 1.54 m. Simulation results revealed that average soil moisture storage in vadose zone for different sub areas varied from 12.51 cm to 14.46 cm. The methodology perfected and model used in this study can be used for the assessment of groundwater recharge from other areas and the effect of climate change on groundwater recharge and availability.

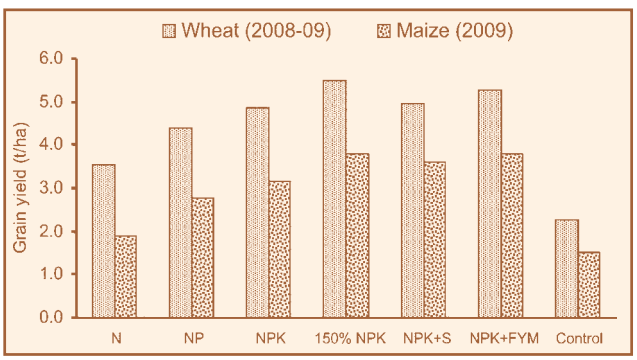
## 3.4 INTEGRATED NUTRIENT MANAGEMENT

### 3.4.1 Long Term Fertilizer Experiments (LTFE)

In a long-term experiment continuing at IARI farm since 1971-72 under AICRP-LTFE, 10 treatments consisting of sub-optimal to super-optimal NPK, fertilizer NP or N alone, NPK supplemented with Zn, S or FYM, and an unfertilized-control were evaluated under maize-wheat cropping system. Optimal (100% of recommended rate) NPK for maize or wheat was 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.

***Yield responses.*** The grain yield of maize and wheat during the year under report revealed that application of 15 t FYM/ha along with recommended NPK or super-optimal NPK (150% of recommended NPK) out-yielded all other treatments. The yields in these treatments were significantly greater than that in optimal (100% recommended rate) NPK, underlining the necessity of upward revision of the fertilizer recommendations. The yield difference between NPKS and NPK, NPK and NP, and that between NP and N alone exhibited a significant response to S, P and K fertilization, respectively. The performance of 100% NPK+ hand weeding was comparable with that of 100% NPK indicating no significant difference between hand weeding and chemical weed control.

A comparison of current yield levels with the averaged maize or wheat yields across the years (1993-94 to 2008-09) showed that the yield gains due to super-optimal NPK or NPK+S over optimal NPK and to NP over N were greater in 2008-09 than those in the averaged yield data. Apparently, the response to P or S, as also to the enhanced rate of NPK was magnified with the passage of time. These data indicated emerging inadequacy of P and S in the soil, which could be offset through an enhanced rate of NPK application, use of FYM and inclusion of S in fertilizer schedule.

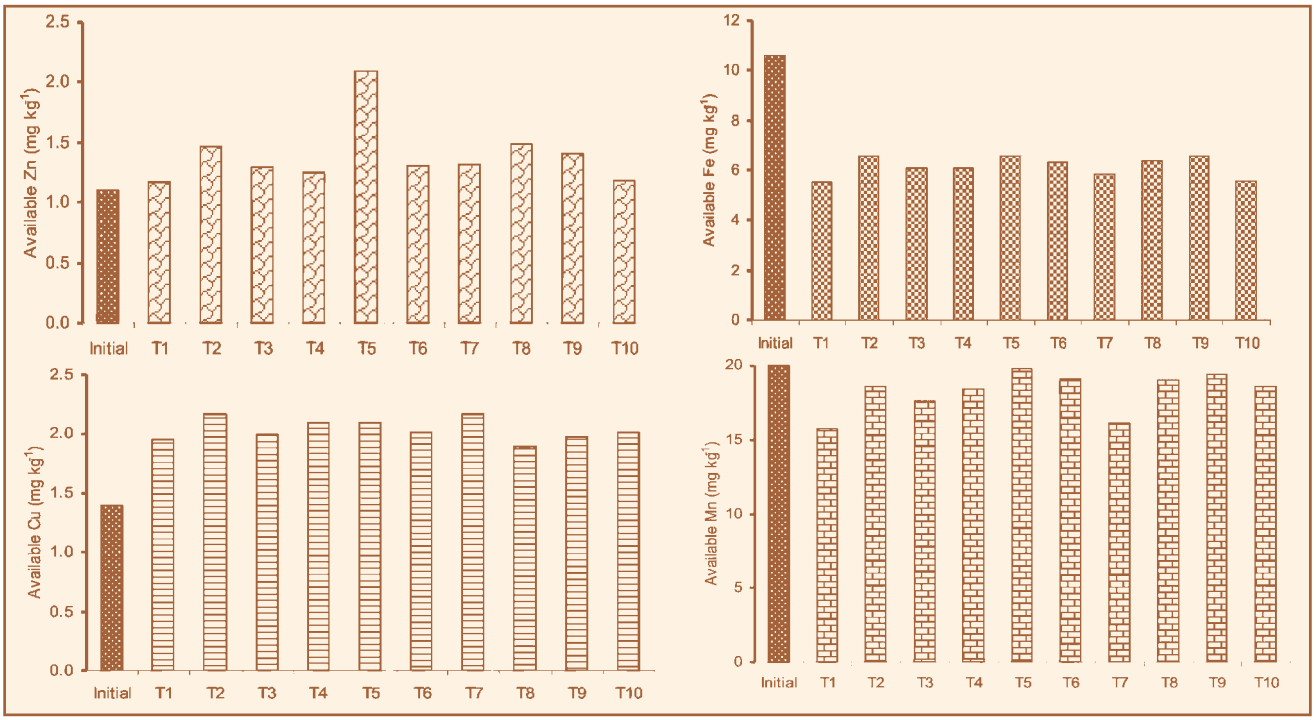



**Long-term effect of fertilizer options on maize and wheat productivity**

***Micronutrient availability.*** Available Zn and Cu contents of surface soil showed a build-up as compared to the initial level of 1.1 and 1.4 mg/kg, respectively. The highest available Zn content of 2.09 mg/kg was recorded in plots treated with fertilizer Zn during *rabi* seasons. On the contrary, available Fe content showed a sharp decline over the years. The initial content of 10.6 mg/kg was depleted to almost half, ranging between 5.5 and 6.6 mg/kg. Available Mn content of soil under different treatments ranged between 15.7 and 19.8 mg/kg, as against the initial content (20 mg/kg). Thus available Mn content was nearly maintained at the initial level in most of the treatments.

### 3.4.2 Integrated Nutrient Supply and Management in Pigeonpea-Wheat System

A field experiment on pigeonpea-wheat system initiated in 2004-05 was continued during 5$^{th}$ consecutive year. The effect of sole application of fertilizer NPK or manures, i.e., FYM and sulphitation pressmud (SPM) alone or in combination, and residue recycling through induced defoliation (ID) in pigeonpea was evaluated. Application of fertilizer NPK along with FYM or SPM significantly increased the yields of pigeonpea and wheat compared with that obtained in fertilizer alone; the magnitude of yield response to integrated nutrient input was greater in wheat. However, organics applied alone did not perform well as the yields under these treatments were significantly lower than those in soil test-based NPK fertilization. Of the two manures included in this study, yields of both crops were constantly greater in SPM plots. The ID treatment imposed through foliar application of 10% urea solution at physiological maturity of extra-short duration pigeonpea caused almost complete defoliation, and thus added to the soil, on an average, 1.6 t/ha of additional leaf-litter. In the treatments receiving ID, 42 to 46 kg N/ha was recycled through additional leaf-litter. The yield of pigeonpea remained unaffected due to ID, but that of subsequent wheat was




**Changes in DTPA-extractable micronutrient status after 38 cropping cycles: $T_1$= 50% optimal NPK (120:60:40), $T_2$= 100% optimal NPK (120:60:40),$T_3$= 150% optimal NPK (120:60:40), $T_4$= $T_2$ + hand weeding, $T_5$= $T_2$ + Zn, $T_6$= 100% optimal NP, $T_{7-}$= 100% optimal N, $T_8$= $T_2$ + FYM, $T_9$= $T_2$ + S, and $T_{10}$= control**

increased by 0.55 to 0.68 t/ha over that of the treatments receiving fertilizer NPK alone.

An analysis of soil samples (0-15 cm) drawn after completion of five pigeonpea-wheat crop cycles revealed significant impact of integrated nutrient supply in improving the hydraulic conductivity and mean weight diameter, and in decreasing the soil bulk density in comparison to these parameters in fertilizer alone treatments. Soil organic C and mineral-N content also showed marked increase under conjoint use of fertilizer NPK and organic manures.

## 3.5 NUTRIENT MANAGEMENT

### 3.5.1 Appraisal of Multi-nutrient Deficiencies in Soils and their Redressal through Site Specific Nutrient Management (SSNM)

In the IARI-IPNI India Programme collaborative research project, 100 soil samples (0-15 cm) from village Azampur (Saharanpur District) representing foothills of Kumaon Himalayas (AESR 9.1) were analysed for soil fertility appraisal. The nature and extent of simultaneous inadequacy of two or more nutrients were also assessed. Besides, on-farm experiments on site-specific nutrient management (SSNM) in pearlmillet-wheat and pearlmillet-mustard cropping systems at village Lohtaki (District Gurgaon) were concluded.

#### 3.5.1.1 Soil fertility appraisal

Soil pH ranged between 7.8 and 8.9 with 22% samples exhibiting alkalinity problem. Soils contained organic C and available P in high fertility range, and only 7% samples represented K-responsive category. On the other hand, deficiencies of S and B were widespread and almost uniformly distributed throughout the village. Whereas almost all samples contained available (hot water soluble) B below the threshold level of 0.50 mg/kg, as many as 76% samples exhibited S deficiency. Among DTPA extractable micronutrients, Zn deficiency was noticed in 22% samples. Over 50% samples suffered from simultaneous deficiencies

of S and B. S, Zn, B was the other prominent multi-nutrient deficiency combination accounting for 18% soil samples.

### 3.5.1.2 On-farm experiments on SSNM

On-farm experiments for evaluation of SSNM vis-à-vis other fertilizer options in pearlmillet-wheat and pearlmillet-mustard cropping systems were continued at Lohtaki village. Data of 28 experiments conducted during the past two years revealed superiority of SSNM over other practices in both cropping systems. The average yield gain over FFP was 1.66 to 1.81 t/ha in pearlmillet, 2.16 t/ha in wheat and 1.44 t/ha in mustard. Fertilizer NPK prescriptions as per targeted yield approach of STCR when supplemented with secondary and micronutrients were comparable with SSNM and distinctly superior to other options. As the experimental sites suffered from severe K deficiency, use of fertilizer K in adequate amounts resulted in marked increase in crop yields, although the advantage was greater when K was applied as per state recommendation instead of farmers' fertilizer practice. Also, the cereal-cereal system accrued relatively greater benefit from K fertilization.

**Effect of fertilizer options on grain yield (t/ha) of crops (2-year data averaged)**

| Treatment | Pearl millet-wheat system (16 experiments) | | Pearl millet-mustard system (12 experiments) | |
|---|---|---|---|---|
| | Pearl millet | Wheat | Pearl millet | Mustard |
| SSNM | 4.02 | 5.56 | 4.11 | 2.86 |
| TY | 3.52 | 4.90 | 3.48 | 2.50 |
| TY+ micro | 3.91 | 5.32 | 3.88 | 2.74 |
| SR | 3.04 | 4.28 | 3.00 | 2.04 |
| SR+K | 3.58 | 4.83 | 3.62 | 2.25 |
| FFP+K | 2.62 | 3.83 | 2.70 | 1.67 |
| FFP | 2.21 | 3.40 | 2.45 | 1.42 |

SSNM: Site-specific nutrient management; TY: Fertilizer NPK as per AICRP-STCR's yield adjustment equations; TY+Micro: TY+secondary & micronutrients; SR: State *ad-hoc* recommendation; FFP: Farmer's fertilizer practice

Soil analysis after completion of two cropping cycles revealed only a marginal improvement in organic C content under SSNM and TY treatments over the initial content. On an average, soil available P under SSNM was greater than the initial content by 3 kg/ha in post-mustard and by 5 kg/ha in post-wheat samples, whereas a depletion of about 5 kg P/ha under SR+K in post-mustard and that of 5.3 kg/ha under FFP+K in post-wheat samples was recorded. The K content also got depleted in FFP and SR treatments, and the magnitude of such depletion was greater in pearlmillet-wheat system. A marginal build-up in K content was noticed under SSNM only. Available S content of post-mustard soil was fairly maintained at the initial level in SSNM and TY+Micro treatments, whereas an average decline of 3.2 to 6.7 kg/ha compared with the initial content was recorded in other treatments. A general decline of varying magnitude (2.4 to 8.2 kg/ha) in available S content was, however, recorded in post-wheat soils.

The message of these on-farm experiments is that the existing fertilizer recommendations are inadequate to meet the nutrient demands of intensive cropping systems. Upward revision of fertilizer recommendations and inclusion of deficient secondary and micronutrients would be inevitable to achieve and sustain high productivity without impairing soil health.

## 3.5.2 Development of Basic Data and Soil Test Based Fertilizer Recommendations for Wheat and Maize

From the soil test-crop response correlation field experiments conducted on wheat (HD 2851) and maize (Madhuri), the basic data generated on nutrient requirement and per cent utilization efficiency of nutrients from soil, fertilizers and manure by above mentioned crops, the following soil test based fertilizer recommendations for targeted yield were developed.

These fertilizer adjustment equations developed for wheat and maize can be utilized for adjusting the fertilizer doses according to soil fertility status of N P K and their requirement by these crops for specific levels of targeted yield production. The fertilizer application based on these

**Basic data and soil test based fertilizer adjustment equations for wheat and maize**

| Parameter | N | $P_2O_5$ Wheat (HD-2851) | $K_2O$ | N | $P_2O_5$ Maize (Madhuri) | $K_2O$ |
|---|---|---|---|---|---|---|
| NR | 21.90 | 8.70 | 36.50 | 36.40 | 12.60 | 30.10 |
| % CS | 22.62 | 36.31 | 31.67 | 31.25 | 39.02 | 18.41 |
| % CF | 43.12 | 23.28 | 105.65 | 56.95 | 26.67 | 71.05 |
| % CFYM | 17.24 | 26.75 | 127.35 | 42.87 | 7.60 | 57.17 |

**Soil test based fertilizer adjustment equations for maize and wheat**

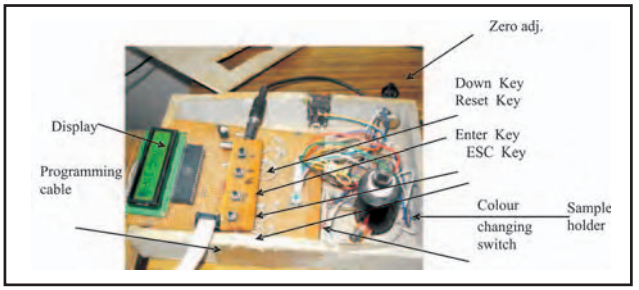
| With FYM | Without FYM |
|---|---|
| **Wheat (HD 2851)** | |
| FN = 57.0 T – 0.52SN – 2.00 FYM | FN = 57.0 T – 0.52 SN |
| $FP_2O_5$ = 37.4 T – 3.57 SP – 5.27 FYM | $FP_2O_5$ = 37.4 T – 3.57 SP |
| $FK_20$ = 34.5 T – 0.36 SK – 5.08 FYM | F $K_2O$ = 34.5 T – 0.36 SK |
| **Maize (Madhuri)** | |
| FN = 64.0 T – 0.55 SN – 2.75 FYM | FN = 64.0 T – 0.55 SN |
| $FP_2O_5$ = 47.2 T – 3.34 SP – 1.80 FYM | $FP_2O_5$ = 47.2 T – 3.34 SP |
| $FK_2O$ = 42.2 T – 0.31 SK – 2.10 FYM | $FK_2O$ = 42.4 T – 0.31 SK |

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

recommendations provides balanced nutrition to the crops as per their requirements, prevents unnecessary use of fertilizer nutrients and gives better response, yield and profit to the farmers. In case of integrated nutrient management, for each tonne of FYM application the fertilizer dose of (N, $P_2O_5$ and $K_2O$) can be reduced by 2.0, 5.3 and 5.0 kg/ha for wheat and 2.7, 1.8 and 2.1 kg /ha for maize, respectively.

### 3.5.3 Development of Low Cost Soil-Water-Test Kit Based on a Programmable Portable Colorimeter

A low cost programmable colorimeter (LCPC) was fabricated. Minimum number of components and cheaper components were utilized to make it cheaper (LEDs instead of tungsten lamp, and LDR instead of photocell were used). A microcontroller with 32 KB memory, an LCD display and four press button keys are the other major components of this colorimeter. The uniqueness of this colorimeter is that it can be programmed to display fertilizer recommendation to




**A low cost programmable portable colorimeter**

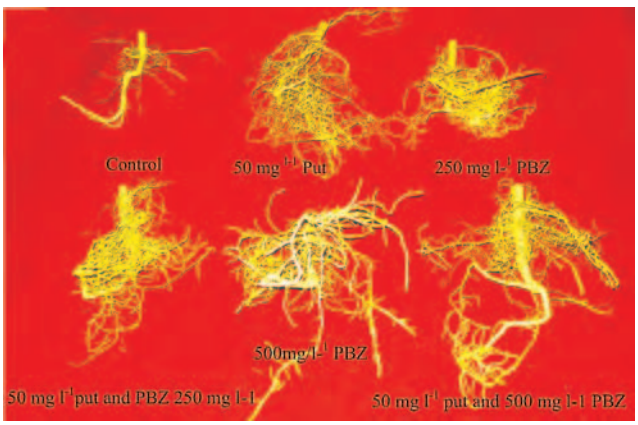
selected crops (at present, wheat and maize) from soil test data based on targeted yield approach.

## 3.6 ORCHARD MANAGEMENT

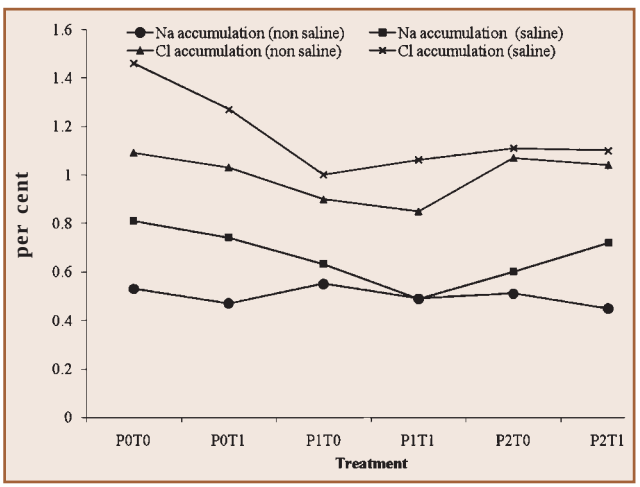
### 3.6.1 Effect of Salinity, Paclobutrazol and Putrescine on Sour Orange Citrus Rootstock

The effectiveness of paclobutrazol (PBZ) and putrescine (Put) against NaCl stress in sour orange citrus rootstock was tested. The application of PBZ was more effective in mitigating deleterious effects of high salinity on sour orange. The superoxide dismutase (SOD) activities increased by 16.62% in sour orange leaves as compared to control. Application of PBZ or Put alone or in combination increased SOD levels under both saline and non-saline conditions. The maximum SOD activity was found in combined treatment of 500 mg/l PBZ and 50 mg /l Put under both conditions. Similarly, catalase activities increased significantly (53.97%) as compared to control. In the presence of NaCl, higher activity (33.9%) in comparison to that of salinised control was noticed when seedlings were treated with 50 mg/l Put alone. In both conditions, proline content was found to be maximum (27.09% higher than that of non-salinised control and 21.52% higher than that of salinised control) with the application of 250 mg/l PBZ along with 50 mg/l Put. Further,

interaction among salinity, PBZ and but also had a significant effect on leaf and root $Na^+$ content. Under non-salinised seedlings, the lowest $Na^+$ content (15.25% lower than control) in leaf tissues was obtained when sour orange plants were treated with the combined dose of 500 mg/l PBZ and 50 mg/l of Put. While in the presence of NaCl, 39.58% lower $Na^+$ accumulation was recorded when seedlings were treated with the combined dose of 250 mg/l PBZ and 50 mg/l Put, addition of NaCl to the watering solution promoted accumulation of $Cl^-$ in both leaf and root tissues. Mean effect of PBZ showed that application of PBZ decreased $Cl^-$ content in leaves but did not influence concentration in root tissues. Application of Put reduced leaf $Cl^-$ content in both leaf and root tissues.




**Effect of salinity, PBZ and Put on root growth of sour orange seedling**




**Effect of salinity, PBZ and Put on $Na^+$ and $Cl^-$ accumulation in sour orange leaves ($P_0$ = 0.0 mg/l PBZ; $P_1$ = 250 mg/l PBZ; $P_3$= 500 mg/l PBZ; $T_0$ 0.0 mg /l Put; $T_1$ = 50 mg/l Put)**

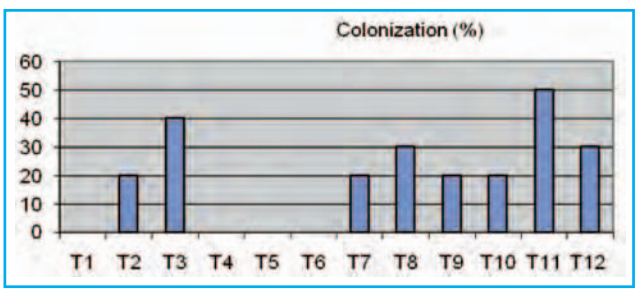
## 3.6.2 Screening of Citrus Germplasm against Graded Levels of NaCl

An experiment was laid out with six genotypes of citrus to identify the salt tolerant root stock with four EC levels. Heavy defoliation was observed in each EC levels in Troyer except control. The minimum defoliation was observed in Sohsarkar followed by Sour orange and Karna Khatta. The maximum increase in growth in terms of plant height and number of leaves was found in Sohsarkar followed by Sour orange under NaCl stress. Out of these, Troyer was most susceptible.

## 3.6.3 Effect of Arbuscular Mycorrhiza Fungi and Helper Bacteria in Lemon cv. Kagzi Kalan

In lemon cv. Kagzi Kalan, twelve treatment combinations of biofertilisers, namely, control –$T_1$, Mixed strain ( Nutrilink) -$T_2$, *Glomus intraradices* -$T_3$, Bacteria (*Providencia* sp.)-$T_4$, Cyanobacteria (*Anabaena iyengarii*)-$T_5$, *Providencia* sp. + *Anabaena iyengarii* -$T_6$, *Glomus intraradices* + *Providentia* -$T_7$, *Glomus intraradices* + *Anabaena iyengarii*-$T_8$, Mixed strain + *Providentia*+ *Anabaena iyengarii*-$T_9$, *Glomus intraradices* + *Providentia* + *Anabaena iyengarii*-$T_{10}$, Mixed strain + *Azotobacter* + PSB (*Pseudomonas striata* and *Bacillus polymyxa*) -$T_{11}$ and *Glomus intraradices* + *Azotobacter* + PSB-$T_{12}$ were tried with an objective to improve plant performance.

*Glomus intraradices* (40%) and mixed strain with *Azotobacter* and PSB (50%) showed the best colonization abilities among the nine mycorrhizal treatments applied.




**Effect of AMF and helper bacteria on root colonisation**

Based on the variations in plant height, it was observed that *Providencia* in combination with *Anabaena iyengarii* (66.5 cm) and *Anabaena iyengarii* alone (64.0 cm) were better

promoters of plant growth. The photosynthetic rate was found to be the highest (20.60 µmol /$m^2$/s) in the combination treatment of *Glomus intraradices* with *Azotobacter* and PSB. The plants with treatment *Glomus intraradices* and cyanobacteria ($T_8$) showed the highest internal $CO_2$ levels (286.75 mm moles/ $m^2$/s). Mixed strain with *Azotobacter* and PSB ($T_{11}$) showed the highest chlorophyll content (2.12 mg/ 100g). Treatment of soil with AMF, bacteria and cyanobacteria considerably improved the soil quality in terms of microbial biomass carbon, alkaline phosphatase and FDA as compared to control.

## 3.7 PROTECTED CULTIVATION TECHNOLOGY

### 3.7.1 Vegetable Crops

#### 3.7.1.1 Suitability of walk-in-tunnels for off-season cultivation of summer squash during peak winter season

Walk in tunnels are temporary protected structures made by using half inch GI pipes of 20 feet length (bended in semi circles) and covered with a transparent plastic of 150 – 200 micron thickness having size of 4.0 meter width and 2.0 meter height. The length of the tunnel is 25 – 30 meter and in technically suitable for growing complete off-season summer squash crop. During October to January months, 25 days' old seedlings of summer squash (var. Australian Green) were transplanted in the second week of October 2009 on raised beds at a spacing of 150x50 cm under drip fertigation system. Walk in tunnels were erected over the crop in the first week of December, 2009 and continued up to the end of the crop (i.e. 20th January, 2010). Walk in tunnels are technically suitable and economical for complete off-season summer squash cultivation under Delhi conditions.

**Walk-in-tunnel for off-season summer squash cultivation**

#### 3.7.1.2 Evaluation of shade net house for green coriander cultivation during peak summer season

Shade net house made by using 60% shading intensity net, black in colour was evaluated for green coriander cultivation during peak summer months (April to June). Coriander crop was sown by seeds on raised beds under drip irrigation systems in the first week of April 2009. Harvesting of green coriander was started in 3rd week of May 2009 and 80.0 kg of green coriander was harvested from 100 $m^2$ area of shade net house with a gross income of Rs 4800 /100 $m^2$ and cost : benefit ratio 3.0. Shade net cultivation of coriander proved promising.

**Green coriander crop under shade net during peak summer season**

#### 3.7.1.3 Hybrid seed production of pumpkin (var. PH 1) under insect proof net house and open field conditions

An experiment for comparison of insect proof net house and open field conditions for hybrid seed production in pumpkin (var. Pusa Hybrid 1) was conducted during the

**Economics of walk-in-tunnels for growing off-season summer squash under drip fertigation**

| Crop | Date of transplanting | Erection date | Date of first harvesting | Period of harvesting | Fruit yield (kg/100$m^2$) | Gross income (Rs/100$m^2$ ) | Cost benefit ratio |
|---|---|---|---|---|---|---|---|
| Summer squash (var. Australian Green) | 10-10-09 | 20-11-09 | 10-12-09 | 10-12-09 to 20-1-10 | 340.0 | 6,800 | 1:2.50 |

**Hybrid seed production of pumpkin under insect proof net house**

### 3.7.1.5 Economics of tomato and cucumber cultivation under zero energy naturally ventilated greenhouse

Zero energy naturally ventilated greenhouse was evaluated for tomato and parthenocarpic cucumber cultivation. Tomato (var. G.S. 600) was transplanted on 25-7-2008 and continued up to the end of April 2009, whereas, three crops of parthenocarpic cucumber were grown by transplanting the seedlings from first week of August 2008 to the end of April 2009. The zero energy naturally ventilated greenhouse is technically suitable and economical for growing tomato crop for a period of 270 – 280 days whereas

**Effect of growing conditions on seed yield and seed quality of pumpkin (var. Pusa Hybrid 1)**

| Crop growing conditions | Flowers pollinated/ plant | Fruits set/ plant | Mature fruits/plant | Seed yield (g/fruit) | Seed yield (g/plant) | Av. seed yield (t/ha) | Incidence of virus (%) |
|---|---|---|---|---|---|---|---|
| Net house | 4.2 | 3.4 | 3.2 | 76.87 | 261.36 | 1.82 | <1.0 |
| Open field | 3.4 | 1.9 | 1.4 | 45.05 | 63.07 | 0.47 | >60.0 |

summer season of 2009. First the seedlings of the parental lines of Pusa Hybrid 1 were raised in Plug-tray nursery raising system in the month of January 2009 and 15 days' old seedlings of female and male lines were transplanted on February 5, 2009 in 3:1 ratio under insect proof net house and open field conditions on raised beds at a plant spacing of 150 x 90 cm. Highly significant difference in seed yield and seed quality was recorded under insect proof net house compared to that under open field conditions. Virus incidence under net house was also recorded <1.0%, whereas it was >60.0% under open field seed crop of pumpkin.

### 3.7.1.4 Evaluation of plug tray nursery raising technology for raising sweet corn seedlings

Generally sweet corn crop is sown by seeds, but owing to heavy rains during rainy season severe damage is caused to the crop stand in the field. Similarly, the summer crop sown by the farmers from the end of February to mid-March is also not successful due to poor pollination caused by high temperature in the month of May. Therefore, the plug tray nursery raising technology was evaluated for raising the seedlings of sweet corn by using the plug trays having cell size (volume) of 10 cc. Seedlings were ready for transplanting only 25 days after sowing and no mortality was recorded during transplanting of the seedlings in the main field during both rainy season and summer season.

**Plug tray nursery of sweet corn seedlings**

**Naturally ventilated greenhouse for growing tomato and cucumber**

**Economics of tomato and cucumber cultivation under zero energy naturally ventilated greenhouse**

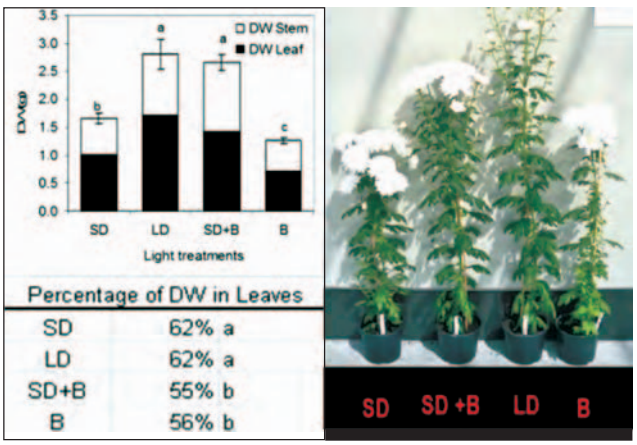
| Crop | Duration of the crop | Yield (t/1000 m$^2$) | Gross income (Rs/1000 m$^2$) | Cost: benefit ratio |
|---|---|---|---|---|
| Tomato (GS 600) | July-end to end of April (one crop) | 16.0 | 3,20,000 | 1:2.25 |
| Parthenocarpic cucumber | August first week to end of April (three crop) | 12.0 | 3,20,000 | 1:2.00 |

three crops of parthenocarpic cucumber can be grown successfully under Delhi conditions.

## 3.7.2 Flower Crops

### 3.7.2.1 Artificial flower induction in *Chrysanthemum morifolium* by the use of PAR

*Chrysanthemum morifolium* cv. Zembla plants were grown in a home box creating artificial long days (LD) by the use of light emitting diodes (LED) with 80% red (R) and 20% blue (B) maintained @ 100 µ mol /m$^2$ /sec by using royal blue light @ 455 nm and red light @ 640 nm wavelengths. It was observed that PAR induced the bud induction in LD treatments and the maximum dry mass accumulated over the period until bud induction was the highest (2.82 g/day) in




**Dry mass accumulation and PAR induced flowering under long days**

the plants under LD, followed by SD+B (2.61 g/day) showing that dry mass decreased due to longer daily PAR-period (11hour vs 15hour) in the plants and the reduced dry weight at SD with 100% B compared to SD mixed with R and B. The time taken for bud induction did not differ significantly among the plants under SD (28 days), SD+B (30.8 days) and B (30.5 days) except in the plants grown under LD (61 days).The experiment reflected the diurnal response under LD exposure with LEDs.

### 3.7.2.2 Day length extension response and crop growth modeling in *Chrysanthemum morifolium* cvs. LeMans and Zembla

The effect of extended day length from 0 (short day as control), 6,9,12 to15 days on growth and flowering response in *Chrysanthemum morifolium* cvs. LeMans and Zembla grown in 14 cm plastic pots using pot-mix and fertigated daily under a model greenhouse with 24 /18 $^0$C day and night temperature, 70-75 % relative humidity and a light intensity @ 100 µ mol /m$^2$/ sec for 9 hours as short day was observed. There was a significant increase in plant height, stem diameter, internode length, number of leaves, leaf area, number of buds and size of individual bud and flower and attributed from the differential mass gain in stem (1.06 g / day in LeMans and 1.18 g/day in Zembla) and flowers (1.29 g/day in LeMans and 1.43 g/day in Zembla) as compared to the control (0.63g/day/plant in LeMans and 0.83g /day/plant in Zembla). A linear growth response due to day length extension was noted with improvement in growth and flowering characteristics through dry mass accumulation over the treatment duration.


**Differential growth and flowering due to extended photoperiods**

### 3.7.2.3 Plant height and stem elongation in short day *Chrysanthemum morifolium* cv.Snowball in response to $GA_3$ application under naturally ventilated greenhouse

An experiment was conducted on *Chrysanthemum* under SD length $GA_3$ response to study the application to the stem elongation in cv. "Snowball". The plants exhibited significant response to stem elongation, and maximum plant height (48 cm) was attained in the plants sprayed with 150 ppm, and registered 136% and 43% increase in plant height and internodes length, respectively, over the control in 15 days of application. However, the decreased individual leaf area (-21%) in the plants treated with 250 ppm $GA_3$ was prominently observed, followed by 200 ppm $GA_3$ application response.

Control 50 75 100 150 200 250 (ppm)

**Stem elongation response of $GA_3$ in standard *Chrysanthemum***

## 3.7.3 Drip Irrigation

### 3.7.3.1 Design and installation of low pressure drip irrigation system for protected cultivation

Low pressure drip irrigation system was designed and installed for 6000 $m^2$ area to be used for various types of protected structures. The maximum working pressure head estimated was 3.0 meter to be generated from a platform of 1.50 meter height and water tank of 10,000 liter. Drip lateral of 16 mm dia was used with dripper capacity of 1.0 lph and spacing of 0.30 meter.

### 3.7.3.2 Standardization of crop water productivity and fertigation scheduling for tomato grown in protected conditions

The total crop water requirement was found to be 3200 $m^3$ and 3000 $m^3$/ ha, respectively, for tomato grown under pressurized and low pressure drip irrigation system in greenhouse. The total crop water productivity was found to be 78 and 66.7 kg/$m^3$, respectively, for tomato grown with pressurized and low pressure drip irrigation system. Two sets of tensiometers of 30 cm and 60 cm depth were found suitable for fertigation scheduling of 1000 $m^2$ greenhouse.

## 3.7.4 Rainwater Harvesting Technology for Protected Cultivation

About 200 $m^3$ rain water was harvested from a total area of one ha protected area and 3 ha open field area from a total rainfall of 14 mm in the month of November 2009. The total farm water requirement in the month of November was 3000

**Lined and un-lined water harvesting structures at IARI farm**

cubic meter. The total saving in the ground water was 6.67% due to the harvested rain water of 200 cubic meters. The rain water was harvested in 2000 $m^3$ RCC reservoir and 1440 $m^3$ unlined reservoir.

## 3.7.5 Nutrient Dynamics and Fertigation Scheduling in Kinnow

The total average crop water requirement for 8-year old kinnow grown in Delhi condition with drip fertigation was found to be 60 liters and 20 liters/plant/day, respectively, in summer and winter seasons. The total nutrient requirement was found to be 600 g nitrogen, 300 g phosphorous and 500 g potassium per year for fully mature kinnow tree grown with drip fertigation. The average maximum yield of 50 kg per tree was found from the tree getting 500 g potassium per year.

## 3.8 AGRICULTURAL ENGINEERING

### 3.8.1 Garlic Planter

For the development of a precision garlic planter, a commercial spoon type metering mechanism was tested in laboratory for assessing the planting uniformity of garlic cloves. The quality of feed index, multiple index and miss index were 62.9%, 13.9% and 23.2%, respectively. The damage to cloves during operation was 9.77%. With a degree of variation of 23.65, proper singulation of garlic cloves was not achieved by the metering system. Though the average observed spacing was close to the theoretical spacing, the metering system needs modification due to higher multiple index, miss index and clove damage as well as the quality of feed index being lower than the acceptable limit.

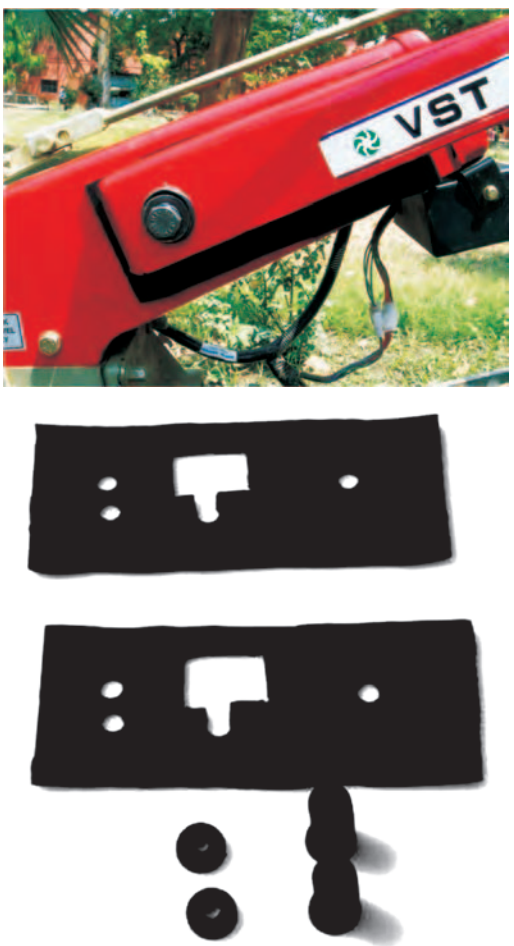
**Laboratory testing of metering system for garlic cloves**

### 3.8.2 Effect of Garlic Clove Planting Orientation on Emergence and Crop Stand

Since the orientations of garlic cloves planted on soil have direct impact on crop emergence, field experiments were conducted with three treatments : vertical placement (T1), side-wise placement (T2) and upside down placement (T3). The emergence was recorded from 10$^{th}$ day of planting up to 60$^{th}$ day of planting. The average germination percentage on different days after planting indicated that the emergence rate was the highest with cloves placed sideways, but without significant difference in the germination with cloves placed vertically. The germination of cloves placed upside down was significantly lower than the other two treatments. The crop stands of cloves under T1 and T2 were acceptable owing to early emergence as compared to that under T3. Hence, the seed tube and furrow opener of a garlic planter need to be designed for placement of garlic cloves in vertical or side placement.

### 3.8.3 Vibration Studies on Power Tiller

Since power tiller operators are exposed to a high level of vibration, a study was conducted to analyze the vibrations occurring during transportation on farm roads, tilling with cultivator and rota-tilling. The highest values of vibrations (5.96, 6.81 and 8.00 m/s in tilling with cultivator, transportation and rota-tilling, respectively) were observed in x-direction in all the operations, and were major contributors to the




**Bush and sheet rubber interventions for power tiller**

total vibration magnitude. Appropriate intervention measures (bushes with collar for nut and bolt contacts, and plane sheet for surface to surface contacts using rubber, PU and rubber + PU materials) were assessed. Rubber interventions were best suited with the average exposure time for occurrence of white finger syndrome increasing by 137.6%, 150.7% and 143.37% in transportation, tilling with cultivator and rota-tilling operation, respectively, for an eight-hour daily exposure. With the use of the rubber interventions, the working heart rate of operator reduced significantly.

### 3.8.4 Onion Seed Extractor

Experiments were conducted in a laboratory test set-up with provisions of varying design variables of an indicated spike tooth extraction mechanism suitable for mechanical extraction of onion seed. The mechanism gave an extraction efficiency of 98.93% and cleaning efficiency of 97.07%. The seed loss ranged between 2.15% and 3.08% at cylinder speeds of 3-5 m/s. The costs of seed extraction by mechanical onion seed extractor and manual/conventional method were Rs. 1,800 and Rs. 9,000/tonne of onion umbel, respectively. The break-even point for seed extractor was 78.77 h, 31.51% of annual utility. The payback period of seed extractor is 2.4 years.

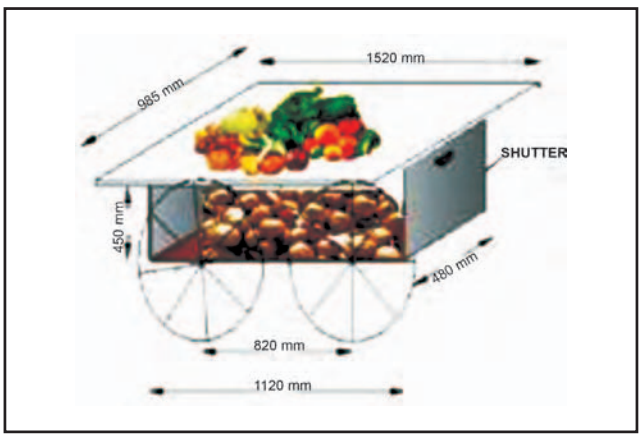
**Onion seed extractor**

### 3.8.5 Motorized Vegetable Seed Extractor

A prototype of motorized vegetable seed extractor developed was tested for seed extraction from brinjal in collaboration with SPU of IARI. The use of extractor resulted in 50% saving of time and 90% saving in water requirement for washing and decantation.

### 3.8.6 Design of an Evaporative-Cooled Cart for Mobile Retail Vending of Fruits and Vegetables

Fresh fruits and vegetables need to be preserved by controlling the environment around them while in storage. Application/provision of low cost evaporative cooling technology on mobile vending units is the need of the hour for small time vendors of vegetables. Conceptual design of an evaporatively cooled fruit and vegetable vending cart

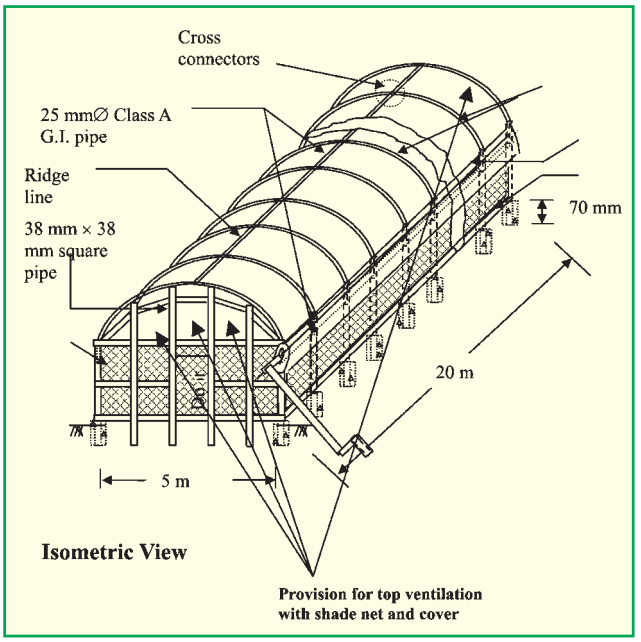



**Conceptual design/drawing for evaporatively cooled mobile vending cart for fruits and vegetables**

was developed. Provision of keeping the fruits and vegetables in the space (1120×480×450 mm) under the top platform (between the four wheels) was made to increase the storage capacity. Design drawings were prepared to make arrangements for making the lower section evaporatively cooled so that fruits and vegetables can be kept safely for a longer period of time by the retail vendors.

### 3.8.7 Studies on Efficient On-farm Utilization of Solar Eenergy

***Drying studies on onion.*** A solar cabinet dryer (natural convection) was used for drying studies on onion. The moisture content of onion in the solar cabinet dryer (SCD) was reduced from 87.69% to 5.38% in 8 h as against 16 h in open sun drying (OSD). The drying rate was initially lower at low moisture content, and was higher in solar cabinet




**A modified naturally ventilated polyhouse**

dryer than in open sun drying. The quality of produce dried in SCD was better than that in OSD. The solar heat exchanger/ heat collector is being improved to improve the efficiency of drying system.

***Masonry wall lean to polyhouse for heat storage.*** A lean to polyhouse was designed and the material for construction (polyethylene, insect proof nets) was procured. The north side brick wall facing the sun in winter would get heated during the day and keep the polyhouse warmer during the night. In summers, the wall would not get solar radiation due to almost vertical movement of the sun.

***Design improvement of existing polyhouse.*** The locations of vents in the existing naturally ventilated polyhouse are not suitable during summer seasons and are being modified.

## 3.8.8 Fabrication of Pigeonpea Stripping & Threshing Machine

Pigeonpea plants are dicotyledonous, bold seeded and woody, which make them problematic for threshing. Conventionally pods are separated manually by flail wooden stick followed by animal trampling or tractor treading. Seed is separated from threshed mass by winnowing. But this process is very time - and labour- intensive. Furthermore, it induces injury and considerable losses in terms of un-threshed material, injured seed and split kernels. In this context, a system of stripping and threshing was developed at Regional Station, Karnal. Stripping operation was carried out by modified Olpad Paddy thresher. The stripped pods were threshed with the developed pulse thresher at optimized operational parameters for pigeonpea. Both the machines can be operated in field itself as they use power source as diesel engine or tractor. This feature reduced the problems on bulk handling of material. The harvested material of pigeonpea comes around 250 $m^3$/ha. Furthermore, this system of stripping and threshing leave intact the plant part, which is required by farmer for their domestic use. The stripping system requires only slight modification of paddy thresher, in which there is an additional expenditure of four thousand only (Rs. 4000). Threshing of pods can be effectively managed by selecting optimum operational parameters, which do not involve any additional cost. Hence, it can also be utilized for paddy, chickpea, mungbean, cowpea and peas.

**Performance of pigeonpea stripper and thresher**

| Method | Labour (Man-h/ha) | Cost (Rs/ha) | Efficiency (%) |
|---|---|---|---|
| **Striping** | | | |
| Conventional (Manual) | 500 | 15,000 | 92.0 |
| Stripper | 348 | 3,224 | 99.0 |
| **Threshing** | | | |
| Shifting Tractor treading + winnowing | 300 | 9,000 | 90.0* |
| Thresher | 72 | 1,010 | 99.0** |
| **Total operation** | | | |
| Conventional | 800 | 24,000 | 82.8 |
| Mechanical | 420 | 4,234 | 98.2 |

• with internal injury, ** without internal injury

### 3.8.9 Farm Operation Services

#### 3.8.9.1 Field operation

The Farm Operation Service Unit (FOSU) is catering to the needs of the divisions/project directorates/ establishment of the Indian Agricultural Research Institute for conducting field experiments. The entire farm of about 750 acres is under the management control of FOSU. About 35 acres are rainfed and the rest of the area is irrigated. During summer, after harvesting of *rabi* crops such as wheat, mustard, gram, soybean, peas, etc., deep ploughing was done. The fields were prepared after the first rainfall. Around 115 acres of land was put under green manuring by broadcasting *dhaincha* seed and incorporating crop into soil by using cultivator and planker. The green manuring crop buried into soil in the months of August and September resulted in an increase in fertility of the soil. During the year, a massive programme of cleanliness was undertaken on roads, drainage channel, sewage *nala*, new area, *mela* ground, top block of the farm, main garden, Todapur garden, WTC garden and around reservoir. Because of this the whole farm area at the Institute is better looked. Inspite of depleted man power and more micro-experiments, the Unit made efforts to satisfy the needs of each experiment. Almost 90% sowing of wheat in *rabi* season was completed by the end of November. Owing to this, the development of crop was better and the yields would be higher. During the year, a massive programme of laser leveling of the fields was undertaken. Approximately 102 acre area was laser leveled to enhance water use efficiency. All imported and indigenous machines available with the Unit were repaired well in advance to meet the requirement of experiments. A number of new machines/ equipment such as tractors (35 hp, 2 nos.), power sprayer for Shaan Tractor, disc harrow and spares for Disc harrow, etc., were procured to improve the management of farm operation. Procurement of a number of new machines/ equipment such as tractors (65-70 hp and more than 70 hp), laser land leveler, general purpose combine, experimental field plot combine, etc., was under progress.

#### 3.8.9.2 Irrigation distribution management

The farm is divided into (i) rainfed (ii) canal irrigated, and (iii) tube well irrigated areas. Major demands of water are met by tube well irrigation system. The Institute has 19 tube wells to pump ground water for 24 hours. All the tube wells were made functional thus making available more irrigation water for the experimental crops. Besides, canal water was also made available for timely irrigation of the crops.

The Institute has a very efficient and effective underground irrigation system. The pipelines are 3 feet below the ground and have 105 outlets to irrigate different field plots. Against specific requisition, a particular outlet is opened to allow water flow and irrigate a specific field plot. To further augment the irrigation efficiency and to reduce the loss of precious water, approximately 3000 m of *pucca* channels were being constructed on priority. Two reservoirs collect water from tube wells during the night and supplies it during the day through undergrounds pipelines. During the process of pumping water, sands are pumped and get settled in the reservoir, which reduce the capacity of the reservoirs. Hence, the cleaning of reservoir was done on top priority.

## 3.9 POST-HARVEST TECHNOLOGY AND MANAGEMENT

### 3.9.1 Evaluation of Novel Ready to Serve (RTS) Beverage without Sugar from Bael Fruits

RTS beverages of different degrees of sweetness, viz., 10° B, 12° B and 14° B were developed from bael fruit pulp with *Stevia* (calculated on the basis of 200% sweetness index compared to cane sugar). It was observed that addition of S*tevia* did not increase the total soluble solids (TSS) of the drinks as predicted. RTS drink of 10° Brix was more acceptable in all the sensory parameters as it was having less after taste when compared to drinks of 12°Brix and 14° Brix. Increased quantity of *Stevia* addition did not increase the degree of sweetness in terms of brix reading. However, after taste increased gradually with the increase in quantity of S*tevia*.

### 3.9.2 Integrated Post-harvest Management of Strawberry

Occurrence of deformed fruit is a serious problem in strawberry cultivation in northern India due to excess cold during January–February. Farmers face huge economic loss

some times up to 35% or more. Foliar application of Polyamine putrescine @100 ml/l at flower initiation stage reduced this malady up to 18%.

**Deformed strawberry fruits**

Pre-harvest foliar application of bioagent *Pseudomonas fluroscence* (0.5 OD) at flower initiation stage reduced the incidence of post harvest diseases of strawberry fruits during one week storage at room temperature (26 ± 2 °C and 55 % RH).

### 3.9.3 Phytochemical Analysis of *Ber* (*Zizyphus mauritiana* Lamk) Germplasm

A comprehensive phytochemical analysis of *ber* germplasm generated useful information for nutritionists as well as for horticulturists. Documentation of results on antioxidant activity of *ber* can be used as a valuable reference to choose and recommend foods or products to increase the dietary intake of antioxidant phytochemicals.

A good correlation between antioxidant activity and total phenol ($r_{FRSA}$ = 0.478) and ($r_{FRAP}$ = 0.655) was found which indicates polyphenolics are major determinants of antioxidant activity in *ber* cultivar having free radical scavenging activity. *Ber* cultivars, ZG 3, Sonaur 5, Gola, Rashmi, Elaichi and Kaithali are potential genotypes high in phytochemical composition and antioxidant activity. Cultivars rich in bioactive molecules can offer genes with desired antioxidant properties and fruit chemistry profiles for enhanced health benefits. Such information can help consumers make informed choices and reap the full potential of horticultural products.

### 3.9.4 Processing Effects on the Quality of *Ber* Juice

An extraction technique adopted for *ber* juice production was found to make significant differences to the quality of juice in terms of its phytochemical composition. Heat extraction methods can significantly alter polyphenolic recovery in the pulp. Hot breaking treatment, viz., high temperature short time (HTST) resulted in 1.3 fold increase in total polyphenolic content in comparison to that of fresh fruit. Thermal processing offers tremendous potential to improve the functional quality of *ber* pulp in terms of its antioxidant activity. Processed *ber* pulp had higher antioxidant (AOX) potential than fresh fruits. Positive significant correlation exists between polyphenol and AOX.

### 3.9.5 Effect of Pre-Harvest Sprays of Calcium Salts on Post-harvest Quality and Bitter Pit Incidence in Apple

Three sprays of aqueous solution of calcium chloride at 30, 15 and 7 days before harvest were found better than

**Effect of pre-harvest spray of calcium chloride on post harvest quality and bitter pit incidence in Royal Delicious apples at the end of 6-month storage in cold store (2°C and 90% RH)**

| $CaCl_2$ concentration (%) | Physiological loss weight (%) | Decay loss (%) | Firmness (N) | Bitter pit incidence (%) | TSS (%) | Ascorbic acid content (mg/100 g pulp) |
|---|---|---|---|---|---|---|
| 0 | 15.2 | 12.3 | 15.5 | 22.1 | 12.3 | 1.3 |
| 0.5 | 12.6 | 11.6 | 16.3 | 13.2 | 13.6 | 1.6 |
| 1.0 | 9.8 | 7.2 | 19.3 | 6.2 | 15.3 | 1.8 |
| 2.0 | 9.2 | 7.0 | 19.5 | 6.0 | 15.0 | 1.8 |

that of calcium nitrate and calcium sulphate with respect to retention of texture, colour and quality of Royal Delicious apples during storage. Calcium chloride spray @ 1% exhibited significant reduction of bitter pit, decay and weight loss with high value of fruit firmness at the end of six months' storage in cold store. This treatment also inhibited Lipoxygenase activity (LOX) in fruits and showed high content of Ca in fruit tissues.

to make tomato soup, sauces and paste with good organoleptic quality.

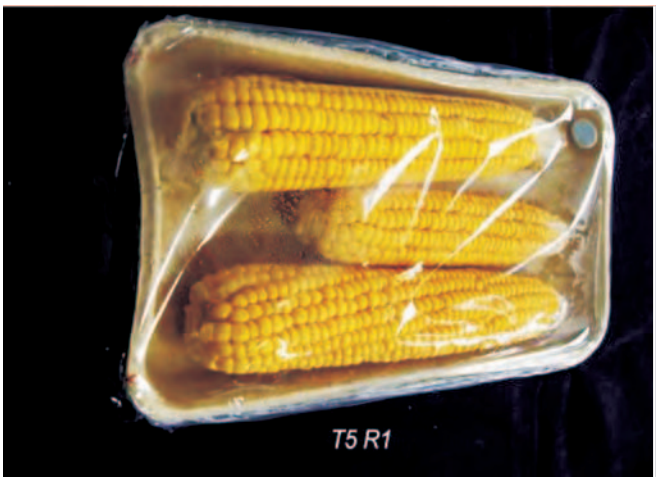
### 3.9.7 Pre-Cooling of Sweet Corn for Retention of Post Harvest Quality during Storage

Loss of sugars and shriveling of grains of harvested sweet corns are the major post harvest problems that reduce the marketability and thus incur huge post harvest losses.

**Effect of pre-cooling techniques on total soluble solids (TSS) and sugar content of sweet corn cv. Win Orange during low temperature storage**

| Treatments | TSS ( °Brix) | | | | Total sugars (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 day | 10 DAS | 20 DAS | 30 DAS | 0 day | 10 DAS | 20 DAS | 30 DAS |
| Control | 19.67 | 15.33 | 12.33 | 8.33 | 13.94 | 9.75 | 6.38 | 2.91 |
| HC 2 hAH | 19.33 | 17.33 | 16.28 | 13.00 | 13.81 | 12.58 | 11.05 | 4.92 |
| HC 4 hAH | 18.70 | 16.30 | 15.33 | 12.88 | 13.73 | 12.26 | 10.05 | 4.34 |
| HC 6 hAH | 18.70 | 16.00 | 15.00 | 12.33 | 13.68 | 12.05 | 9.67 | 3.86 |
| PI 2 hAH | 19.67 | 17.66 | 16.67 | 14.22 | 13.95 | 12.70 | 11.15 | 5.23 |
| PI 4 hAH | 19.00 | 16.67 | 15.66 | 13.12 | 13.82 | 12.44 | 10.84 | 4.54 |
| PI 6 hAH | 19.33 | 16.67 | 15.00 | 12.00 | 13.63 | 12.09 | 9.75 | 4.03 |

HC= Hydro-cooling, hAH= hours after harvest, PI= Package icing, DAS= Days after storage




Twenty days after storage with pre-cooling (by package icing)

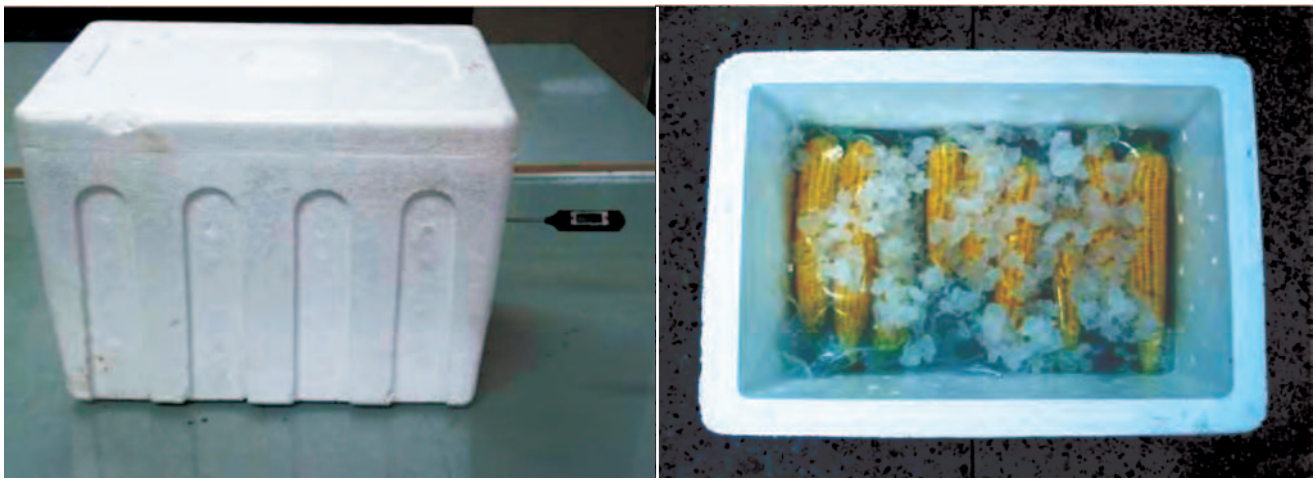

Twenty days after storage without pre-cooling

**Effect of pre-cooling on quality of sweet corn**

### 3.9.6 Preparation of Tomato Powder

A process for the preparation of tomato powder from blanched and unbalanced tomato slices (8 mm thick) by drying in cabinet drier to an equilibrium moisture content of 5.5% was developed. It could be reconstituted well and used

Rapid and faster pre-cooling could check the post harvest losses of sweet corn. Package icing within 2 hours after harvest was found to check the sugar loss and retain the marketable quality of harvested sweet corns up to 20 days at 2 °C and 90 ± 2% Relative Humidity (RH).



**Pre-cooling of sweet corn by package icing**

### 3.9.8 Physical Properties of Pearl Millet and Chickpea

Moisture dependent engineering properties, useful to design equipment for handling, processing and storing of pearl millet and chickpea (BGD 72) were determined at different moisture contents between 8% and 26% (w.b.). Properties, viz., bulk density, true density, porosity, angle of repose, coefficient of friction, terminal velocity and hardness were also determined. It was found that with the increase in moisture content, the bulk density, true density and coefficient of friction of both pearl millet and chickpea decreased whereas the angle of repose and terminal velocity increased. The results indicated increase in the flowability characteristics with increase in moisture content but higher space requirement in storage and processing equipment.

### 3.9.9 Evaluation of Grains for Quality

Quality Protein Maize (QPM), pearl millet and some varieties of chickpea were evaluated for a few quality traits like protein, starch, total antioxidant, phenol, trypsin inhibitor. and lypoxygenase activity. It was evident from the data that all these grains had substantial phenolic compounds and antioxidants indicating their usefulness for health. Lypoxygenase activity in varying range inferred their relative susceptibility towards degradation. Higher activity could lead to early degradation. It was also observed that the protein content was in the range of approximately 10-11% in pearl millet and maize whereas in chickpea, it was 20%.

**Some quality characteristics of selected grains**

| Grain | Protein (%) | Starch (%) | Antioxidant (µmoles Trolox/ 100g) | Trypsin inhibitor (TIU/g) | Phenol (µg/g) | Lipoxygenase activity (µmoles/min/g fresh weight) |
|---|---|---|---|---|---|---|
| Maize (QPM) | 11.81 | 61.78 | 25.8 | 54.80 | 3005 | 1.36 |
| Pearl millet | 10.87 | 60.38 | 33.5 | 128.00 | 1015 | 2.8 |
| Chickpea | | | | | | |
| P372 | 20.93 | 49.13 | 89.8 | 39.20 | 1200 | 2.0 |
| BGD72 | 21.44 | 50.59 | 90.7 | 66.00 | 1410 | 5.4 |
| P1108 | 21.01 | 51.56 | 31.8 | 57.20 | 1510 | 2.2 |
| P1053 | 21.88 | 52.53 | 59.2 | 58.00 | 1260 | 5.1 |
| P1088 | 21.44 | 50.59 | 68.8 | 53.60 | 1365 | 8.0 |
| P256 | 20.93 | 48.64 | 73.0 | 40.00 | 1760 | 5.0 |

### 3.9.10 Development of Extruded Products

Ready-to-eat extruded products were developed from pearl millet, maize, barley and sorghum along with Bengal gram as minor ingredient and their quality characteristics like moisture content, ash content, expansion ratio, antioxidants and phenol contents, and lypoxygenase activity were determined. It was found that the moisture content of the extruded products reduced from about 13% to 1.25-4.5% indicating the increased shelf life of the product. Expansion ratio is an important property for puffed products and it was found to reduce with increasing levels of Bengal gram in the product but was found to be organoleptically good up to 20% incorporation. Antioxidant and phenol contents reduced after extrusion and, therefore, processing parameters need to be optimized for minimum loss. Lypoxygenase activity decreased after extrusion processing, again indicating better shelf life.


**Extruded products from different grains**

# 3.10 MICROBIOLOGY

## 3.10.1 Microbial Analysis of Microbes in Extreme Environments and Bioprospecting for Novel Molecules and Genes

### 3.10.1.1 Bacterial diversity in Sambhar salt lake

Four soil and water samples each were collected from different sites of Sambhar salt lake, Rajasthan. The population count of bacteria in different soil and water samples showed variations with the media employed. Seventy-eight isolates tolerant to 10% NaCl were obtained from these soils and water samples employing six different media. Maximum number of isolates were obtained on methyl red agar medium indicating a higher population of gram-positive bacteria. However, only 45 were able to grow well during purification and these were screened for tolerance to higher salt concentrations. Out of these, forty-three were able to grow on 10% and 15% NaCl. One isolate (SSM62) was found to have an absolute requirement of salt and could grow only at 15% NaCl concentration. Ten and 4 isolates could tolerate 20% and 25% NaCl concentration, respectively.

**Population of salt tolerant bacteria and isolates obtained on different media**

| Media used | Cfu/g soil | Cfu/ml water | Morphotypes selected |
|---|---|---|---|
| Crystal violet agar medium | $96.5 \times 10^4$ | $12 \times 10^4$ | 16 |
| Methyl red agar medium | $155.5 \times 10^4$ | $158 \times 10^4$ | 21 |
| Salts medium (20%) | $2 \times 10^3$ | 0 | 2 |
| Jensen's N free agar medium | $1 \times 10^3$ | 0 | 2 |
| King's B medium | $103 \times 10^4$ | $40.5 \times 10^4$ | 25 |
| Trypticase Soy agar medium | $81 \times 10^4$ | $88.5 \times 10^3$ | 12 |

### 3.10.1.2 Diversity of actinomycetes in Bikaner desert soils

A total of 85 actinomycetes were isolated from Bikaner desert soils using three different media, viz., Ken-Knight Munier , Starch casein agar and Kuster's agar medium. Functional diversity among the isolates was evaluated with regard to productin of hydrolytic enzymes, biocontrol activity and phosphate solubilization. A total of 56 cultures were found positive for carboxymethylcellulase (CMCase), 33 for xylanase and 43 cultures for amylase activity. Phosphorus solubilization activity was found in 24 cultures. Fifteen cultures were found to suppress the growth of plant pathogenic fungi *Macrophomina phaseolina* in plate assays.

### 3.10.1.3 Diversity of disease suppressing bacteria

One hundred and fifty bacteria were isolated on Kings B and nutrient agar media from endorhizosphere and rhizosphere soil samples. Among the isolates, 20 were found to suppress the growth of bacterial and fungal soil borne pathogens, viz., *Xanthomonas oryzae*, *Xanthomonas campestris*, *Ralstonia solanacearum*, *Rhizoctonia solani*, *Fusarium oxysporium*, *Pyricularia oryzae*, and *Sclerotium rolfsi*.. Two isolates showed the volatile production of HCN within 24 h incubation. Twenty isolates were found positive for siderophore production on CAS medium plates. None of the isolates was found positive for chitinase enzyme production on colloidal chitin medium plates.

### 3.10.1.4 Collection of samples and isolation of microalgae

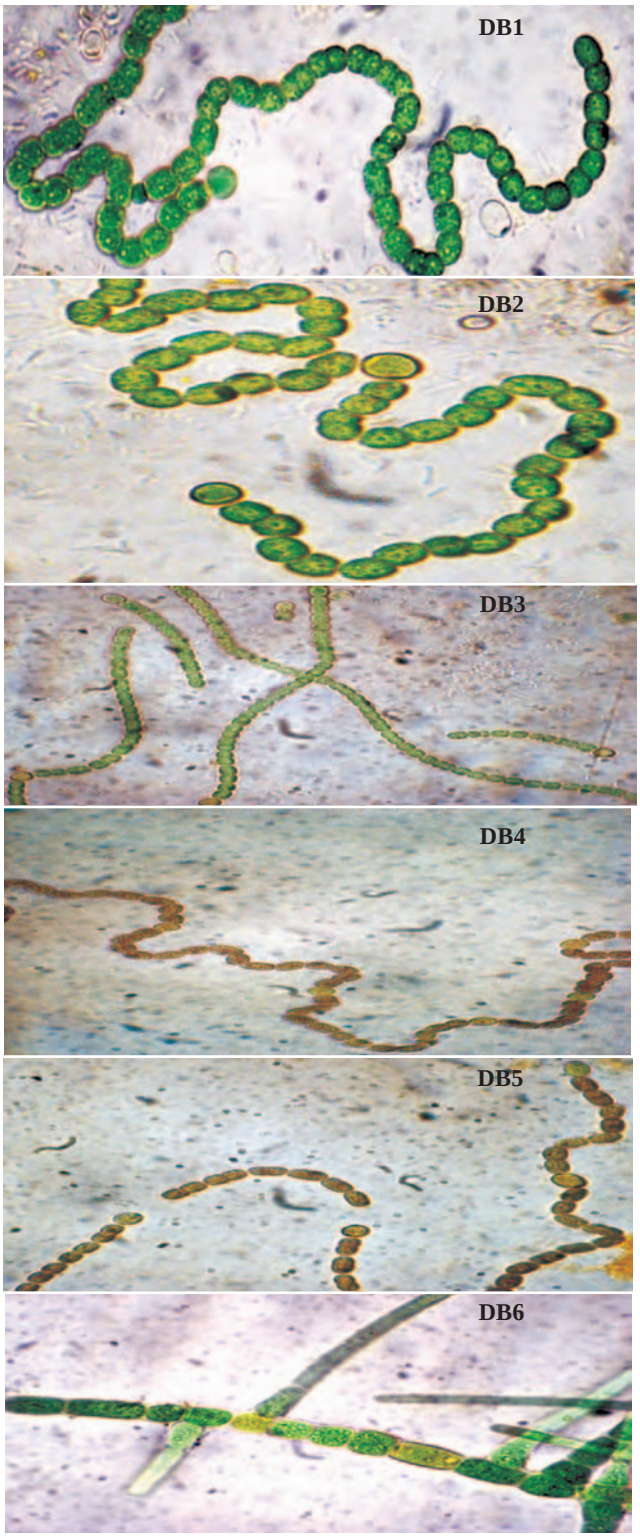
Soil and water samples collected from Leh, Shillong and three aquatic bodies, namely, Anasagar, Pushkar lake from Ajmer and Sambhar lake from Sambhar were subjected to enrichment culture technique using BG 11 medium for the isolation of microalgae. Twenty-six and 23 strains of microalgae were isolated from Leh and Shillong samples, respectively. Twenty three strains of cyanobacteria isolated from aquatic bodies of Ajmer were subjected to morpho-physiological and molecular characterization. The cultures were identified to the species level and showed variations in morphological characters. Three non-heterocystous cyanobacterial strains were isolated from Sambhar lake. The molecular characters in terms of RFLP profile for 16S amplified product depicted closeness of the cyanobacterial isolates from the same order. Cyanobacterial strain *Plectonema wollei* isolated from Sambhar lake showed the highest carotenoids, total phycobiliins as well as nitrate reductase activity and could be further exploited for pigment isolation.

**Taxonomic designation of cyan bacteria isolated from aquatic bodies of Ajmer**

| Taxonomic designation | Strains | Origin/Source |
|---|---|---|
| *Anabaena spiroids* | DB 1 | Anasagar |
| *Nostoc piscinale* | DB 2 | „ |
| *Nostoc paludosum* | DB 3 | „ |
| *Nostoc hatei* | DB 4 | „ |
| *Nostoc carneum* | DB 5 | „ |
| *Westiellopsis prolofica* | DB 6 | „ |
| *Phomidium purpurascens* | DB 7 | „ |
| *Microcystis lamelliformis* | DB 8 | „ |
| *Phomidium angustissimium* | DB 9 | „ |
| *Phormidium ceylanicum* | DB 10 | „ |
| *Nostoc commune* | DB 11 | „ |
| *Plectonema nostocorum* | DB 12 | „ |
| *Nostoc calcicola* | DB 13 | Pushkar lake |
| *Plectonema yellowstonense* | DB 14 | „ |
| *Plectonema molle* | DB 15 | „ |
| *Plectonema indica* | DB 16 | „ |
| *Phomidium molle* | DB 17 | „ |
| *Phomidium foveolarum* | DB 18 | „ |
| *Plectonema notatum* | DB 19 | „ |
| *Anabaena variabilis* | DB 20 | „ |
| *Plectonema wollei* | DB 21 | Sambhar lake |
| *Phormidium ambiguum* | DB 22 | „ |
| *Oscillatoria peronata* | DB 23 | „ |

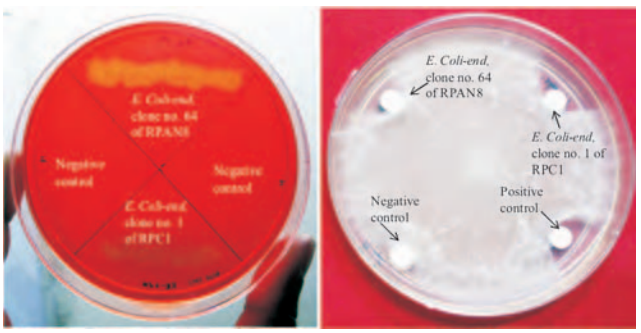
### 3.10.1.5 Novel endoglucanases in cyanobacteria

An investigation was undertaken for identifying and characterizing gene(s) involved in the fungicidal activity in *Anabaena laxa* RPAN8 and *Calothrix elenkinii* RPC1. Functional analysis of genomic library clones was carried out in terms of fungicidal activity against *Pythium debaryanum* and *P. aphanidermatum*, followed by evaluation of endoglucanase activity. Bioinformatic tools guided sequence analyses revealed the presence of novel endoglucanases belonging to families % peptidase M20 and GH5. The identification of promoter regions, rbs, signal peptide and cleavage sites in the sequences in 3 selected clones provided evidence for translation of *end* encoding




**Photomicrograph of cyanobacterial isolates obtained from Anasagar**

endoglucanase in these cyanobacterial strains. The presence of signal peptides ranging from 21 – 27 amino acid residues revealed the secretory nature of these proteins. The current study emphasizes the significance of such endoglucanase producing cyanobacterial strains as potential biocontrol agents against pathogenic fungi.




**Functional analyses of β-1, 4 endoglucanase and fungicidal activity from genomic library clones of RPAN8 and RPC1: (a) β-1, 4 endoglucanase activity on CMC plates in clones (64 and 1) of RPAN8 and RPC1, respectively, and (b) fungicidal activity (in terms of zone inhibition) against *Pythium aphanidermatum*. The insertless vector transformed *E. coli* was used as negative control. Nystatin (100U) was used as a positive control for fungicidal activity**

## 3.10.2 Biopigments: A Value Added Product from Cyanobacteria

Forty cultures of cyanobacteria held in the germplasm at the Centre for Conservation and Utilization of Blue Green Algae (CCUBGA) were screened for pigment biosynthesis. A preliminary study revealed that pigment biosynthesis was maximum during early stage of growth up to log phase and declined on further incubation. Among all the cultures tested, *Anabaena* strains produced the highest amount of phycocyanins (PC) and allophycocyanin pigments as compared to strains belonging to *Nostoc*, *Calothrix* and *Phormidium*. The repeated freezing and thawing resulted in maximum extraction of pigments as compared to other methods. These were further standardized for optimization and purity.

Total pigments were analyzed from 23 cyanobacterial isolates obtained from three aquatic bodies of Ajmer. Distinct variability was recorded with respect to these attributes. Isolate DB 21 produced the maximum amount of carotenoids (22.36 µg/ml) and total phycolbilins (72.71 µg/ml). Among the phycobilins, maximum amount of phycocyanin, allophycocyanin and phycoerytrin was produced by DB21, DB16 and DB10, respectively. Out of the total isolates, phycocyanin rich strains were identified and would be studied further to decipher the molecular basis of enhanced PC content.

## 3.10.3 Microbial Inoculants for Nutrient Management

### 3.10.3.1 Optimization of conditions for *in vitro* development of biofilms (fungi, bacteria or cyanobacteria based) with different combinations of microbial inoculants

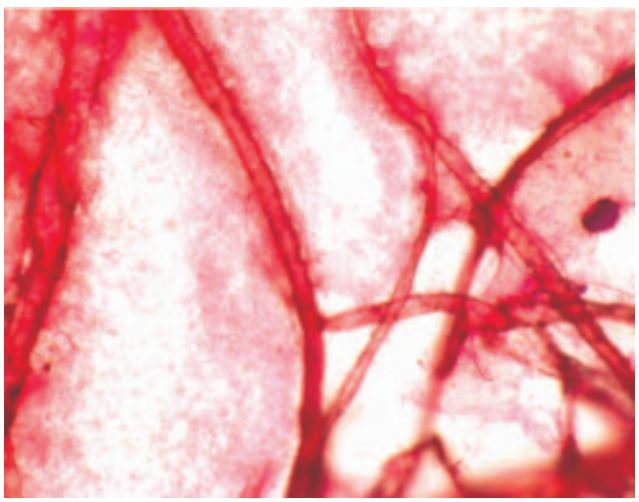
A novel strategy of developing biofilms of inoculant strains was optimized. Biofilms were prepared using fungal matrix (*Aspergillus awamori*, *Trichoderma viride* and *Priformospora indica*) and cyanobacterial matrix (*Anabaena torulosa)*. *Bradyrhizobial – A. awamor*i biofilms were developed following co-culturing in three different media-nutrient broth, potato dextrose broth and yeast mannitol broth (YMB) and finally YMB was selected as it gave optimum growth of both the cultures. Quantification studies revealed that $8.15 \times 10^6$ spores/ml of *A. awamori* and $1.7 \times 10^9$ rhizobial cells/ml are optimum for the biofilm preparation. Further optimization of dosage showed that mixing 10 ml of $8.15 \times 10^6$ spores/ml and 5ml of rhizobial cells **(**$1.7 \times 10^9$/ml) were optimum for the formation of biofilm in 50 ml of YMB medium and yielded about 0.28 g (wet weight) of biofilm. The biofilm showed the zone of phosphorus solubilization in Pikovskaya medium.

**Total protein content and wet weight of the biofilm**

| Treatment | Total protein (µg/ml) | Weight of biofilms (g) |
|---|---|---|
| *Bradyrhizobium* (control) | 328.6 | |
| *A. awamori* (control) | 582.5 | |
| *A.awamori* (5ml) + *Bradyrhizobium* (5ml) | 594.5 | 0.20 |
| *A.awamori* (7ml ) + *Bradyrhizobium* (5ml) | 628.46 | 0.21 |
| *A.awamori* (10ml ) + *Bradyrhizobium* (5ml) | 640.76 | 0.28 |

*Average of three replications

An attempt was made to optimise the nutritional and cultural parameters for the formulation of fungal-bacterial biofilms by the use of axenically cultivable plant growth promoting fungi *Piriformospora indica* and *Pseudomonas striata*. A nutrient medium capable of supporting the growth of both test organisms as co-culture system was devised. Optimisation of the physical parameters followed by regular monitoring (microscopic examination) of the co-culture revealed the adherence of the bacterial cells on the hyphal surface.



**SEM of biofilm of *Piriformospora indica* and *Pseudomonas striata***

*Azotobacter-Pseudomonas striata* biofilm was prepared and tested for PGP activities (P solubilization, IAA production). Although both the bacteria were able to grow in modified Jensen's medium but no significant difference was observed in PGP activities compared to single inoculation.

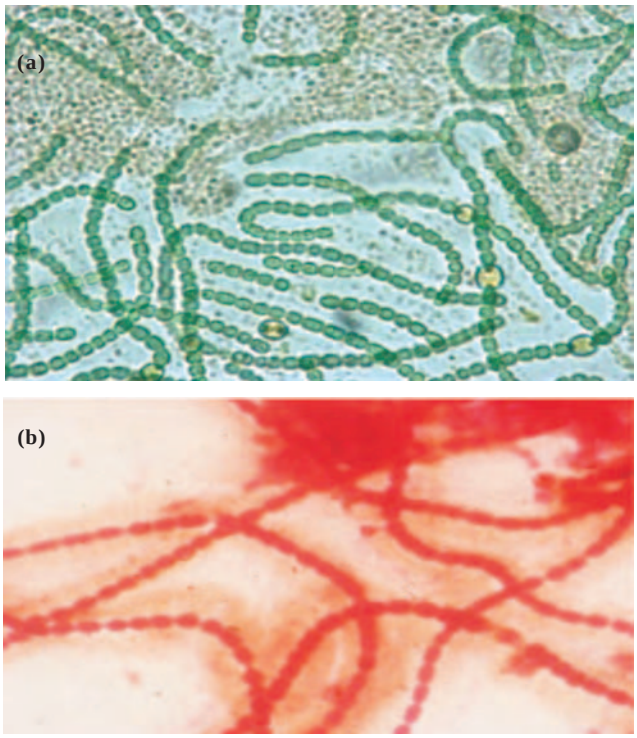
Conditions and microbial load for the development of biofilms using *Trichoderma viride* and *Pseudomonas fluorescens* were optimized. Fifty ml of spore suspension (46 x $10^4$/ml) of *T. viride* and 5 ml of *P. fluorescens* broth culture (8 x $10^9$ cfu/ml) inoculated to 500 ml of nutrient broth and incubated at 30 $^0$C could result in the formation of biofilms. The microscopic examination of biofilms showed the attachment of bacterial cells in the biofilms. The biocontrol activity of biofilms developed was on a par with or superior to the individual components of biofilm using dual plate assay against four pathogenic fungi, viz., *Macrophomina phaseoilna*, *Fusarium oxysporum*, *Pythium* sp. and *Rhizoctonia*.

The utility of cyanobacteria as matrices for agriculturally useful bacteria was evaluated using a selected strain *Anabaena torulosa* with *Azotobacter*, *Pseudomonas*, *Serratia* and *Mesorhizobium*. The biochemical attributes were compared with individual bacterial, cyanobacterial cultures in respective medium and BG 11 medium. Such biofilms were analyzed in terms of proteins, chlorophyll, IAA production, acetylene reducing activity (ARA), P solubilisation and antagonism towards selected phytopathogenic fungi. The substrate utilization profiles were also generated for the biofilms and individual strains. An enhancement in the population counts was also recorded in *Anabaena torulosa-Serratia* and *Anabaena torulosa-Pseudomonas* biofilms which also exhibited increased ARA and IAA production, besides enhanced antagonism towards phytopathogenic fungi. Microscopic analyses revealed colonization of *Anabaena* filaments by the bacterial strains. Such novel biofilms with agriculturally useful traits need to be evaluated at field level as useful inputs for sustainable and environment friendly agriculture.

### 3.10.3.2 Organic farming in rice based cropping system through microbial inputs

On the basis of field experiments conducted during 2003-09, a protocol was developed for *basmati* rice cultivation through organic management for sustainable productivity and better quality under rice-wheat-green gram cropping system. Four bio-inoculants, viz., blue green algae (BGA) @ 2.0 kg/ha, *Azolla* @1.0 tonne / ha, vermicompost and farm yard manure (FYM) @ 5.0 t/ha each, applied alone or in combination were evaluated. However, in wheat *Azolla* was replaced by *Azotobacter* but other treatments remained the same.

In the beginning of experiment in 2003, the yield of wheat cv. Pusa Vishesh was quiet poor but it increased over the years. During *rabi* 2009, wheat yield reached 4.14 t/ha under organic farming and it was 8.4% higher than that obtained with the recommended dose of chemical fertilizers. A significant enhancement in grain yield of wheat was recorded owing to the application of different bio-inoculants, applied




**Microphotographs of the biofilms of *Anabaena torulosa* with *Azotobacter* (without (a) and with gram staining (b) at 40x magnification)**

alone or in combinations, over that of the absolute control. The wheat grain yield increase was found to be ranging from 6.8% to 31.2% owing to single organic amendment, however; the yield was 180% higher when all four bio-inoculants were applied together. The wheat grain yield (4.14 t/ha) obtained under combined application of four bio-inoculants was the highest among all the treatments though it was statistically on a par with the yield recorded under recommended dose of chemical fertilizer application (3.82 t/ha). There was no serious incidence of any insect-pest or disease in organically grown wheat crop. The yield level of wheat indicated that organic wheat can also be grown under rice - wheat system. Though its yield may be low in the beginning, it may enhance in the following years.

Besides providing optimum wheat yield, soil quality was also improved because of organic management of rice-wheat system which was evident by the continuously increased soil microbial population (actinomycetes, bacteria, fungi and BGA) and soil organic matter (SOM) level due to the application of bio-inoculants in comparison to those in the absolute control and the recommended fertilizer application. Wheat grain analysis for iron, zinc, manganese and copper nutrients showed a significant increase in iron, zinc and manganese contents in the treatments having 3 or 4 bio-inoculants over that of the control treatment.

### 3.10.3.3 Effect of different organic amendments on grain yield of wheat

On the basis of the finding on organic cultivation of rice and wheat, an experiment was initiated in *kharif* 2009 to develop a protocol for organic farming in rice based cropping (including vegetables) system through microbial inputs. *Basmati* rice (Pusa Basmati 1121) grown under organic management with four inputs (blue green algae, *Azolla*, vermicompost and farm yard manure) gave the highest rice grain yield (4.46 t/ha) followed by yield under integrated nutrient management (INM) (4.32 t/ha) and chemical fertilization (4.18 t/ha). Rice grain analysis showed significantly higher concentration and uptake of iron, zinc and manganese in organically grown crop compared to those of INM and chemically fertilized crops. An increase in population of beneficial insects like spiders was recorded under organic farming. An improvement in physical, microbial and chemical properties of soil was observed under organic management over those of INM and chemical fertilizer management.

### 3.10.3.4 Development of *Azotobacter* bio-inoculants for saline soils

Ten isolates of salt tolerant (up to 600 mM NaCl) *Azotobacter* sp. were obtained from soil samples collected from salt affected areas of Aligarh and Hisar. They were further screened for their tolerance to different concentrations of chloride and sulphate salts of sodium, calcium and magnesium. All the ten isolates showed similar tolerance to $Na_2SO_4$ and five isolates (H 11, H 12, H 15, A 24 and A 32) showed better tolerance to higher concentrations of NaCl. Isolates H 11, H 12, H 13, H 14 and A 32 showed better tolerance to both chlorides and sulphates of calcium while five isolates, viz., H 12, H 13, H 16, A 11 and A 24

showed better tolerance to both chlorides and sulphates of magnesium.

### 3.10.3.5 Profiling of *Azolla* in relation to crop improvement

Molecular profiling of different species of *Azolla* revealed two groups: Group I consisting of one species *A. pinnata*, and Group II consisting of three species *A. microphylla*, *A. rubra* and *A. filiculoides*. Further, on the basis of relative growth rate, biomass production and adaptability, *Azolla microphylla* was selected for chemical profiling in relation to crop improvement. The biomass production and cellular constituents were optimized in *A.microphylla* using different artificial growth media, and variation in the growth rate, biomass production and cellular constituents was observed. It was also observed that the organism was able to grow well and could multiply under various conditions such as in tap water, secondary treated effluent water as well as amended effluent water. Biomass production of *A. microphylla* was checked on partially treated municipal wastewaters and it was found to show ideal doubling time of 2.3 days on secondary treated sewage when temperature was around optimum. After growth of *Azolla microphylla*, for 7 days, there was reduction of up to 72 per cent in total organic content of wastewaters. Total phosphorous and available phosphorous in primary and secondary treated wasterwaters showed a removal ranging between 83-96 per cent and 68-96 per cent, respectively. The nitrite content showed reduction from 70 to 92 per cent. But there was no significant reduction in ammonia content. Thus, *Azolla* biomass can be produced on wastewaters and used for different applications. Effluent treated water, although supported growth, had no positive effect on the cellular constituents especially anthocyanin and chlorophyll but resulted in increase in the sugar and protein contents. Seasonal variation in the cellular constituents was noticed in *Azolla* grown in indoor as well as outdoor conditions. Preliminary data on the seasonal variation in the cellular constituents and their role would be evaluated further for efficient utilization and exploitation of *Azolla* in relation to crop improvement.

## 3.10.4 Microbial Degradation of Agro-waste and Plastics

### 3.10.4.1 Selection of isolates for composting of agro-residue at low and high temperatures

Soil samples as well as degraded material were collected from extreme environments of low (Leh region) and high (Manikaran region) temperatures for isolation of psycrophiles and thermophiles efficient for production of hydrolytic enzymes. Thirty-five psycrophilic and 40 thermophilic isolates were analysed for enzyme activities. Based on the qualitative tests for different enzymes, only 10 isolates were selected for the respective enzyme activity at different temperatures, viz., 10 °C, 20 °C, 30 °C, 40 °C and 50°C. For CMCase activity, the isolate A4 registered maximum value of 0.145 IU/ml at 20°C. Similarly for cellobiase, xylanase and amylase activity, the isolates A4 (0.047 IU/ml), C9 (0.071IU/ml) and C8 (1.181 IU/ml), respectively, performed well even at 10°C. With the increase in temperature beyond 20°C, the activities of enzymes were found to reduce considerably. This clearly shows that the combination of three isolates A4, C9 and C8 could be further exploited for rapid composting at low temperature.

In the case of thermophiles, 3 isolates M 10, M 75 and M 48 were selected based on qualitative tests and were subjected to quantitative analysis of various enzymes like CMCase, cellobiase, xylanase and amylase. The results clearly showed that the isolate M 75 could degrade cellobiose, xylan and starch at 70 °C, 55 °C and 65 °C, respectively. Hence, it also shows that the enzyme is not only stable but also active till 70 °C and the isolate M 75 recorded maximum cellobiase activity of 0.20 IU/ml, xylanase 0.21 IU/ml and amylase 0.12 IU/ml while the isolate M 10 showed the highest CMCase activity (1.46 IU/ml) at 70 °C. The above results have generated the resource base of microbes for the development of a consortium of these selected isolates to bioagument the composting process at low and high temperatures.

### 3.10.4.2 Development of microbial consortia for biodegradation of plastics

The degradation of plastic may proceed through microbial action, photodegradation or chemical degradation.

Microorganisms, including bacteria and fungi, are known to be involved in the degradation of both natural and synthetic plastics, which proceeds in a gradual manner employing more than one type of organism. Soil samples collected from three different sites of Delhi, viz., Karnal bypass landfill, Majnu ka tila and Okhla sewage were used as initial inoculum for isolation of low density polyethene degrading microogranisms. Conditions with regards to cultural medium, pH, and nitrogen source were optimized for the degradation of plastic strips. Amongst the various media tested, phosphate buffer supported the maximum activity of plastic degradation. Glass test tubes containing 10 ml of sterile 0.2M phosphate buffer of pH 5.0, 7.0 and 9.0 were used and pre weighed strips of plastic (2 cm by 21 cm) were placed along the entire length of the tube. Each tube was inoculated with 100 µL of the soil dilutions and incubated without shaking for 4, 8 and 12 weeks at 30 °C. The degradation of plastic was observed more in samples collected from Majnu ka tila. After a week of incubation, the plastic strips placed in phosphate buffer of pH 5.0 showed fibre formation or serration near the top of the tube. The portion of the plastic that was dipped in $PO_4^-$ buffer, did not show any change. In the control tubes, also, there was no physical change in the plastic strips. The rate of degradation was fast at pH 5.0 as compared to that at pH of 7 and 9. After 3 months, there was about 62% decline in the weight of polyethylene strips. The sample was enriched following sequential transfer in the medium containing LDDE as the only C and N source and a total of 10 cultures (8 bacteria and 2 fungi) were isolated. Three and two isolates were positive for acetamide hydrolysis assay and fluorescein diacetate hydrolytic assay, respectively, indicating the presence of hydrolytic activity in these isolates. The isolates are in the process of further characterization.

### 3.10.5 HIP (Highly Iterated Palindrome) Extended Primer Based Fingerprinting of *Nostoc* Strains

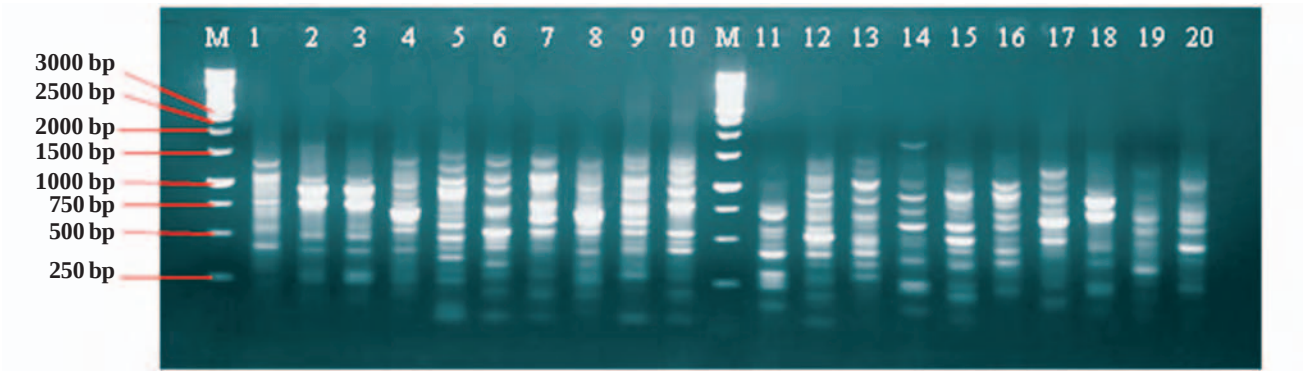
*Nostoc*, a diverse genus of cyanobacteria belonging to the order Nostocales and the family Nostocaceae has tremendous potential as soil conditioners, biofertilizers, biomonitors of soil fertility, water quality, etc. Three HIP (octameric palindromic sequence) based primers, viz., HIP

**Fibre formation or serration in plastic strips near the top of the tube inoculated with sewage soil inoculums (0.2M phosphate buffer, pH 5.0)**

AT, HIP TG and HIP GC were used to carry out fingerprinting of twenty *Nostoc* strains procured from culture collection at CCUBGA, IARI. These primers generated reproducible and 100% distinct polymorphic bands revealing a wide range of variability among the *Nostoc* strains studied. These HIP primers also yielded one to two unique bands ranging in size from 340 bp to 1700 bp, which will be very useful molecular markers for rapid and accurate identification of agriculturally and industrially important *Nostoc* strains. Dendrogram analysis indicated a great deal of heterogeneity among the strains used. No specific clustering was observed based on geographical origin. *Nostoc* strains were divided into two major clusters with two and eighteen strains, respectively.

### 3.10.6 Bioremediation of Polycyclic Aromatic Hydrocarbons (PAH) through Microbial Consortia

Polycyclic aromatic hydrocarbons (PAHs) are widely distributed environmental contaminants in the soil that occur in various ecosystems. In the present investigation, contaminated soil samples collected from oil refinery sites at four different geoclimatic locations across India were used for isolation of PAH utilizing microorganisms on selective minimal medium. Sixty-six bacterial strains were isolated



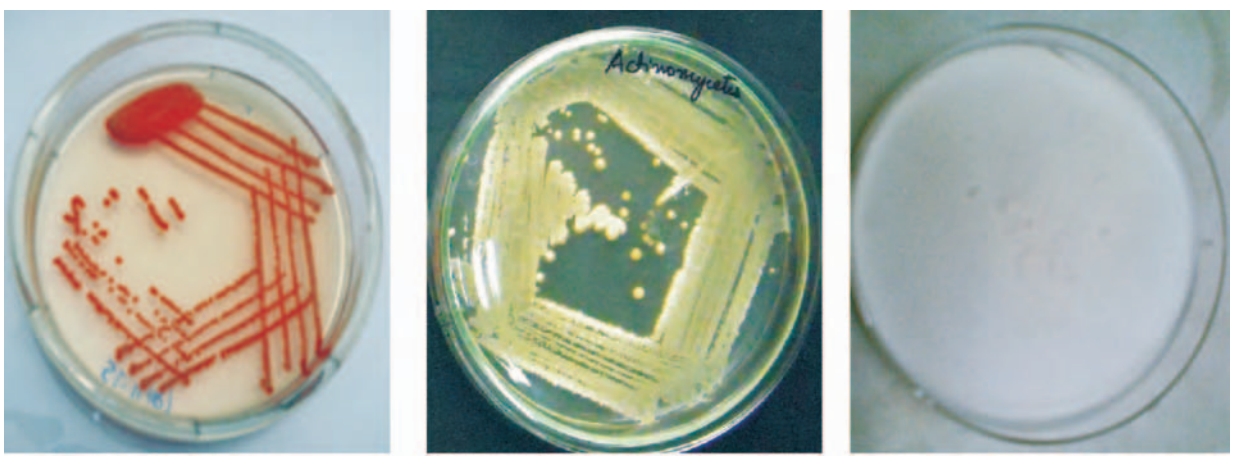

**Amplification profiles of *Nostoc* strains generated by HIP extended primer HIP GC**

having the capability to utilize PAH compounds as sole carbon source. Finally all the isolates were tested for their potential to grow in minimal media with 100 ppm PAH mixtutre. The best 15 bacterial strains were selected for their biosurfactant production potential as well as activity of ring cleavage enzyme catechol dioxygenase. Among all the isolates, a novel enteric bacterial strain identified as *Serratia marcescens* showed capability for biosurfactant production, catechol dioxygenase activity as well as PAH degradation. This is the first report of a representative of the genus *Serratia* capable of exhibiting immense metabolic flexibility in degrading PAHs compounds. Similarly, results of HPLC analysis confirm PAH degradation potential of an actinomycete, *Streptomyces rochei* PAH 13 and a fungal strain, *Phanerochaete chrysosporium* VV 18 at three different PAH concentrations (10 ppm, 50 ppm and 100 ppm). These three microbes, namely, *Serratia marcescens* PAH-L11, *Streptomyces* sp. PAH 13 and *Phanerochaete chrysosporium* VV 18 were selected for the development of consortia for *in vitro* PAH degradation in minimal medium with 100 ppm of PAH mixture. HPLC based quantization of PAH-dissipation by the microbial consortia is underway.

## 3.11 ENVIRONMENTAL SCIENCES

### 3.11.1 Impact of Elevated Temperature and $CO_2$ on Growth and Yield of Rice and Groundnut

Rice variety Pusa 44 grown at low, medium and high nitrogen levels at elevated temperature (+0.8-3.5 $^0$C) showed marked reduction in yield under low, medium and high N levels owing to reduction in grains/panicle and panicles/pot. Grain yield showed greater thermal sensitivity as




***Serratia marcescens* L 11** ***Streptomyces rochei* PAH13** ***Phanerochaete chrysosporium* VV18**

**Microbial strains selected for consortia development for PAH degradation**

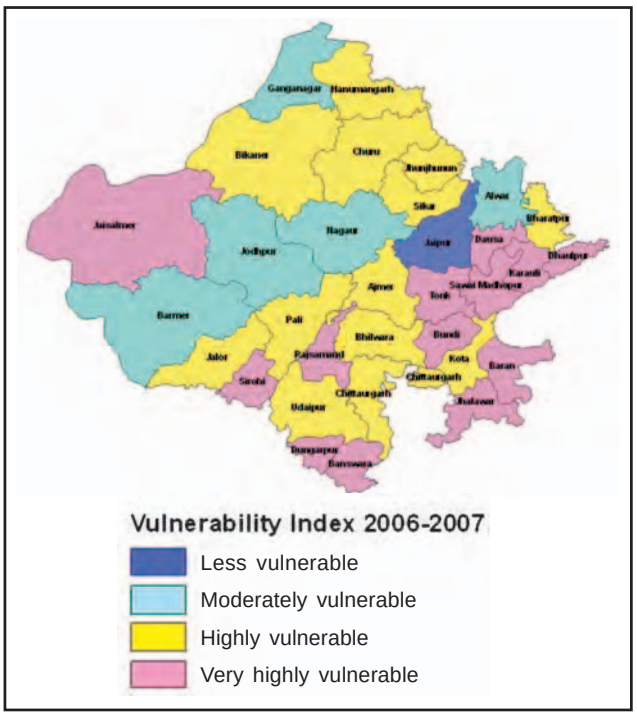
compared to biomass under all N levels. Plants grown under low N level showed higher thermal sensitivity compared to those grown under medium and high levels. Groundnut B95 grown under elevated temperature showed marked reduction in biomass and seed yield. Groundnut exposed to elevated temperature during vegetative, reproductive and entire growth phases showed greater thermal sensitivity during reproductive growth phase followed by vegetative growth phase. However, the elevated $CO_2$ (560 ppm) in free air $CO_2$ enrichment (FACE) enhanced the biomass and seed yield of rice as well as groundnut at all N levels but the $CO_2$ fertilization effect was greater on grain yield as compared to that on biomass especially at higher N level.

### 3.11.2 Effect of Low Radiation Stress on Growth and Yield of Wheat and Chickpea

The effect of global dimming or low radiation on crop growth and yield was assessed by exposing wheat ( PBW 343 and HD 2643), and chickpea (BGD 72 and BG 1105) to two radiation levels of 80% and 65% of sunlight intensity by using nylon sheets of different mesh. The results revealed that both the biomass and yield of wheat and chickpea cultivars reduced drastically with low radiation. Both wheat and chickpea cultivars showed almost similar degree of reduction in their biomass and yield by low radiation. Both the vegetative and reproductive growths of wheat were equally affected by low radiation, while in chickpea, the seed yield was more detrimental to low radiation as compared to vegetative growth.

### 3.11.3 Vulnerability Assessment of Agriculture to Climate Variability in Rajasthan

A vulnerability index, a function of exposure, sensitivity and adaptive capacity was developed for Rajasthan by the indicator approach. Exposure, sensitivity and adaptive capacity (ESA) were determined by different proxy indicators. District wise data were collected for exposure (changes in maximum and minimum temperatures, rainfall and frequency of drought), sensitivity (irrigation intensity, crop diversification index, per cent of small farmers and per cent of rural population density) and adaptive capacity (15 different parameters). Principal component analysis was used to generate weightage for the different indicators, and an over all vulnerability index was calculated. Results show that the districts such as Rajasmand, Dungarpur, Dhaulpur, and Dausa, Karauli facing large climatic variations are more vulnerable as compared to other districts, viz., Ganganagar, Jaipur, Ajmer, and Pali with relatively less climatic variations.




**Vulnerability assessment of Rajasthan to climate change by ESA approach**

### 3.11.4 National Inventory of Greenhouse Gases (GHG) Emission from Indian Agriculture

The inventory of GHG emission by Indian agriculture was developed for the base year 2000 according to IPCC 2006 national GHG inventory preparation methodology. Annual emission of $CH_4$ was estimated to be 3.49 Tg and the direct emission of $N_2O$-N from managed soils was estimated to be 132.3 Gg for the year 2000. In India, rice is cultivated under various water management conditions depending on the availability of water. Continuously flooded rice emitted maximum methane (1,111 Gg) followed by flood prone (827 Gg) and single aerated (598 Gg) rice cultivated areas. In 2000, rice cultivation contributed 87.3 million tonne (Tg) $CO_2$ equivalent, whereas, agricultural soils had a global warming potential of 39.4 Tg $CO_2$ equivalent.

### 3.11.5 Mitigating Greenhouse Gas and Nitrogen Loss with Improved Fertilizer Management

The efficacy of neem oil coated urea (NOCU) fortified with different concentrations of melacins in mitigating $N_2O$ and $CH_4$ emissions from irrigated rice in the Indo-Gangetic plains was tested in field conditions. Emission of $N_2O$-N ranged from 0.3 to 16.7 g/ha/d. NOCU fortified with 10%, 20%, and 75% melacins reduced the $N_2O$-N emissions by 19%, 21% and 25%, respectively, as compared to urea. The NOCU fortified with melacins also influenced the emission of $CH_4$. Methane emission from rice ranged from 9 to 697 g/ha/d. NOCU fortified with 10%, 20%, and 75% melacins reduced the methane emissions by 5%, 11% and 18%, respectively. The total global warming potential (GWP) was lower with all the concentrations of melacins as compared to urea, suggesting that NOCU fortified with melacins can be used for mitigating greenhouse gas emission from the rice-wheat systems.

A decision support system (DSS) named InfoNitro (information on nitrogen management technologies in rice) was also developed to quantify inputs, outputs and balance of N in soil; GHG emission/mitigation and N use efficiency with the prominent N management technologies in rice in Haryana. Global warming potential (GWP) reduced by 1% to 9% by using various technologies. However, the technologies, except no tillage, mid-season drying and alternate flooding reduced the net income of the farmers. When the environmental cost (cost of N loss and GWP) was included, net income with various technologies was either on a par with or more than that of the farmers' practice.

### 3.11.6 Potential and Cost of Carbon Sequestration in Indian Agriculture

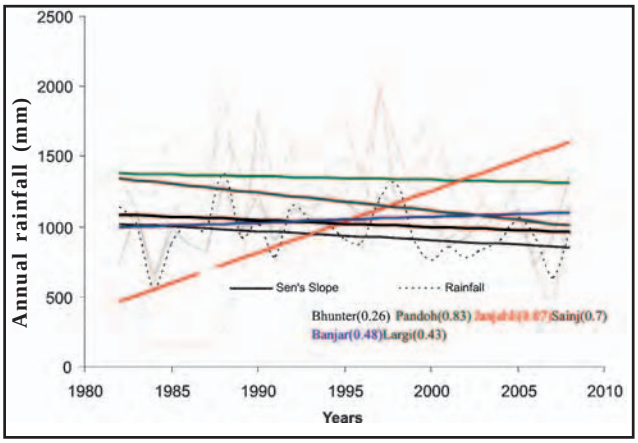
Analysis of data from 26 long-term experiments (LTEs) in different agro-climatic zones (ACZs) of India revealed that NPK+FYM treatment sequestered 0.33 Mg C/ha/yr whereas the NPK treatment sequestered 0.16 Mg C/ha/yr as compared to that of the control. The carbon sequestration potential (CSP) in different nutrient management scenarios ranged from 2.1 to 4.8 Mg C/ha during the study period (average 16.9 years) of the LTEs. Total CSP in all the ACZs of the country was 300.2 Tg to 620.9 Tg. However, in 17 out of 26 LTEs, the NPK+FYM treatment had higher soil organic carbon (SOC) and also higher net returns than those of the NPK treatment. In the remaining 9 LTEs, SOC sequestration in the NPK+FYM treatment was accomplished with decreased net returns suggesting that these are economically not attractive and farmers have to incur additional cost to achieve carbon sequestration.

### 3.11.7 Utilization of Distillery Wastewaters for Ferti-irrigation in Agricultural Fields

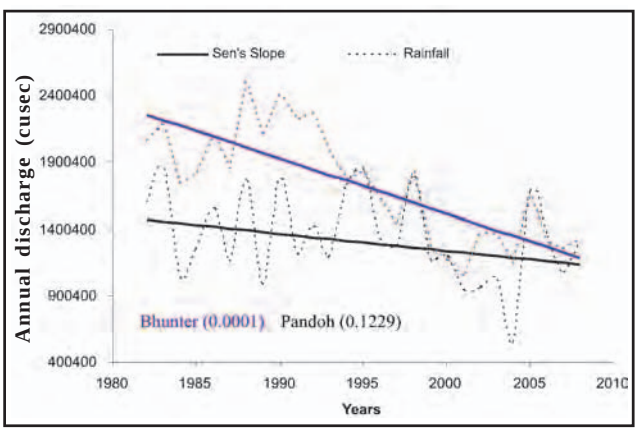
Two year studies on maize, mustard, wheat and rice crops irrigated with distillery effluent (PME: post methanation effluent and STE: secondary treated effluent) in sandy loam soils at Gajraula, JP Nagar district, U.P., showed that both biomass and grain yields were lower in treatments where 100% nitrogen requirement was met through effluent as compared to the treatments in which N requirement was met partially through the effluent. The 25% N requirement through effluent and the remaining through inorganic fertilizers gave a yield equivalent to that of the control treatment (with recommended doses of N, P, K). There was not much difference in the crop yield as well as soil quality between one time application with PME and split application of STE along with irrigation water. Salt movement in soil profile (0-60 cm) was discernible from distinct patterns in soil EC (1:2.5) after *rabi* (mustard and wheat) and *kharif* (maize and rice) experiments.

### 3.11.8 Rainfall and Water Discharge Pattern in the Lesser Himalayan Region

Rainfall and river water discharge of Beas river in Himachal Pradesh were analyzed for the exploration of possible trend over period of three decades (1981-2008). Annual data of rainfall from six rain gauge stations, namely, Bhunter, Banjar, Janjehli, Largi, Pandoh, and Sainj along with water discharge data of Beas river at Bhunter and Pandoh were used for analysis. It was found that four out of six rain monitoring stations showed no significant change in rainfall pattern while one station showed moderately increasing trend and other showed moderately decreasing trend. The river water discharge at both the stations has a significant decreasing trend during the study period. This disparity between the trends of rainfall with the river water discharge




**Annual rainfall and Sen's Slope of six rain monitoring stations (Value shown in bracket is the level of significance, Mann Kendall test)**

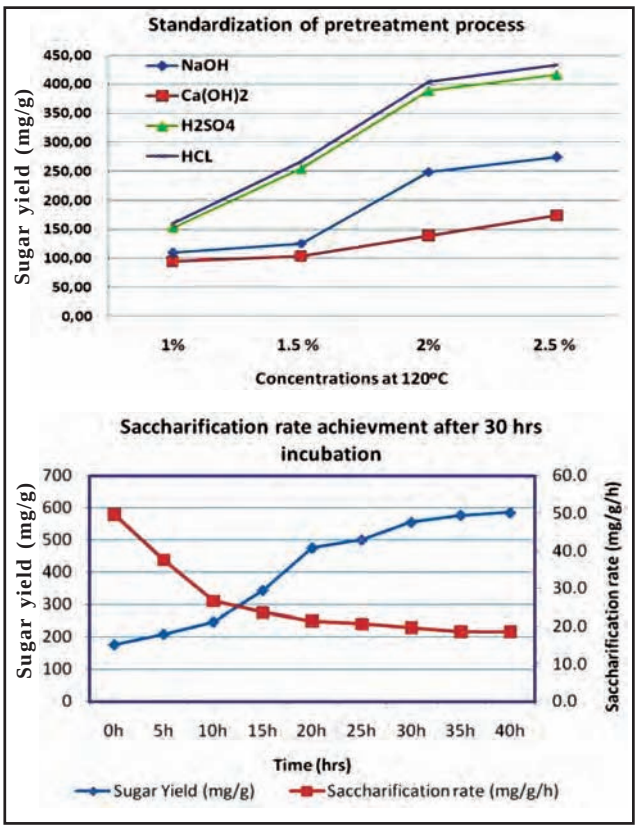



**Annual river water discharge and Sen's Slope of Bias river at two monitoring stations (Value in bracket is the level of significance, Mann Kendall test)**

in the study area indicates that water is being increasingly utilized /trapped for different purposes in the Beas valley which needs to be further investigated to quantify the economic valuation of water resources.

## 3.11.9 Conversion of Agri-residues into Fermentable Sugar

Acid pre-treatment of maize residues was found more effective than the alkali pre-treatments. Enzymatic saccharification of pre-treated residues released sugars regularly till 30 h of incubation and remained constant thereafter. However, after attaining the maximum of 49.6 mg/g/h, the rate of saccharification decreased slowly.



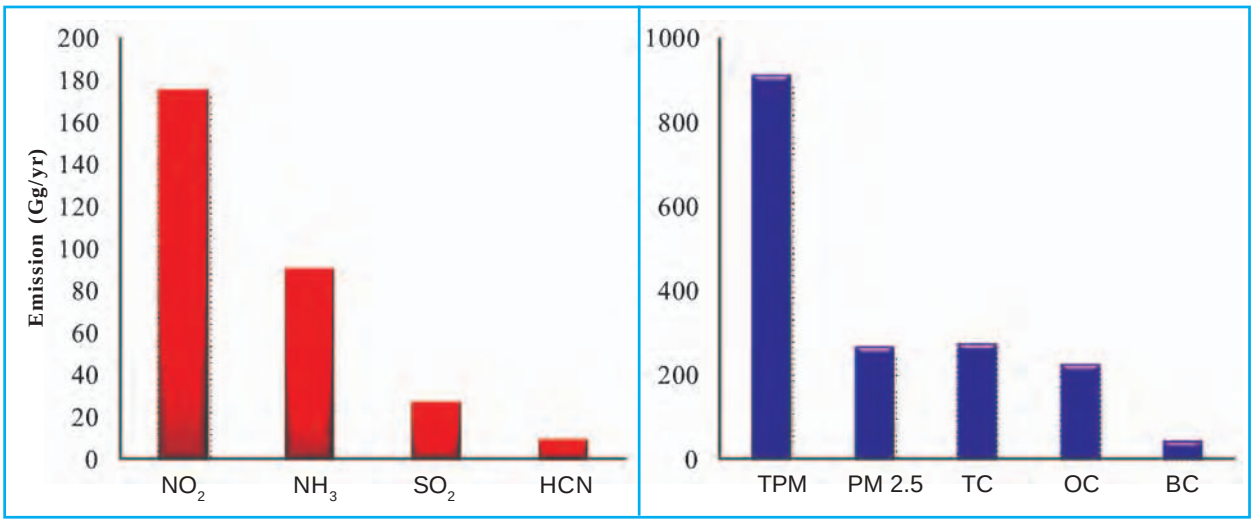

**Effect of pre-treatments and saccharification on sugar yield from lignocellulosic maize residues**

## 3.11.10 Determination of Optimum Condition for Cellulase Production by *Bacillus* sp.

A potentially aerobic, thermophilic, and cellulolytic bacterium designated as *Bacillus* sp. was isolated from hot spring, Vajreshwari (19°29′12″ N and 73°1′ 33″ E), Maharashtra, India. Optimal pH for buffer pH effect was 6.5 for both carboxymethyl cellulase (CMCase) and filter paper unit (FPU) assay. Both the activities declined with the further increase in pH. Optimum temperature for carboxymethyl cellulase activity for crude enzyme samples from *Bacillus* culture was 55 $^{o}$C. Fifty per cent of cellulase activity still retained at 60 $^{0}$C. However, the FPU activity didn't vary significantly at both the temperatures.

## 3.11.11 Evaluation of Impacts of Air Pollution on Crops

To evaluate the impact of elevated ozone on crop productivity, field experiments for growing rice (Pusa 44),




**Emission of pollutants from burning of crop residues**

maize (HQPM1) and chickpea (Pusa 1103) were carried out under controlled environment conditions (Open top chambers). The rice crop was exposed to higher ozone concentration during vegetative and flowering growth stages. Ozone exposure during the vegetative phase in rice resulted in visible injury on leaf surface and there was a significant decline in net photosynthetic rate. Exposure to higher ozone during flowering stage resulted in 21% yield loss as compared to that in ambient air. The maize crop was grown under two elevated ozone levels. The yield decreased from 755 g/m$^2$ (ambient $O_3$) to 655 g/m$^2$ (ambient + 25-35 ppb $O_3$) and 535 g/m$^2$ (ambient + 45-50 ppb $O_3$). Higher ozone levels significantly affected the biomass partitioning. The decline in carbon allocation to the roots under elevated ozone was more. The root:shoot ratio declined by 12% under elevated ozone as compared to that of the ambient air. In the case of chickpea, significant decline in the number of secondary branches and number of pods/branch led to a decline in yield under elevated ozone concentrations (ambient + 25-35 ppb $O_3$).

### 3.11.12 Emission Estimates of Gaseous and Aerosol Species from Burning of Crop Residues in India

The national and state-wise inventory of gaseous and aerosol species from burning of crop residues was developed for the base year 2000 according to IPCC national greenhouse gases inventory preparation methodology. Using the above methodology, annual emission of $CH_4$, $N_2O$, $SO_2$, $NO_2$, $NH_3$, HCN, CO, $CO_2$, NMVOC, $PM_{2.5}$, and total carbon from burning of crop residues in India were estimated to be 0.2 Tg, 4.94 Gg, 28.23 Gg, 176.43 Gg, 91.74 Gg, 10.59 Gg, 6.49 Tg, 107 Tg, 1.11 Tg, 275 Gg and 282 Gg/annum, respectively, for the base year.

# 4. CROP PROTECTION

## 4.1 PLANT PATHOLOGY

### 4.1.1 Molecular Diagnosis

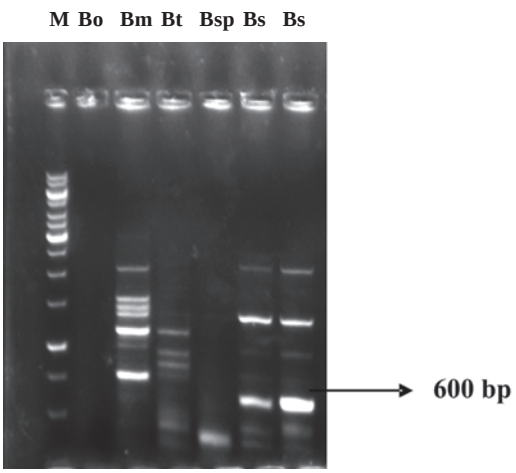
***Rhizoctonia bataticola.*** ITS1 and ITS4 regions of eleven *Rhizoctonia bataticola* isolates (dry root rot of chickpea) representing different RAPD groups were characterized based on restriction profile and sequencing. Restriction profile of amplicons (500-650 bp) varied and the isolates were differentiated into five groups. Sequence analysis of six isolates revealed that the ITS region of Karnataka isolate (RbI) was the longest (670 bp, EU 375546), followed by that of Punjab (Rb5, 652 bp, EU375545), Jharkhand (Rb16,557 bp, EU 375547), Madhya Pradesh (Rb26, 545 bp, EU75550), Rajasthan (Rb17,537 bp, EU 375548) and Haryana (Rb21, 499 bp, EU 375549). Isolates shared 96-100% similarity and were differentiated into three clusters with Rb1 (Karnataka) and Rb5 (Punjab) forming one cluster, Rb16 (Jharkhand), Rb21 (Haryana) and Rb26 (Madhya Pradesh) forming another cluster, and Rb17 (Rajasthan) forming separate cluster.

***Fusarium oxysporum* f. sp. *ciceris.*** ITS region based specific primers (FOC F1: 5′-AAGGAGACAACTC CCAAACCCCC-3′) and FOC R1: 5′-CTTGCCGCATAGGG CTCGC-3′) were designed for the detection of race 4 of *F. oxysporum* f. sp. *ciceris* (FOC) causing wilt of chickpea. Primers were validated against 25 Rajasthan isolates (race 4) and an amplified product of approximately 300 bp was obtained.


**Amplified product from 25 different *F. oxysporum* f. sp. *ciceris* (FOC) isolates collected from different areas of Rajsthan: Jaipur-FOC 4, 6, 7, 47, 48; Sardargarh-FOC 68, 69, 70, 71; Suratgarh-FOC 58, 73, 78; Churu-FOC 84, 85, 87; Sikar-FOC 2, 36; Alwar-FOC 5, 11; Jetsar-FOC 59, 79; Udaipur-FOC 50; Tonk-FOC 3; and Sriganganagar-FOC42,60 by the use of primers FOC F1 and FOC R1. Lane M: 100 bp ladder**

***Bipolaris sorokiniana.*** Polyclonal antibodies raised against extracellular and mycelial proteins of virulent strain of *B. sorokiniana* (BS 25) *(*spot blotch of wheat*)* were able to detect the presence of pathogen in infected leaves by DAC-ELISA at 1:100 dilution and 1:10 dilution respectively. *B. sorokiniana* isolates were differentiated into two major serogroups. The least virulent isolate BS 7 belonged to a separate group and other isolates BS 1, BS 18, BS 36, BS 48, BS 68, BS 59 and BS 25, BS 44, BS 87 and BS 32 formed another group.

Efforts were made to develop species specific markers for the detection of *B. sorokiniana*. A 650 bp amplicon identified through URP- 1 F- PCR was cloned and sequenced. Of five primer pairs designed, the primer pair, BSF-GGTCCGAGACAACCAACAA and $BS1FR_1$ AAAGAAA GCGGTCGACGTAA specifically amplified a 600bp amplicon only in *B. sorokiniana*.




**PCR based amplification of *Bipolaris* spp. by the use of BSF and $BS1FR_1$ primers. Lanes-M: 1 kb ladder; Bo: *B. oryzae*; Bm: *B. maydis*; Bt: *B. tetramera;* Bsp.: *B. specifera;* Bs: *B. sorokiniana* isolates**

***Xanthomonas campestris* pv. *punicae* (Xcp).** Xcp isolates (bacterial blight of pomegranate) originating from Delhi (2), Karnataka (4) and Maharashtra (4) were identified as highly virulent (disease score 7-9), when screened for their virulence level through leaf infiltration technique. However, genetic variability was observed within the virulent population of Xcp when subjected to PCR amplification using RAPD A2 primer.

***Ralstonia solanacearum*.** Of the 65 *R. solanacearum* isolates (Race 1) orginating from Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Jharkhand and West Bengal, 57 isolates of capsicum, chilli, brinjal and potato were identified as biovar 3 and eight tomato isolates as biovar 4.

## 4.1.2 Biological Control

### 4.1.2.1 Bioefficacy of bioformulations

***Chaetomium based bioformulations*.** Cg2 WP and Cg2 SL were validated against late blight (LB) of potato under field conditions at CPRI regional station, Modipuram. Though fungicide treatment was the most effective (76-94%), yet various bio-formulation treatments significantly reduced the disease severity (up to 62 %).

**Testing of Cg2 bioformulations against late blight (LB) of potato under field conditions ****

| Treat-ments*** | % blight Cg2SL (0.2%) | % reduction in severity | Cg2WP (0.2%) | % reduction in severity |
|---|---|---|---|---|
| T1 | 17.5 (24.6300)* | 46.15 | 30.0 (33.1075) | 62.73 |
| T2 | 18.75 (25.6150) | 42.3 (42.7925) | 46.25 | 42.54 |
| T3 | 22.5 (28.1200) | 30.76 (42.0525) | 45.0 | 44.09 |
| T4 | 1.75 (7.5300) | 94.61 | 4.0 (11.2800) | 76.5 |
| T5 | 32.5 (34.6750) | - | 80.5 (65.0525) | - |
| **CD (P=0.05%)** | **3.75** | | **9.04** | |

* ARSIN values in parenthesis

** Randomized block design field experiment with potato variety K. Pukhraj sown in 3 m x 3 m plot per replication

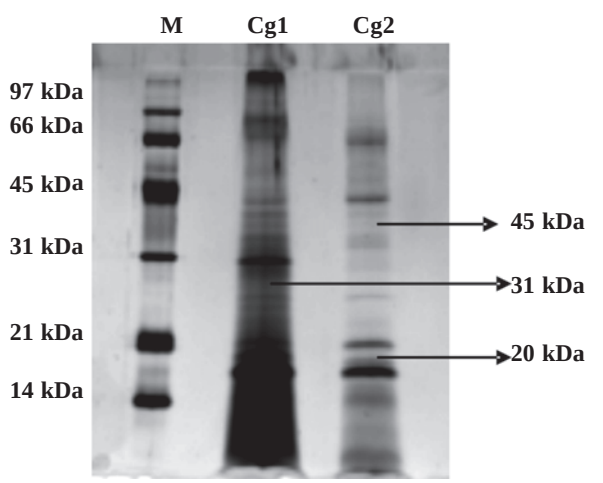
*** T1: sprays before and after the onset of LB (at 8 days interval); T2 : spray at and after the onset of LB; T3 : spray at the onset of LB; T4 : Dithane M-45 0.25% (3 sprays); and T5 : control (untreated)

***Trichoderma based bioformulations*.** Among various treatments tested, a combination of seed treatment with thiamethoxam 70% WS (Cruiser) and Pusa 5SD @4 g/kg each followed by two foliar sprays of a mixture of thiamethoxam 25% WG (Actara, 0.02%) and carbendazim (0.05%) at 21 DAS and 35 DAS showed maximum seed germination (77.6%) and grain yield (906.7 kg/ha) with minimum development of wet root rot (5.2%), *Cercospora* leaf spot (6.3%) and yellow mosaic (6.3%). The combination proved to be highly beneficial with Rs. 6.69 return per rupee.

Field demonstration on the management of black root rot (Kali jad) of groundnut caused by a wide range of fungal pathogens (*Rhizoctonia solani, Thielaviopsis basicola, Pythium aphanidermatum, Aspergillus flavus, Aspergillus niger, Sclerotium rolfsii)*, was also conducted in Jaipur district using *Trichoderma harzianum* based bioformulations (Pusa Th3 SD & FS) on seven groundnut varieties covering nine villages (57 ha) during 2009. Bioformulations resulted in 25-65% reduction in disease incidence and up to 3.69 t/ha increase in yield. Variety M13 showed the highest disease reduction of 65% and significant increase in yield of 36.9%.

### 4.1.2.2 Protein profiling of *Chaetomium globosum*

Protein profiling of *Chaetomium globosum* isolates (Cg1 and Cg2) showed a common band of 45 kDa. Other prominent bands of 31 kDa and 20 kDa were observed in




**Protein profiling of *Chaetomium globosum* isolates Cg1 and Cg2; M: Marker lane**

Cg1 and Cg2, respectively. MASCOT search analysis of purified protein showed it to be matching with a protein from *C. globosum* CBS 148.51 (Q2HCC7_CHAGB), *Neurospora crassa* (Q7RX80_NEUCR) and *Gibberella zeae* (Q4I554_GIBZE).

### 4.1.3 Host Resistance

#### 4.1.3.1 Evaluation of genotypes for disease resistance

***Wheat.*** Of the 648 wheat entries of IARI under Plant Disease Screening Nursery (PDSN), HW4034-1, DL 1188, DL 2049 and DL 2050 were free from yellow, brown and black rusts across the test locations.

Of the 44 accessions evaluated against a mixture of virulent pathotypes of *Bipolaris sorokiniana* (BS-75, 34,55,63), nine accessions of *A. squarrossa*, seven of *T. spelta*, three of *T. sphaerococcum*, two of *T. dicoccum*, one each of *T. monococcum, T. compactum, T. amplissifolium, T. pursicum, T. abassinicum, T. tergidum, T. carthlicum, T. polonicum, T. diccocoides, T. timopheevii,* Mexican dwarf and Nikin Kin remained free of infection.

***Maize.*** Of the 221 elite maize genotypes evaluated against maydis leaf blight (MLB, *Bipolaris maydis*) and banded leaf and sheath blight (BLSB, *Rhizoctonia solani*), only 17 lines, viz., CMH 08-282, BIO 265, NMH 920, HQPM 5, X7B 403, GK 3059, KMH 3669, HTCH 5401, MCH 37, MCH 38, MDMH 101, BH 408005, KDMH 1001, HM 8, HM 9, COMP R-2007-1 and JH 1527 exhibited resistance to both the diseases.

Of the 196 inbreds from the Directorate of Maize Research (DMR) evaluated against BLSB, 18 entries 95-7, DMSC16, HKI-PC-4B-1, HKI-PC-BT-3, KHI-PC-7, HKI-PC-8-2, WINPOP-8, WINPOP-21, WINPOP-21, B335, CML395, MIRT&PT-3, HKI164-7-2, CML451Q, PFSR-R9, SW-930-313-23-PO-49-54-1-3-1-1-1-2-1-2-1-2-3-1-1-2, JCY2-1-2-1-1B-1-2-3-1-1-1, and JCY3-7-1-2-1-B-1-1-4-1 showed resistant reaction.

Of the 30 inbred lines from IARI, three lines, viz., IPA-3-6-10, IPA-09-8057-1 and IPA-09-8060B-1 showed resistant reaction to MLB disease and other three lines, viz., IPA-40-F-17, IPA-3-6-10 and IPA-09-8057-2 were tolerant to BLSB disease.

***Legumes.*** Of the 131 chickpea genotypes evaluated against wilt (*Fusarium oxysporum* f.sp. *ciceris*) and *Ascochyta* blight (*Ascochyta rabiei*), two genotypes, GNG 1861 and WCG 2005-2 showed resistance against wilt and only one genotype H01-80 shoved resistance against *Ascochyta* blight. Of the 65 field pea genotypes, KPMR 839, RFP 30, IPF 8-20, RFP 26, Pant P 74, Pant P 101, Pant P 114 and HFP 554 were resistant against powdery mildew. Of 25 urdbean entries, P 2015, P 2016 and P 2023 and P 2023 and of the 33 mungbean entries, P 1014, P 1016 and P 1023 showed multiple resistant reactions against *Cercospora* leaf spot, *Macrophomina* blight and yellow mosaic diseases.

***Papaya.*** Of the ten papaya cultivars screened for resistance against *Papaya ring spot virus* (PRSV), Red Lady (59.82%) was most susceptible followed by CO 6 and Pune Selection-1 (28.57%), which was least susceptible.

#### 4.1.3.2 Adult plant resistance (APR) in wheat

***Yellow rust.*** Of the 250 wheat entries under AVT, IARI entries HS 502, HD 2967, HD 2982, HD 2983, HI 8680 (d), HI 8682 (d) and HW 5207 possessed a high degree of APR to yellow rust.

***Stem and leaf rusts.*** Varieties released for central India (HI 8498, HI 8381, HI 1544, HI 1531, HI 8627, DL 788-2 and HD 4672) and peninsular India (DDK 1001, DDK 1009, NIAW 917, DDK 1025, UAS 415, NIAW 34, Raj 4083, HD 2781, K 9644, MACS 1967 and AKDW 2997-16) showed high resistance to Nilgiri flora of black and brown rust pathogens at seedling and adult stages.

#### 4.1.3.3 Inheritance of resistance to stem and leaf rusts

***Stem rust.*** Three independent dominant genes for stem rust resistance, each in WH 542 and HW 2402, and two dominant independent genes for resistance in HD 2687 were identified. $F_2$ segregation of intercrosses (diallel crosses) of test cultivars to pathotype 21 (9G5) did not show any susceptible segregant indicating the presence of at least one common gene in these cultivars.

***Leaf rust.*** Seedling resistance to leaf rust pathotype 12-2 was conditioned by a single gene in B 276 and Guji 'S', and by two genes each in AKDW 4339, CPAN 6118, and VD

2001-14. Allelic tests showed that these genes were different from each other, except the one common between VD 2001-14 and Guji 'S'. Thus, a total of seven diverse leaf rust resistance genes were identified. These are different from *Lr23*, the leaf rust resistance gene most commonly postulated among Indian *durum* wheat genotypes as the leaf rust pathotype 12-2 is virulent on *Lr23*.

Of the12 bread wheat varieties studied, allelic tests with the near-isogenic line carrying *Lr34* confirmed the postulation of *Lr34* in Frontana, GW 173, and HD 2189; but not in C 306, HI 1077, K 9107, Kalyan Sona, NI 5439, PBW 175, PBW 373, UP 2338, and WH 147.

### 4.1.3.4 Virulence typing of rust pathogens

Of the 506 wheat leaf rust and the 146 wheat stem rust samples analysed for virulence patterns, leaf rust race 77-5 (121R63-1) was most dominant followed by 77A (109R31), 77-8 (253R31), 17(61R24) and 77-7 (121R127) in Nilgiri hills of Tamil Nadu. An analysis based upon standard deviation about mean revealed that the population of pathotypes 77-5 (121R63-1) and 77A (109R31) existed on par but both together were significantly higher than other pathotypes, namely, 77-7 (121R127), 77-8(253R31) and 17(61R24). In black rust, two pathotypes 40A(62G29) and 40-1(62G29-1) prevailed in equal proportions as deduced from the analysis of standard deviation about mean.

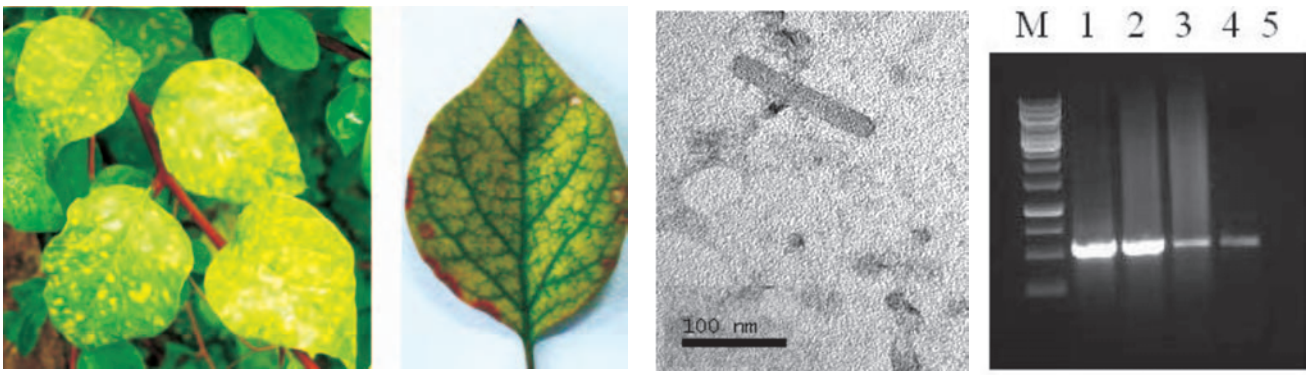
## 4.1.4 Viral Diagnosis

***Foorkey disease of large cardamom.*** Etiology of foorkey disease of large cardamom (*Amomum subulatum*), characterised by profuse vegetative growth of stunted tillers and unproductive clumps remained unaddressed since 1936. Polymerase chain reaction (PCR) and rolling circle amplification (RCA) were employed and six distinct circular full-length DNA components encoding putative master-Rep (M-Rep), satellite-Rep (sRep) and coat protein (CP), three DNAs of unknown function (FU1, FU2 and FU3) and a partial DNA component encoding putative nuclear shuttle protein (NSP) were cloned and sequenced. All the circular DNA components contained 1079-1134 nt and a potential stem-loop structure. Rep, sRep and CP components contained one major open reading frame (ORF) on the virus sense strand, whereas, three full-length U1, U2 and U3 DNAs contained no major ORF. Except the sRep, all the DNA components contained strikingly similar stem and loop structure. Rep, sRep and CP components shared maximum sequence similarities (58.7-78.3%) and phylogenetic affinity with *Banana bunchy top virus* and *Abaca bunchy top virus* in the genus *Babuvirus* and distant relationship with the members in the genus *Nanovirus* under family Nanoviridae. The present study provides evidence of a new species, *Large cardamom bushy dwarf virus* under the genus *Babuvirus* and family Nanoviridae.

***Badnaviruses infecting Bougainvillea spectabilis.*** Leaf dip electron microscopy of symptomatic bougainvillea samples showing distinct severe yellow mosaic (SYM) and chlorotic vein-banding (CVB) symptoms, respectively revealed the association of bacilliform virus particles measuring 120-150 nm x 20 nm. Cloning and sequencing of


(A) (B) (C)

**Foorkey disease of large cardamom: (A) healthy clump bearing flowers, (B) foorkey affected degenerated clumps, and (C) detection by PCR Rep-specific primer pair, AV5 and AV6 (Lanes: 1 and 2- diseased samples; H: healthy control; M: 1 kb ladder)**




(a) (b) (c) (d)

**Severe yellow mosaic (a) and chlorotic vein-banding (b) symptoms on *Bougainvillea spectabilis* leaves, bacilliform particles in leaf-dip preparations (c) and PCR detection of RT and RNase H region of *Badnavirus* infecting *Bougainvillea spectabilis* (d). Lane M: 100 bp DNA ladder, Lanes 1 and 2: Tirupati isolates; Lanes 3 and 4: Delhi isolates and Lane 5: Asymptomatic healthy control**

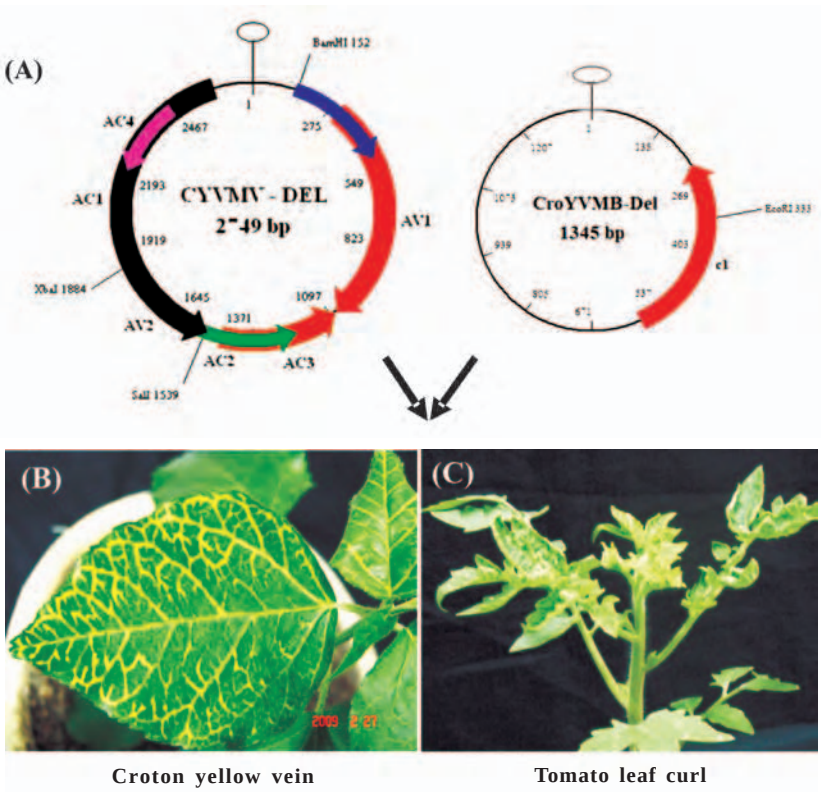
putative ribonuclease H (RNase H) and reverse transcriptase (RT) coding regions in ORF3 (577 bp) indicated that two distinct badnaviruses were associated with *B. spectabilis* from two different locations in India, as they shared nucleotide identity of less than 80% with each other within the RT and RNase H region (Tirupati isolate: GQ254410 and New Delhi isolate GQ254411). They also showed less than 80% identity with other badnaviruses infecting bougainvillea reported previously from Brazil and Taiwan.

***Toria phyllody.*** Toria (*Brassica rapa* cv. *toria*) plants with phyllody, virescence, witches broom, extensive malformation of floral parts, formation of bladder like siliques and flower sterility symptoms were observed in IARI experimental fields, New Delhi, during October 2008, the incidence ranging from 0.9 to 11.0 per cent. Sequencing of amplified PCR product (GU111554) obtained by the use of universal phytoplasma specific P1/P7 primers revealed that the phytoplasma associated with toria phyllody shared 98-99% identity with the rRNA gene sequence of *Knautia arvensis* phyllody (Y18052) from Italy, Khafr almond witches broom phytoplasma (DQ195209) from Iran, Pigeonpea witches broom phytoplasma (AF248957) from USA and *Candidatus* phytoplasma phoenicium (AF515636) from Lebanon and Iran, belonging to Pigeonpea witches broom (PPWB) 16Sr IX group of phytoplasma. This is the first report of the association of a member of 16Sr IX group of phytoplasma with *Brassica* plant in India.

**Witches broom symptoms associated with toria phyllody**

***Croton yellow vein mosaic virus (CYVMV) causing tomato leaf curl.*** The full length clones of DNA-A (2749 nt) and DNA-beta (1345 nt) obtained from the CYVMV isolate collected from IARI experimental field were sequenced. Sequence analysis showed that DNA-A shared maximum identity of 84% with *Papaya leaf curl virus* from Pakistan. Monomeric DNA-A and DNA-beta prepared from the cloned DNAs through rolling circle amplification method produced typical yellow vein mosaic symptoms in croton when bombarded through biolistic-gun. When these infectious DNA components were bombarded on tomato, typical leaf

curl disease developed. The progeny virus from both croton and tomato was successfully transmitted by whitefly to both the host plants, thus establishing the etiology of croton yellow vein mosaic disease and the role of a weed infecting begomovirus in causing leaf curl disease in tomato.




**Genome organisation of DNA-A and DBA-beta of *Croton yellow vein mosaic virus* (CYVMV) (A), croton (B) and tomato (C) showing yellow vein mosaic and leaf curl symptoms, respectively, following bombardment of DNA-A and DNA-beta of CYVMV**

## 4.1.5 Viral Genomics

***Cucumber mosaic virus* (CMV).** Complete genome of RNA1 (GU111227) segment of CMV (Delhi isolate) (GU 111227,3358nt) contains single ORF which starts at nucleotide position 95 and terminates at 3076. Comparative sequence analysis revealed that RNA1 shared 88-98% overall sequence identities at nucleotide level with other CMV sub group IB isolates.

***Citrus tristeza virus* (CTV).** By the use of 30 pairs of overlapping primers, complete genome of a CTV isolate (Kpg3) from Darjeeling hills of Northeast Himalayan Region of India was amplified, cloned and sequenced. The genome is 19253 nt long consisting of 12 open reading frames and 5´UTR and 3´UTR of 107nt and 274 nt, respectively. Kpg3 genome shared 79-94% nucleotide sequence identity with CTV isolates from other countries. The highest nucleotide sequence identity (94%) was observed with Spanish (T318A) and Israeli (VT) isolates and the lowest identity with Florida (T36) and New Zealand NZRB isolates.

***Papaya ring spot virus* (PRSV).** Complete genome of PRSV (pathotype W) from India is 10335 nt long (EU 475877) excluding 3 terminal poly (A) tail. The genome consists of a single open reading frame encoding a polyprotein of 3347 aa. The genome shared high degree of sequence identity at nucleotide (89%) and amino acid (94%) levels with PRSV genome of pathotype P (EF 017707). Sequence comparison of the individual citrons except P1U (up to 33%) also revealed similar trend.

## 4.1.6 Transgenic Resistance

### 4.1.6.1 Identification of promoter in cotton leaf curl Multan betasatellite

Three different promoter deletion constructs (βP1, βP2, βP3) with *GUS* gene were designed to identify the putative promoter region of the βC1 genes. Histochemical staining of the leaf samples of *N. benthamiana* and tomato, and unripened fruit of tomato agro-infiltrated with promoter constructs showed good *GUS* gene expression.

### 4.1.6.2 Construction of artificial microRNA for leaf curl resistance

Artificial micro RNA (amiRAV1) was constructed by using *Arabidopsis* pre-miR159a (273bp) and replacing micro RNA sequences with siRNA sequences (21-nt sequence (UACAGGCCAUAUACAACA UUA) targeting AVI gene (nt 966-986) of ToLCNDV (GenBank accession no. 15015), and

healthy tobacco plants were transformed with the constructs to observe viral silencing through challenge inoculation. Control plants (untransformed tobacco) showed severe symptoms while amiRAV1 transformed tobacco, when challenged inoculated, showed significant resistance. About 66% amiRAV1 virus challenged transformants showed no symptom development.

## 4.2 ENTOMOLOGY

### 4.2.1 Insect Pest Management

#### 4.2.1.1 Cereals

Rice germplasm, Rathu Heenati, Sinnasivappu and MR 1523 were promising when screened in glass house against brown planthopper (BPH), *Nilaparvata lugens*, with PTB 33 and TN-1 as resistant and susceptible checks, respectively.

**Screening of rice germplasm against brown planthopper (BPH), *Nilaparvata lugens***

| Germplasm | Damage score (0-9 scale) | Days to wilting | Nymphal survival (%) |
|---|---|---|---|
| Rathu Heenati | 3.7 | 10.3 | 15.5 |
| Sinnasivappu | 2.3 | 10.6 | 16.7 |
| MR 1523 | 1.7 | 10.7 | 16.7 |
| INRC 3021 | 7.0 | 10.3 | 22.9 |
| MO. 1 | 7.0 | 10.3 | 22.9 |
| PTB 33 (resistant check) | 1.0 | 9.2 | 6.2 |
| TN1 (susceptible check) | 9.0 | 7.0 | 27.1 |
| Mean | 4.5 | 9.8 | 18.7 |
| C.V. (%) | 68.84 | 13.56 | 39.20 |

InfoCrop model was calibrated and validated for rice leaf folder damage on Pusa Basmati 1. The validated model was used to simulate economic injury levels (EILs) for the leaf folder at two control expenditures, viz., Rs. 1540 and Rs. 1800 required for two sprays of quinalphos and cartap hydrochloride, respectively, and three market prices of Pusa Basmati 1 (Rs. 20/kg, Rs. 25/kg and Rs. 30/kg). The EILs had negative relationship with market value of produce while these were positively related to control expenditure. These were lower during initial crop growth stages indicating higher crop vulnerability to the pest during 40-60 days after transplanting. Further the validated model was also used to formulate iso-loss curves that depicted various pest damage and crop age combinations resulting in similar yield loss.

Spectral signatures were established for leaf folder, *Cnaphalocrosis medinalis* damage on rice with remote sensing using spectroradiometer. Spectral reflectance of infested and un-infested rice crop did not differ in visible range (350 – 700 nm). The major difference in spectral reflectance was found in near infrared (NIR) (780 – 1350 nm) where un-infested crop had higher reflectance compared to infested crop. Difference between signatures of un-infested and infested crop increased with infestation severity and crop age.

#### 4.2.1.2 Soybean

Among ninety-six soybean lines evaluated under natural conditions during *kharif* 2009 against stem fly and yellow mosaic virus (YMV) disease transmitted by white fly, *Bemisia tabaci*, DS 2614 and SL 744 were identified as the most promising sources of resistance to whitefly and can be incorporated in the breeding programme as donors for developing high yielding varieties endowed with resistance to whitefly.

**Reaction of soybean lines to YMV transmitted by whitefly**

| Variety | Mean YMV disease incidence (scale 1 - 9) | | | Reaction to YMV |
|---|---|---|---|---|
| | 2007 | 2008 | 2009 | |
| DS 2614 | - | 1.00 | 1.00 | R |
| SL 744 | 1.66 | 1.00 | 1.00 | R |

An insecticidal trial on soybean variety JS 335 was conducted under field conditions with four doses of imidacloprid 70 WS and three doses of thiamethoxam 70WS along with an untreated control during *kharif* 2009. A perusal of the data revealed significant differences between the various treatments and untreated control. Seed treatment with imidacloprid 70WS @10.0 g/kg seed was most effective against the major pests of soybean as indicated by the maximum per cent avoidable yield loss.

**Efficacy of insecticides as seed treatment against major insect-pests of soybean**

| Treatment | Mean % stem tunneling | | Mean YMV incidence due to whitefly (Scale 1-9) | Mean injury score due to grey weevil damage (Scale 0-3) | Grain yield t/ha | Per cent avoidable yield loss |
|---|---|---|---|---|---|---|
| | At flowering | At harvest | | | | |
| Imidacloprid 70WS 2.5 g/kg seed | 28.54 (32.89) | 42.21 (40.48) | 4.00 | 1.00 | 1.444 | 1.73 |
| Imidacloprid 70WS 5.0 g/kg seed | 26.67 (30.89) | 33.55 (35.38) | 3.66 | 1.00 | 1.601 | 11.37 |
| Imidacloprid 70WS 7.5 g/kg seed | 15.58 (23.08) | 14.25 (21.85) | 2.66 | 1.00 | 1.597 | 11.15 |
| Imidacloprid 70WS 10.0 g/kg seed | 7.64 (15.53) | 12.11 (20.31) | 2.66 | 1.00 | 1.863 | 23.83 |
| Thiamethoxam 70WS 1.5 g/kg seed | 26.75 (31.06) | 36.84 (37.28) | 3.33 | 1.00 | 1.538 | 7.74 |
| Thiamethoxam 70WS 2.0 g/kg seed | 14.95 (14.95) | 25.30 (30.10) | 2.33 | 1.66 | 1.696 | 16.33 |
| Thiamethoxam 70WS 3.0 g/kg seed | 7.14 (15.44) | 14.53 (21.61) | 2.00 | 1.66 | 1.819 | 21.99 |
| Control | 34.03 (35.37) | 52.41 (46.44) | 6.33 | 2.33 | 1.419 | - |
| S.Em ± | 2.23 | 3.00 | 0.36 | 0.18 | | |
| CD (5%) | 6.74 | 9.07 | 1.08 | 0.54 | | |
| CD (1%) | 9.39 | 12.64 | 1.51 | 0.75 | | |

### 4.2.1.3 Mustard

One hundred two germplasm/cultivars of *Brassica* were screened against mustard aphid *Lipaphis erysimi* during *rabi* 2009-10. The Mean Aphid Infestation Index varied from 0.03 to 1.63 at flowering stage while at the pod stage it increased from 0.76 to 2.80 when graded on a scale of 0 to 5.

An IPM trial against *L. erysimi* on *Brassica juncea* variety Pusa Bold was conducted with seven treatments along with a control. The first spray was at the ETL of the mustard aphid followed by a second one after 15 days. Neem oil @ 2% was most effective among all the treatments against mustard aphid as indicated by the significant reduction in the aphid population and also increased yield compared to all the other treatments.

### 4.2.1.4 Vegetables

A field trial on okra var. *Arka Anamika* conducted during *kharif* 2009 with nine treatments and a control indicated that neonicotinoids, viz., thiamethoxam 25WG @ 25g a.i/ha and acetamiprid 20SP@20g a.i./ha were most effective among all the treatments against leafhoppers during the first spray. Further, insecticidal mixtures, viz., triazophos (35EC) + deltamethrin (1EC) and chlorpyriphos (50EC)+cypermethrin (5EC) were highly effective on 1$^{st}$ day and 7$^{th}$ day while profenophos (40EC)+cypermethrin (4EC) was only effective on 1$^{st}$ day against leafhopper. The mixtures, viz., triazophos + deltamethrin and chlorpyriphos+cypermethrin were also very effective against whitefly on 1$^{st}$ day and 7$^{th}$ day of spray. Two dosages of insecticides, viz., triazophos (350 g and 700 g a.i./ha), as well as deltamethrin (10 g and 20 g a.i./ha) and their registered mixture, triazophos+deltamethrin (360 g and 720 g a.i./ha) were assessed and found highly effective against leafhopper and whitefly but low doses of triazophos(350 g a.i./ha) and deltamethrin (10 g a.i./ha) were not effective against whitefly.

**Impact of various insecticide schedules on the population of leafhopper *Amrasca biguttula biguttula* Ishida on okra (var. Arka Anamika)**

| Treat-ment | Insecticide schedules | Dose (a.i./ha) | Pre-spray | No. of nymphs of leafhoppers/15 leaves | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | I Spray | | | II Spray | | |
| | | | | 1 DAS | 7 DAY | 14 DAS | 1 DAS | 7 DAS | 14 DAS |
| $T_1$ | Thiamethoxam (25 WG) – triazophos (40 EC) | 25g 350g | 81.00 | 15.00 | 14.00 | 16.33 | 30.33 | 30.33 | 33.00 |
| $T_2$ | Thiamethoxam (25WG) - triazophos (40 EC) | 25g 700g | 80.00 | 10.67 | 10.00 | 13.00 | 19.67 | 19.33 | 25.67 |
| $T_3$ | Thiamethoxam (25WG) - Triazophos+deltamethrin (36 EC) | 25g 360g | 100.00 | 10.67 | 12.00 | 22.00 | 17.33 | 22.33 | 36.33 |
| $T_4$ | Thiamethoxam (25 WG) - Triazophos+deltamethrin(36 EC) | 25g 720g | 83.67 | 15.33 | 16.00 | 24.00 | 13.00 | 15.67 | 35.00 |
| $T_5$ | Acetamiprid (20 EC) -Chlorpyriphos +cypermethrin(55 EC) | 20g 550g | 96.00 | 11.67 | 24.00 | 34.00 | 16.00 | 30.67 | 55.33 |
| $T_6$ | Acetamiprid-Profenophos+ cypermethrin(44 EC) | 20g 440g | 113.67 | 17.00 | 25.00 | 31.33 | 35.67 | 35.33 | 64.33 |
| $T_7$ | Acetamiprid (20 EC) - Deltamethrin (2.8 EC) | 20g 10g | 111.00 | 15.00 | 30.00 | 31.67 | 27.00 | 19.67 | 39.33 |
| $T_8$ | Acetamiprid (20 EC) - Deltamethrin (2.8 EC) | 20g 20g | 88.33 | 11.00 | 28.00 | 28.00 | 15.67 | 6.00 | 39.33 |
| $T_9$ | Control | - | 87.33 | 62.00 | 57.00 | 51.67 | 44.67 | 34.33 | 71.00 |
| S.E. | | | 13.69 | 4.08 | 7.66 | 3.10 | 3.71 | 1.54 | 13.46 |
| C.D.(0.05) | | | 29.02 | 8.65 | 16.24 | 6.58 | 7.87 | 3.27 | 28.54 |
| C.D.(0.01) | | | 39.98 | 11.92** | 22.37** | 9.07** | 10.83** | 4.50** | 39.32 |

## 4.2.2 Storage Entomology

Studies on relative toxicity of microwave heat treatment 70 watts for 30,45,60,75,90 and 120 seconds against all the stages of cigarette beetle *Lasioderma serricorne* revealed that mortality of all stages was dose dependent. Based on $LD_{50}$ values, egg stage (251.2; 434.1J/gm) was found to be the most susceptible followed by pupal stage. Adult stage was least susceptible with 271.77 $LD_{50}$. However, all the four life stages showed complete kill in 120 seconds.

Toxicity of fly ash and diatomaceous earth @ 0.5, 1.0, 1.5, 2.0 and 5.0 g/kg against adult storage insects, (viz., *Tribolium castaneum, Sitophilus oryzae, Rhyzopertha dominica* and *Callosobruchus maculatus*) on wheat grain and *moong* showed that toxicity of both material was dose dependent. Based on per cent mortality, order of susceptibility was *Sitophilus oryzae >Callosobruchus maculatus>Rhyzopertha dominica>Tribolium castaneum.* Diatomaceous earth showed better toxicity compared to fly ash. With diatomaceous earth, complete mortality of all insects except *T. castaneum* occurred at maximum dose after 48 h and at 1.5 mg/kg dose after 48 h.

## 4.2.3 Biological Control

A total of 40 indigenous and exotic insect cultures comprising parasitoids, predators and their hosts were maintained in the Biological Control Laboratory. Field studies revealed the presence of fortuitous biological control of mealybug, *Phenacoccus solenopsis*, due to sole occurrence of parasitoid, *Aenasius bambawalei.* The host specificity of *A. bambawalei* to *P. solenopsis* was established. The parasitoid did not parasitize local mealy bugs, viz., *Ferrisia virgata, Planococcus citri, Maconellicoccus hirsutus, Nipaecoccus viridis* and *Rastrococcus iceryoides*. Kairomonal effect of whole body wash extract of spotted boll worm *Earias vitella* was studied against *Trichogramma achaeae, T. brasiliensis, T. chilonis, T. evanescens, T. exiguum* and *T. japonicum.*

**Kairomonal effect of whole body extract of *E. vitella* against different species of *Trichogramma***

| Body with conc. (ppm) | *Trichogramma* spp. | | | | | |
|---|---|---|---|---|---|---|
| | *T. chilonis* | *T. brassiliensis* | *T. achaeae* | *T. evanescens* | *T. japonicum* | *T. exiguum* |
| 1 | 3.25 | 3.42 | 2.14 | 2.68 | 3.47 | 2.99 |
| 10 | 4.26 | 5.12 | 3.62 | 3.11 | 4.89 | 4.20 |
| 100 | 5.21 | 4.88 | 4.08 | 3.89 | 6.12 | 4.58 |
| 1000 | 5.92 | 6.08 | 5.17 | 4.20 | 5.18 | 5.08 |
| 100000 | 6.72 | 7.11 | 6.70 | 5.94 | 6.14 | 6.19 |
| Control | 2.10 | 1.88 | 1.95 | 0.88 | 2.00 | 1.07 |

Among different spp, *T. brasiliensis* elicited the highest response to *E. vitella* extract as compared to *T. evanescens* in terms of parasitoid activity index (PAI). Hydrocarbon profile of *E. vitella* indicated the presence of saturated hydrocarbons in the range of $C_{13}$ to $C_{30}$ with varying quantities.

## 4.2.4 Insect Physiology

Studies on the inheritance of Cry1Ac resistance along with various biological traits in *Helicoverpa armigera* were continued this year. Two important traits, viz., larval period and larval weight were associated with Cry1Ac resistance/ susceptibility.The larval period ranged from 23 to 27 days in the resistant parents and 15-18 days in susceptible parents on untreated diet. As expected the $F_1$ progeny was either on a par or performed better than the resistant parents on the untreated diet and showed a larval period in the range of 14-19 days.

The larval weight of the resistant parents on the untreated diet ranged 11.3-22.1 mg, and that in susceptible parents ranged 27.1-40.7 mg. The larval weight of the $F_1$ progeny ranged from 19.6-38.4 mg on untreated diet. Significant difference was found in the mean larval weight between resistant (17.13±0.95) and susceptible (32.96±1.86) parent (t= 6.25, P=0.0), and between the resistant parent and their $F_1$ reciprocal cross (27.52±1.93) on untreated diet (t=5.1, P= 0.001). However, larval weights of the susceptible parents and their $F_1$ hybrids did not differ significantly from each other on untreated diet (t=1.82, P=0.102).

The normal larval period and the body weight (normal larval growth) were the dominant traits associated with susceptible strain as contrasted to longer larval period and the lower body weight (slow growth) associated with resistance trait. Further, the inheritance of larval period in $F_2$ and backcross progeny suggested the existence of a major resistant gene or a set of tightly linked loci associated with Cry1Ac sensitivity.

Susceptibility of *Pectinophora gossypiella* larvae to Cry1Ac was assayed using 16-day diet incorporation bioassays with MVP-II® (19.7% Cry1Ac) obtained from Monsanto Imagine Inc., and the seed powder of KDCHH441BGII cotton hybrid expressing Cry1Ac and Cry2Ab2 was procured from Krishidhan Seeds limited, Jalna.

Cotton bolls infested with pink bollworm, particularly those of non-Bt cotton, were collected from different locations. The adults emerging were collected in a jar where a twig of cotton was kept for egg laying. These were then transferred to artificial diet for the larvae that hatched from eggs. Bioassays were performed on the 5 day old larvae. The control consisted of diets without any toxin or equivalent of non-Bt cotton seed powder.

These studies showed that except for Amreli population, all other populations were susceptible to Cry1Ac.

**Susceptibilty of larvae of *Pectinophora gossypiella* from different locations to Cry1Ac**

| Population | $LC_{50}$ (µg/ml) with fiducial limits 95% | Slope | Chi-sq |
|---|---|---|---|
| Adilabad | 0.037 (0.013-0.089) | 1.38± 0.38 | 0.67 |
| Amreli | 1.75 (0.959-24.80) | 1.89± 0.68 | 0.05 |
| Delhi | 0.052 (0.032-0.083) | 1.57± 0.26 | 2.02 |

Seed powders of KDCHH441BGII containing two toxins, Cry1Ac and Cry2Ab2 were toxic to all populations suggesting synergistic effect against larvae of pink bollworm.

Field trials were conducted to evaluate six hybrids belonging to Bollgard II, one variety of Bt cotton and two hybrids belonging to Bollgard, viz., MRC 7017Bt BG II, MRC 7031 Bt BG II, MRC 7160 Bt BG II, MRC 7347 Bt BG II, MRC 7351 Bt BG II, MRC 7918 Bt BG II, Bikaneri Narma Bt, MRC 6029 Bt BG I, and Mallika Bt along with Mallika Non-Bt.

Per cent seed cotton damage (weight basis) ranged from 29.78 to 41.95 for Bollgard II hybrids, 35.1 to 40.2% for Bollgard and Bt variety and the highest of 52.1% for non-Bt Mallika hybrid. The seed cotton yield (t/ha) ranged from 0.38 to 1.44 for Bollgard II hybrids; 0.52 to 1.36 for Bollgard and Bt variety while it was 0.087 in non-Bt Mallika hybrid.

Studies showed significant differences in their boll damage and yield performance. However, bollworms infestation was very less. It suggests the possibility of involvement of other factors in boll damage including physiological state of crop.

**Effect of different Bt cotton hybrids on opening, damaged seed cotton and seed cotton yield during *kharif*, 2009**

| Treatment | Opening (%) | Damaged seed cotton (%) | Seed cotton yield (t/ha) |
|---|---|---|---|
| MRC 7017Bt BG II | 69.57 (56.69) | 32.23 (34.56) | 1.437 |
| MRC 7031Bt BG II | 73.07 (59.17) | 37.21 (37.56) | 1.116 |
| MRC 7160Bt BG II | 68.95 (56.22) | 29.78 (33.07) | 0.719 |
| MRC 7347Bt BG II | 28.30 (31.74) | 30.51 (33.30) | 1.024 |
| MRC 7351Bt BG II | 36.84 (37.09) | 41.95 (40.33) | 0.886 |
| MRC 7918Bt BG II | 71.33 (58.26) | 38.38 (38.20) | 0.377 |
| MRC 6029Bt BG I | 72.27 (58.34) | 40.21 (39.32) | 1.362 |
| Mallika Non Bt | 39.46 (38.80) | 52.08 (46.33) | 0.087 |
| Bikaneri Nerma Bt | 39.95 (39.20) | 35.09 (36.27) | 0.638 |
| Mallika Bt | 24.90 (29.83) | 38.33 (38.17) | 0.521 |
| SEm ±<br>C.D. at 5% | 3.29<br>9.80 | 3.49<br>10.38 | |

Figures in parenthesis are Arc sine transformed value

Laboratory experiments were conducted to evaluate the toxicity of different Cry toxins, viz., MVP II (Cry 1Ac), Cry1C, Cry1B, Aug 05 (Bt isolate) against neonates of *Spodoptera litura* by using diet incorporation method at 1 ppm and 5 ppm. Larval mortality was observed up to 4 days. A perusal of the data showed that only Aug 05 (Bt isolate) was effective against neonates of *S. litura* with 97% mortality at 5 ppm whereas in other cry toxin maximum up to 20% mortality was observed.

Bioassay was carried out on neonates of *S. litura* population using leaves of Bollgard hybrid JKCH 1947Bt, JKCH 1947 non Bt, MRC BG II 7017 Bt, and MRC BG II 7017 non Bt. The results showed that there was no significant difference in per cent mortality among JKCH 1947 Bt, JKCH1947 non Bt, and MRC BGII 7017 non Bt leaves,

**Effect of cry toxins against *S. litura***

| Treatment | Dose (ppm) | No. of Insect Treated | Per cent mortality at 96 hrs |
|---|---|---|---|
| MVPII Cry1Ac | 1 | 75 | 8.00 |
| | 5 | 74 | 13.51 |
| BtkAug05 | 1 | 71 | 40.85 |
| | 5 | 75 | 97.33 |
| Cry 1C | 1 | 50 | 12.00 |
| | 5 | 50 | 20.00 |
| Cry1B | 1 | 50 | 4.00 |
| | 5 | 50 | 12.00 |
| Control | | 74 | 0.00 |

**Toxicity of transgenic Bt cotton and non-transgenic Bt cotton leaves on neonates of *S. litura***

| Cotton hybrid | No. of neonates | Per cent mortality at 96 hrs | Per cent pupation | Per cent adult emergence |
|---|---|---|---|---|
| JKCH1947 Bt | 70 | 5.70 | 75.71 | 49.06 |
| JKCH1947 non Bt | 70 | 5.70 | 85.70 | 85.00 |
| MRC BG II 7017 Bt | 70 | 72.85 | 24.28 | 47.06 |
| MRC BG II 7017 non Bt | 70 | 4.28 | 71.42 | 80.00 |

whereas 72.85 per cent mortality was observed in MRC BG II 7017 Bt. However, there was a significant difference in the case of per cent pupation and percent adult emergence between JKCH 1947 Bt and JKCH 1947 non Bt as well as MRC BGII 7017 Bt and MRC BGII 7017 non Bt cotton hybrids.

Bioassay was carried out on neonates of two populations of *S. litura* population using diet incorporation method. Different quantity of seed powder ranging from 30-150 mg/g of diet of BG II (MRC 7031) was mixed thoroughly with diet. $LC_{50}$ values showed that Raipur population was more susceptible than Ahemdabad population and differed significantly.

**Susceptibility of neonates of *Spodoptera litura* to BG II collected from two different locations**

| Place of insect collection | $LC_{50}$ 96 µg/g diet | Fiducial limits at (95%) | Slope± S.E. | *Df* |
|---|---|---|---|---|
| Raipur | 71.06 | 50.66-120.11 | 1.452 ± 1.71 | 3 |
| Ahmedabad | 174.16 | 129.24-380.25 | 2.39 ± 1.98 | 3 |

Improved semi-synthetic (meridic) diet for mass rearing of *Bactrocera cucurbitae* with bottle gourd as base was able to support good growth. The total development period was reduced by 2.27 days with 3.8% increase in average pupal weight. An average of 39.33 flies emerged from 42.23 cc of fresh diet.

In a separate experiment, better egg laying (2.21 times) was observed when the oviposition trays were covered with the membrane. A thin film of bottle gourd juice spread over the membrane further enhanced the egg laying and up to 71 pupae were formed in single plate. The technique is being tested after improving the diet and culture plates for mass rearing of melon fruit fly.

A solution of mixture of ammonium salts with acetic acid was found effective in laboratory for attracting the fruit flies. The strategy can be explored for developing low cost traps. These salt mixtures can be stored for whole year and the farmer can prepare the solution of suggested concentration in water as and when required.

## 4.2.5 Insect Toxicology

Susceptibilty of the third and fourth instar larvae of cabbage butterfly *Pieris brassicae* was evaluated against commercial formulations of eleven different insecticides in the laboratory using two different methods, viz., leaf dip and direct spray method. Based on $LC_{50}$ values, emamectin benzoate was most toxic through leaf feeding method against both the stages followed by chlorantraniliprole whereas through direct spray method chlorantraniliprole showed

**Toxicity of various insecticides against larvae of *Pieris brassicae***

| Insecticide | Leaf feeding method | | | | Spray method | | | |
|---|---|---|---|---|---|---|---|---|
| | 3rd instar | | 4th instar | | 3rd instar | | 4th instar | |
| | $LC_{50}$(%) | Rt | $LC_{50}$(%) | Rt | $LC_{50}$(%) | Rt | $LC_{50}$(%) | Rt |
| α-Cyhalothrin 5EC | 0.0003 | 3.66 | 0.0013 | 2.61 | 0.0008 | 3.0 | 0.0012 | 5.75 |
| β-Cyfluthrin 2.5EC | 0.0001 | 11 | 0.0013 | 2.62 | 0.0002 | 12 | 0.0006 | 11.5 |
| Bifenthrin 10EC | 0.0001 | 11 | 0.0002 | 17.0 | 0.0001 | 24 | 0.0004 | 17.25 |
| Indoxacarb 14.5SC | 0.0002 | 5.5 | 0.0002 | 3.4 | 0.0008 | 3.0 | 0.0008 | 3 |
| Emamectin benzoate 5WSG | 0.00002 | 55 | 0.00007 | 50.74 | 0.0002 | 12 | 0.0004 | 17.25 |
| Spinosad 45SC | 0.0007 | 7 | 0.0006 | 5.6 | 0.0009 | 2.66 | 0.0015 | 4.6 |
| Chlorantraniliprole 18.5SC | 0.00009 | 12.2 | 0.0001 | 34.0 | 0.0001 | 24 | 0.0002 | 34.5 |
| Pyridalyl 10EC | 0.0004 | 2.75 | 0.0022 | 1.54 | 0.0021 | 1.14 | 0.0212 | 0.32 |
| Flubendamide 39.35EC | 0.0001 | 1.1 | 0.0091 | 0.34 | 0.0003 | 8.3 | 0.0003 | 1.09 |
| Novaluron 10EC | 0.0002 | 5.5 | 0.0029 | 1.17 | 0.0008 | 3.0 | 0.0079 | 0.79 |
| Cypermethrin 25EC | 0.0011 | 1 | 0.0034 | 1 | 0.0024 | 1 | 0.0069 | 1 |

**Bioefficacy of different insecticides against Delhi and Bikaner populations of mustard aphid *Lipaphis erysimi* by leaf-dip method**

| Population | Insecticides | $\chi^2$ | $LC_{50}$% | Fiducial limit% | Relative Toxicity | |
|---|---|---|---|---|---|---|
| | | | | | Thiamethoxam | Acetamiprid |
| Bikaner | Carbosulfan | 7.564 | 0.0007 | 0.0006-0.0010 | 3.50 | 2.33 |
| | Bifenthin | 12.63 | 0.0006 | 0.0001-0.0183 | 3.00 | 2.0 |
| | Imidacloprid | 10.436 | 0.0004 | 0.0001-0.0007 | 2.00 | 1.33 |
| | Acetamiprid | 6.2683 | 0.0003 | 0.0001-0.0005 | 1.50 | 1.00 |
| | Thiamethoxam | 12.585 | 0.0002 | 0.0003-0.0014 | 1.00 | 0.66 |
| Delhi | Carbosulfan | 6.8041 | 0.0032 | 0.0024-0.0041 | 3.55 | 4.57 |
| | Bifenthin | 3.3495 | 0.0036 | 0.0028-0.0047 | 4.0 | 5.14 |
| | Imidacloprid | 4.5940 | 0.0015 | 0.0012-0.0017 | 1.66 | 2.14 |
| | Acetamiprid | 6.2683 | 0.0007 | 0.0005-0.0009 | 0.77 | 1.00 |
| | Thiamethoxam | 12.585 | 0.0009 | 0.0005-0.0014 | 1.00 | 1.60 |

**Toxicity and relative resistance of synthetic pyrethroids against neonates of different strains of *Helicoverpa armigera***

| Pyrethroids | Strain | d.f | $\chi^2$ | $LC_{50}$ (ig / vial) | Fiducial limits | Resistance ratio |
|---|---|---|---|---|---|---|
| Deltamethrin | Nagpur | 5 | 6.06847 | 0.28360 | 0.16422-0.48978 | 7622.43 |
| | Delhi | 3 | 0.91724 | 0.87694 | 0.55700-1.38053 | 23569.85 |
| | Susceptible Lab. Strain | 4 | 5.03088 | $3.72060 \times 10^{-5}$ | $3.67180 \times 10^{-5}$-$4.75080 \times 10^{-5}$ | 1.00 |
| α-Cypermethrin | Nagpur | 5 | 1.03086 | 0.23036 | 0.14727-0.36032 | 6446.54 |
| | Delhi | 6 | *30.58146 | 0.06004 | 0.03478-0.10363 | 1680.20 |
| | Lab. Strain | 5 | 8.93867 | $3.57339 \times 10^{-5}$ | $1.90614 \times 10^{-5}$– $6.69894 \times 10^{-5}$ | 1.00 |
| β-Cyfluthrin | Nagpur | 5 | 0.70824 | 0.00539 | 0.00328-0.00850 | 228.93 |
| | Delhi | 6 | 0.14812 | 0.00888 | 0.00464-0.01704 | 377.15 |
| | Lab. Strain | 3 | 3.56452 | $2.35447 \times 10^{-5}$ | $1.64045 \times 10^{-5}$- $3.37923 \times 10^{-5}$ | 1.00 |

*Significant at P=0.05

lower $LC_{50}$ values followed by emamectin benzoate. Compared to cypermethrin, emamectin benzoate was more than x50 toxic and chlorantraniliprole was more than x12 toxic through leaf dip method against both stages while through direct spray method emamectin benzoate was more than x12 toxic and chlorantraniliprole was more than x24 toxic.

Bio-efficacy of five insecticides was studied against Delhi and Bikaner populations of mustard aphid, *Lipaphis erysimi* by leaf dip method. Acetamiprid and thiamethoxam were found to be more toxic than other insecticides. The $LC_{50}$ values for Bikaner population to different insecticides were 0.0007%, 0.0006%, 0.0004%, 0.0003% and 0.0002% for carbosulfan, bifenthin, imidacloprid, acetamiprid and thiamethoxam, respectively. Similarly, the descending order of toxicity for Delhi population was acetamiprid (0.0007 %), thiamethoxam (0.0009 %), imidacloprid (0.0015%), carbosulfan (0.0032 %) and bifenthrin (0.0036%). The relative toxicity values suggest that in both the populations, thiamethoxam and acetamiprid showed more toxicity by leaf dip method. Furthermore, Delhi population of mustard aphid, *Lipaphis erysimi* was more tolerant to all insecticides compared to the Bikaner population.

The susceptibility of neonate stage of two field strains (Nagpur strain and Delhi strain) and a laboratory strain of *Helicoverpa armigera* towards three pyrethroids,

deltamethrin, α-cypermethrin and β-cyfluthrin was studied using glass vial residue test. The neonate larvae displayed resistance to all the three pyrethroids studied. The highest resistance ratio was to deltamethrin (7,622.43 and 23,569.85 folds for Nagpur and Delhi strains, respectively) followed by α-cypermethrin (6,446.54 and 1,680.20 folds for Nagpur and Delhi strains, respectively) while the lowest resistance ratio was to β-cyfluthrin (228.93 and 377.15 folds for Nagpur and Delhi strains, respectively).

## 4.3 NEMATOLOGY

### 4.3.1 Plant Parasitic Nematodes

An analysis of the soil samples collected from the rhizosphere of cereals, vegetables, fruit trees, pulses and oilseed crops from Allahabad (UP), Karnal belt (Haryana), Jaipur (Rajasthan), Ludhiana (Punjab), and Wellington (Tamil Nadu) revealed the presence of the plant parasitic nematodes, namely, *Meloidogyne incognita*, *Rotylenchulus reniformis*, *Pratylenchus thornei*, *Heterodera avenae*, *M. graminicola*, *Helicotylenchus dihystera*, *Hoplolaimus indicus*, *Basiria graminophila*, *H.dihystera*, *Tylenchorhynchus mashhoodi*, *H. indicus*, *Malenchus* sp., *Hemicriconemoides mangiferae*, *Paratylenchus* sp., *Longidorus* and *Psilenchus*, *Aphelenchus avenae*, *Aphlelenchoides* spp. (mycetophagous), *Acrobeles* sp., *Acrobeloides* sp., Rhabditids (bacteriophagous) and Dorylaimids (saprophagous/omnivorous). Among the beneficial soil nematodes, *Aphelenchus avenae*, *Aphlelenchoides* spp. (mycetophagous); *Acrobeles* sp., *Acrobeloides* sp., Rhabditids (bacteriophagous); Dorylaimids (saprophagous/omnivorous) were encountered almost in all the samples. Four isolates of entomopathogenic nematode were also recorded and found effective against *Helicoverpa armigera* and *Spodoptera litura*.

Surveys of farm areas of IARI Regional Station at Wellington, Coonur, Kallar and Tantea revealed the predominance of *Rotylenchulus reniformis, Scutellonema brachyurus, Pratylenchus thornei, P. coffeae,*and *Xiphinema basiri* with the vegetable crops and tea. Cyst nematodes were not recorded in any of these areas, which showed that these areas are free from potato cyst nematode (*Globodera rostochiensis* and *G. pallida*) which is a serious pest of potato in Ootacamund and Kodaikanal hills of the Nilgiris of Tamil Nadu. Because of the strict domestic quarantine regulations, this nematode has not spread to the adjoining areas.

### 4.3.2 Entomopathogenic Nematode

***Yield enhancement of brinjal by the use of Pusa NemaGel.*** Foliar spray of NemaGel formulation of two entomopathogenic nematode species (*Steinernema thermophilum* and *S. glaseri*) @ 10000 infective juveniles/plant at the time of flowering, resulted in significant increase in the number and weight of brinjal (Pusa Uttam) fruits and their weight. The average per cent increase of the fruit weight in the micro-plots treated with *S. thermophilum* was 60.18% and in those treated with *S. glaseri*, it was 57.84% over that of the control. The fruit number increased by 58.8% and 51.47% in the plots treated with *S. thermophilum* and *S. glaseri*, respectively, over that of the control. In the treated plots, the fruits were cent per cent healthy while in control about 18.25% fruits were infested with brinjal fruit borer, aphids, mites, fungus and mealy bugs.


**Bioefficacy of EPN based NemaGel against natural infection of insect pests on brinjal**

***Bioefficacy of EPN against Helicoverpa armigera and Spodoptera litura.*** A laboratory trial was conducted to evaluate the bioefficacy of four native *Steinernema* strains/isolates (*Steinernema thermophilum*, IARI-EPN-*gj*, IARI-EPN-*mg1*and IARI-EPN-*wb5*) against fifth instar larvae of *Helicoverpa armigera* and *Spodoptera litura*. The experiment was conducted by inoculating IJs of each strain

**Bioefficacy of EPN based NemaGel against natural infestation of insect pests on brinjal at IARI farm, New Delhi**

| Treatment | Average no. of fruits/plant | Total weight of fruits/plot | Per cent increase in no. of fruits | Average weight of fruit/micro plot | Per cent healthy fruits |
|---|---|---|---|---|---|
| *S. thermophilum* | 40 | 3.482 kg | 58.8% | 640 g | 100 |
| *S. glaseri* | 30 | 2.280 kg | 51.8% | 567 g | 100 |
| Control | 28 | 1.212 kg | - | 202 g | 81.25 |

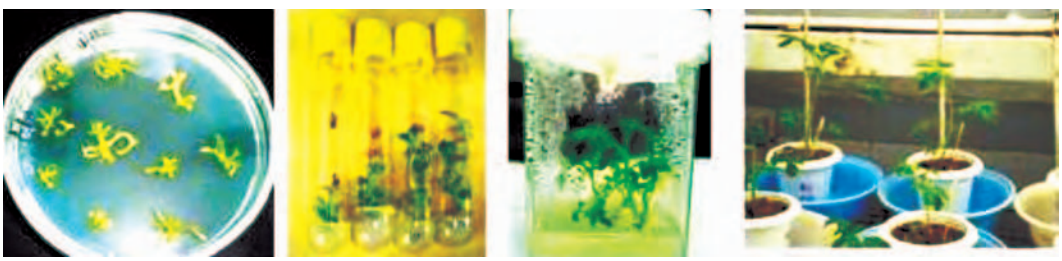
in 24 well culture plates @ 10, 20, 40, 60, 80, and 100 IJs per larva in each well. Observation was taken at 25±2 $^0$C after interval of 24 h, 28 h and 72 h. Among the tested strain/species, *S. thermophilum* was found to be the most effective inducing 100% mortality with 60 IJs per larva within 48 h while for other strains the maximum mortality obtained was 65-85% even at a maximum dose of 100 IJs per larva.

***Field efficacy of EPNs against whitegrubs on ground.*** Bio-efficacy of liquid formulations of two *Steinernema* species (*S. thermophilum* and *S. glaseri*) was evaluated against white grubs (*Holotrichia cosanguina*) infested groundnut at ARS, Durgapura, Jaipur. About 6% and 10% mortalities of the plants were observed in the fields treated with *S. thermophilum* and *S. glaseri*, respectively, as compared to 17.5% in control. The percentage increase in the number of pods in the treated fields of *S. thermophilum* and *S. glaseri* were 50.7% and 57.8%, respectively, as compared to that of the control. Significant reduction in white grubs infestation was also recorded.

## 4.3.3 Molecular Strategy for Nematode Management

Tomato and *Arabidopsis thaliana* were transformed with RNAi constructs for Splicing Factor (SF), Integrase and genes specific to oesophageal gland proteins (AY134442 and AY134444) of *Meloidogyne incognita*.The confirmed transgenic plants ($T_0$ tomato and $T_1$ (*Arabidopsis*) were evaluated for root-knot nematode infection, development and reproduction. In both the crops *Arabidopsis* and tomato, the control plants developed several galls but the transgenic plants expressing the splicing factor and integrase genes in tomato had very few galls, which were significantly smaller in size containing fewer and weak nematode females with lesser eggs in comparison to the control plants. Similarly in *Arabidopsis* plants, expressing AY134444 and AF531170 gene constructs had 3-8 galls on the root system of the transgenics in comparison to control plants where the number of galls ranged from 30 to 75. The results demonstrated that plants expressing ds RNA of essential genes of *M. incognita* are protected against infection by this nematode parasite.

In another study, adzuki bean (*Vigna angularis)* was inoculated with 2nd stage juveniles (J2s) of *Meloidogyne incognita* soaked in double stranded RNA (dsRNA) solution in order to silence five oesophageal gland genes. It resulted in reduced number of galls, and less number of females, egg masses and eggs per eggmass produced per plant in comparison to these in the control where juveniles were soaked in GFP, octamines and water.



**A** **B** **C** **D**

**Tomato transformation with AF 531170 gene. A : cotyledonary leaf explants, B & C: young transformed tomato plants in test tubes, and D: transformed plants at the National Phytotron Facility, IARI**

### 4.3.4 Nematode Management

A field trial undertaken to manage the reniform nematode *Rotylenchulus reniformis* on soybean by applying different methods of nematode management at IARI revealed that a combination of more than one treatment was effective in managing *R. reniformis* population, which resulted in better growth of soybean as compared to the untreated control. The different treatments were: (*Calotropis procera* chopped leaves + twigs (4 kg/6 $m^2$ plots), carbosulfan seed treatment (2%w/w) and triazophos 40 EC (1 l a.i./ha) and their combinations like *C. procera* + carbo sufan ST, *C. procera* + Traizophos, carbosulfan ST + Triazophos, and *C. procera* + carbosulfan ST + Triazophos along with untreated control. The reniform nematode population increased by 10-15% in carbofuran @ 1kg a.i./ha.

In a microplot trial on okra crop against root-knot nematode *Meloidogyne incognita* with eight treatments {Ozoneem Trishul @ 1000 ppm (seed soaking for 2h exposure period), *Aspergillus terreus* (talc formulation + FYM @ 5kg/ha (2 x $10^8$ spores/g) (soil application) and neem cake@ 1 t/ha (soil application)} alone and its combinations, revealed that all the treatments were quite effective in reducing *M. incognita* population in the range of 25%-30% compared to that of the untreated plots. However, minimum nematode population was observed in treatments where all the three components were used together with maximum picking of okra pods.

Significant reduction in the number of galls and better shoot growth of tomato were observed when nano-formulation of carbofuran was applied @ 5 ppm as soil drench, as against the recommended dosages of the commercial formulation (carbofuran 3G) @ 1-1.5 kg a.i./ha. This can be attributed to the reduced fecundity of the nematodes.

Critical lethal radio-frequency (RF) microwaves for egg-masses of root-knot nematode, *M. incognita* were worked out *in vitro*, and *in vivo*. A drastic reduction of hatch was observed when nematode infected dormant and active tuberose bulbs were treated with 2450 MHz electro-magnetic waves for 3 sec. Hatching was completely inhibited at 4 sec of exposure and above.

Sonicated extracts of 14-day old culture of *Synechococcus nidulans* caused significant immobility (91-98%) in infective stages of the nematodes, viz., *Meloidogyne incognita, M. graminicola*, *Heterodera cajani*, *H. avenae* and *Rotylenchulus reniformis* under *in vitro* conditions. The extracts caused 13.33%, 14.08%, 8.62%, 9.24% and 5.40% mortality of J2s of *M. incognita*, *M. graminicola*, *H. cajani*, *H. avenae* and pre-adults of *R. reniformis*, respectively, at 24h, which increased to 42.38%, 44.13%, 23.13%, 28.37% and 26.61%, respectively, at 72h exposure. Significant inhibition [CD (0.05P) = 2.98] in nematode hatching was also observed in sonicated extracts compared to that of the control (medium and water) in all five species of nematodes tested.

## 4.4 AGRICULTURAL CHEMICALS

### 4.4.1 Chemo and Bioprospecting for Agrochemicals through Design, Discovery and Development of Novel Processes and Products

#### 4.4.1.1 Botanical pesticides

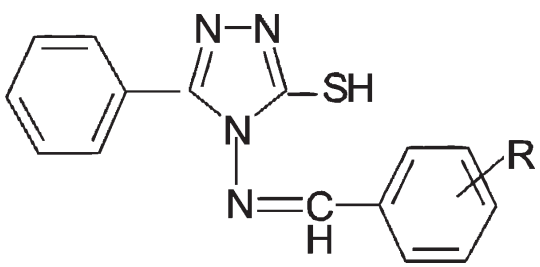
***Extraction and evaluation of plant extractives for their antifungal activity.*** *Rumex nepalensis* Spreng (*jangli palak*) and *Lantana camara* grow wildly and abundantly in many parts of India, and are used by the natives for their astringentcy, and for dyeing purposes. These two plant materials were successively extracted and the extracts concentrated under vacuum and partitioned with ethylacetate and butanol to obtain fractions of different polarity. These fractions were evaluated for antifungal activity against *Sclerotium rolfsii*. Of the various extracts, hexane concentrate of *R. nepalensis* showed more than 50% fungal inhibition at 0.05% concentration, indicating that bioactive constituents reside in hexane extract. *Lantana camara* leaf, fruit and flower hydrodistilates exhibited moderate antifungal activity. Three essential oils from *R. officinalis*, *M. fragrans*, and *Alpinia* spp. also exhibited moderate to significant antifungal activity.

***Antifeedant, IGR and insecticidal activities of acyloxyimino derivatives of fenchone against Spodoptera litura and Tribolium castaneum.*** Naturally occurring essential oil constituent fenchone was structurally

transformed to its various oxime esters and evaluated for antifeedant, IGR and insecticidal activities against *Spodoptera litura*. Fenchone oxime N-O-isovalerate ($AI_{50}$ 0.0016%) was identified as the most active insect antifeedant, followed by three other moderately active esters, namely, N-O-nonanoate ($AI_{50}$ 0.0079%), N-O-octanoate ($AI_{50}$ 0.0131%) and N-O-pivolate ($AI_{50}$ 0.0141%). When screened for insecticidal activity against *T. castaneum*, fenchone oxime N-O-nonanoate ($LC_{50}$ of 0.0199%) was the most active one, followed by N-O-octanoate ($LC_{50}$ 0.0295%), 2-tridecanone oxime N-O-nonanoate ($LC_{50}$ 0.0348%) and 2-undecanone oxime N-O-nonanoate ($LC_{50}$ 0.0418%). However, the most active compound was two times less active than the commercial reference insecticide malathion ($LC_{50}$ 0.0093%).

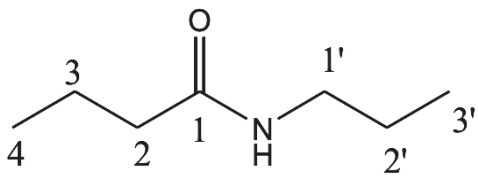
### 4.4.1.2 New synthetic products

***Substituted hydrazones of nalidixic acid hydrazide.*** Thirty-one substituted hydrazones of nalidixic acid hydrazide were synthesized and evaluated for fungicidal, insecticidal, and nitrification inhibitory activities. Maximum antifungal activity was exhibited against *Alternaria porii* with $ED_{50}$ = 34.2-151.3 µg/ml, which is comparable to that of a commercial fungicide, hexaconazole ($ED_{50}$ = 25.4 µg/ml). They were also screened for insecticidal activity against third-instar larvae of *Spodoptera litura* and adults of *Callosobruchus maculatus* and *Tribollium castaneum*. Most of them showed 70-100% mortality against *S. litura* through feeding method at 0.1% dose. These compounds were not found to be effective nitrification inhibitors.




***Glass house evaluation of Schiff bases of 4-amino-3-mercapto-5-phenyl-1,2,4-triazole.*** 4-amino-3-mercapto-5-phenyl-1,2,4-triazoles, viz., R= H, 2-Cl, 4-Cl, 2-$NO_2$, 3- $NO_2$, 4-$NO_2$, 3-$OCH_3$, 4-$OCH_3$, 4-OH and 4-F were evaluated *in vivo* on cowpea against *Meloidogyne incognita*. Among these, 4-benzylidenamino-3-mercapto-5-phenyl-4H-1,2,4-triazole (*in vitro* $LC_{50}$ 19 µg/ml) exhibited the highest activity in glass house test and maximum reduction in number of galls besides high increase in the various plant growth characters of cowpea.

***Biocatalytic amidation of carboxylic acids and their antinemic activity.*** A series of novel N-alkyl substituted amides were prepared by the condensation of equimolar amounts of carboxylic acids with different alkyl amines in the presence of *Candida antarctica* lipase at 60-90 ºC in 16-20 h and evaluated against root-knot nematode, *Meloidogyne incognita*. Among all the tested compounds, N-propyl-butyramide, N-propyl-pentanamide and N-propyl-hexanamide were found to possess significant activity with $LC_{50}$ values of 67.46, 83.49 and 96.53 ppm, respectively. N-propyl-butyramide with $LC_{50}$ value of 67.46 ppm was found to be the most active amide against $J_2$s of *Meloidogyne incognita*.




## 4.4.2 Food Safety, Risk Assessment of Crop Protection Products and Residue Management

### 4.4.2.1 Supervised field trials for pesticide risk assessment

***Persistence and safety evaluation of triazophos and deltamethrin in/on cauliflower and brinjal following application of pre-mix formulation.*** Experiments were conducted in IARI field for safety evaluation of triazophos and deltamethrin in cauliflower and brinjal following the application of their pre-mix formulation, Anaconda (EC: 36%, triazophos 35% and deltamethrin 1%) @ 1 and 2 l/ha on cauliflower (variety PSBK 1) and brinjal (variety Pusa Kranti). The application of pre-mix formulation resulted in initial deposits of 0.105 µg/g and 0.266 µg/g of deltamethrin and 0.854 µg/g and 1.213 µg/g of triazophos in cauliflower curd. The residues in curd persisted for 8 days for deltamethrin and 15 days for triazophos. No residues were detected on 15$^{th}$ day for both the insecticides. Based on the results, waiting period of 3 days is suggested for consumer safety.

***Persistence and safety evaluation of cypermethrin and profenophos (pre-mix formulation) and indoxacarb in/on bitter gourd.*** The persistence of cypermethrin and profenophos following the foliar spray of the combination mix Rocket (EC 44%, cypermethrin 4% and profenophos 40%) and indoxacarb (EC 17.5%) was studied on bitter gourd crop (variety Vishwas). At flowering/fruiting stage, the crop was sprayed with the pre-mix formulation, Rocket @ 1 and 2 l/ha (40 and 80 g a.i. /ha of cypermethrin and 400 and 800 g a.i./ha of profenophos) and indoxacarb @ 70 and 140 g a.i./ha Following the foliar spray of the combination mix Rocket, the initial deposits on bitter gourd fruits were 0.114 µg/g and 0.325 µg/g of cypermethrin and 0.760 µg/g and 1.336 µg/g of profenophos, respectively. The residues in fruits persisted for 8-10 days. On 15$^{th}$ day, no residues were detected in bitter gourd fruits. The residues of profenophos dissipated with a half-life of 2.1-2.6 days and cypermethrin with a half-life of 1.9-2.1 days. Similarly, the initial deposits of indoxacarb were 0.512 µg /g and 0.833 µg /g following its application at 70 and 140 g a.i./ha. The residues in fruits persisted for 7-10 days; however, no residues were detected on 15$^{th}$ day. The residues of indoxacarb in bitter gourd fruits dissipated with a half-life of 1.9-2.6 days. Based on dietary intake calculations, a waiting period of 3 days is recommended.

***Persistence of ready mix formulation of chlorpyrifos and cypermethrin on chickpea.*** Supervised field trials were conducted using Randomized Block Design with three replications to study the residues of ready mix formulation of chlorpyrifos and cypermethrin on chickpea (var. Pusa 256), when used as foliar application. The crop was sprayed with Nacraj 505 EC (5% cypermethrin + 50% chlorpyrifos) at 50% pod formation stage @ 800 and 1600 ml/ha (40 and 80 g a.i./ha for cypermethrin and 400 and 800 g a.i./ha for chlorpyrifos). Samples of chickpea leaves and green pods were collected periodically after the application and analyzed by GLC. Residues of cypermethrin and chlorpyrifos persisted till day 5 and day 7, respectively, in chickpea leaves and green pods and were below the detectable limit in harvested grains (< 0.05 mg/kg cypermethrin, <0.03 mg/kg, chlorpyrifos). Based on the ADI of chlorpyrifos and cypermethrin (0.01 and 0.05 mg/kg/day/body wt, respectively), safe waiting period of 3 days is recommened.

***Persistence of imidacloprid from combination-mix (beta-cyfluthrin + imidacloprid) on tomato.*** Persistence and dissipation studies were conducted through field and laboratory experiments. Tomato crop was grown at the experimental fields of IARI, New Delhi. The insecticide was sprayed @ 20 g a.i. /ha (imidacloprid alone) and @ 40 and 80 g a.i. /ha from combination mix (beta-cyfluthrin + imidacloprid) with fluid rate of 500 l /ha The initial deposit of imidacloprid on tomato ranged from 1.33 mg kg$^{-1}$ to 2.38 mg kg$^{-1}$ from all the treatments. Imidacloprid residues persisted up to 7 days in individual formulation whereas it persisted little higher from combination-mix. The half-life values of imidacloprid residues from tomato were 1.94 to 2.71 days from all the treatments.

***Persistence of pyrazosulfuron in/on rice and field soil.*** A field experiment was conducted in the field of IARI, New Delhi. RBD was followed with four replicates at recommended rates of treatments along with control and weedy check. Pyrazosulfuron, was applied as post-emergent application to rice crop at 20 g a.i./ha. Soil samples were drawn periodically, extracted with $CH_3OH$:$H_2O$ (1:1), partitioned with dichloromethane after acidification and analysed for herbicide residues by HPLC using RP18 column and acetonitrile : 0.1% acidic water (70:30) as mobile phase at 250 nm wave length. Results showed that pyrazosulfuron residues persisted only for 15-20 days in soil. Residues dissipated with a half-life of 5.5 days at recommended rate of application. The residues could not be detected in harvest soil. No detectable amount of pyrazosulfuron was found in rice grains.

### 4.4.2.2 Environmental fate of pesticides

***Leaching behavior of fipronil.*** Leaching of fipronil and its two metabolites (fipronil sulfone and fipronil desulfinyl) was studied separately in packed and intact soil columns under laboratory conditions. In packed column studies, none of the leachate fraction from any treatments showed the presence of fipronil residues. It was observed that as the volume of water added increased, the residue moved to lower depth. However, in all the cases, majority of the fipronil (~90%) remain confined within 0-10 cm depth. Leaching with water equivalent to 400 mm rainfall, the major amount (~75%)

of fipronil shifted to 5-10 cm soil depth. In the case of metabolites fipronil sulfone and fipronil desulfinyl, even with 160 ml of water equivalent to 400 mm rainfall, > 95% of residues remained in the 0-5 cm layer indicating that the metabolites are less mobile as compared to fipronil. A comparison of the mobility behavior of analytical grade fipronil with its two formulations (Regent 5% SC and 0.3G) revealed that formulations slowed down the downward mobility of fipronil in soil column.

***Sorption and degradation of azoxystrobin in soils.*** The persistence of azoxystrobin, a strobilurin fungicide, in rice growing soils from Kolkata (silt loam) and Bangalore (sandy loam) was studied. It was moderately sorbed in both the soils and a comparison of $K_f$ values for azoxystrobin obtained in both soils indicated that it was more sorbed in the silt loam ($K_f$–4.66) soil than in the sandy loam ($K_f$–2.98) soil. Further increase in $K_f$ value of azoxystrobin in 5% compost-amended soils ($K_f$–8.48 and 7.6) indicated that compost provided additional sites for the sorption of azoxystrobin. The $K_{oc}$ values for azoxystrobin in compost-unamended silt loam soil were 2.2 times of the value in the sandy loam soil in spite of the fact that both soils have nearly the same OC content. This suggests that soil OC content is not the only factor responsible for fungicide sorption in soils. Azoxystrobin appeared to be persistent in both the soils and was detected up to 120 days. It was slightly more persistent in the non-flooded soils than in the flooded soils. Biocompost application enhanced azoxystrobin degradation in a sandy loam soil while in silt loam soil, the degradation slowed down. Faster degradation of azoxystrobin in flooded moisture regime suggested that anaerobic microorganisms might be involved in the azoxystrobin degradation.

***Sorption-desorption of metribuzin.*** Sorption-desorption of metribuzin was studied in three soils from IARI, Jhargram and Almora. Freundlich sorption parameters suggested that the order of metribuzin sorption in soils is: Almora > Jhargram > IARI. Among all the soils, Almora soil had maximum OC content (0.63%) while Jhargram and IARI soils had nearly the same OC content. $K_f$ values for metribuzin in IARI, Jhargram and Almora soils were: 0.3, 0.36 and 0.73, respectively. Thus sorption of metribuzin could be correlated to soil OC content. Adsorption isotherms slope value of near unity suggest linear isotherms. Desorption results suggest that 80-85% of sorbed metribuzin from IARI soil was desorbed during desorption, while a considerable portion of the sorbed metribuzin was retained by Jhargram and Almora soils. $K_f$ values for metribuzin desorption in IARI, Jhargram and Almora soils were: 0.16, 0.78 and 0.6, respectively. This suggested that maximum amount of sorbed metribuzin was retained in Jhargram soil. Desorption was correlated to soil pH.

### 4.4.2.3 Decontamination of pesticides

***Screening of plants for remediation of DDT, chlorpyrifos, imidacloprid and bifenthrin from soil.*** Mustard was tried for phyto-remediation of four pesticides, i.e., DDT, chlorpyrifos, imidacloprid and bifenthrin from soil. Mustard was sown in pots filled with treated soil (@ 100 µg/g. After 35-40 days, mustard plants and soil were separately extracted and analysed for the pesticide contents. An analysis of soil and plant samples showed that imidacloprid translocated very fast and nearly 15-18% imidacloprid was removed by mustard plants which was maximum among all the four pesticides studied. Chlorpyrifos and DDT were also removed to some extent (7-8%) but bifenthrin was least absorbed (5.6%) by plants and maximum amount was present in soil. Marigold plants were also studied for phyto-remediation of the above four pesticides in order to replace the edible crop mustard. But imidacloprid and chlorpyrifos showed phyto-toxicity to marigold plants, which could not survive while in DDT and bifenthrin treated soil, marigold plants could survive and removed the pesticides also to some extent (4-5%). Microbes from rhizosphere soil of these plants were isolated for further degradation studies.

***Decontamination of imidacloprid residues from tomato.*** Simple washing with tap water dislodged 37.9-41.2% of imidacloprid residues. The washing had pronounced effect on the removal of 0 day samples as compared to samples collected on 3$^{rd}$ and 7$^{th}$ day after spraying. Washing followed by streaming of 0 day samples of imidacloprid dislodged the residues to the extent of 62.7-66.2%.

### 4.4.3 Innovations in Agricultural Formulations and Application Technology for Safety and Efficacy

#### 4.4.3.1 Development of controlled release formulations

***Azadirachtin-A.*** Controlled release (CR) formulations of azadirachtin-A, a bioactive constituent derived from the seed of *Azadirachta indica* A. Juss (Meliaceae) prepared using commercially available polymers of polyvinyl chloride, polyethylene glycol and laboratory synthesized poly(ethylene glycol) based amphiphilic copolymers and kinetics of release of azadirachtin-A in water from the different formulations was studied. The release from the commercial PEG formulation was faster than the other CR formulations. The rate of release of encapsulated azadirachtin-A from nano-micellar aggregates was reduced by increasing the molecular weight of PEG. The diffusion exponent (n value) of azadirachtin-A in water ranged from 0.47 to 1.18 in the tested formulations. The release was diffusion controlled with a half release time ($t_{1/2}$) of 3.05 to 42.80 days in water from different matrices. The results suggest that depending upon the polymer matrix used, the application rate of azadirachtin-A can be optimized to achieve insect control at the desired level and period.

***Determination of residual monomer in hydrogels.*** A simple HPLC method was developed for simultaneous determination of acrylamide, acrylic acid and/or acrylate present as residual free monomers in water insoluble crosslinked hydrogels. Different extraction techniques comprising conventional, microwave assisted extraction, sonicated extraction of acrylamide were tried, of which one best method – soaking for overnight (recovery = 103.1±2.1%; LOQ 0.2 µg/g) was used for analysis of acrylamide in different gels. Monomer separation was achieved on a C-18 column using isocratic mobile phase consisting of 0.1% *o*-phosphoric acid at a flow rate of 1 ml/min and detected under UV at 210 nm. The analysis of different brands of hydrogel revealed that products based on Pusa hydrogel technology contained non-detectable amounts (<0.2 µg/g) of acrylamide monomer.

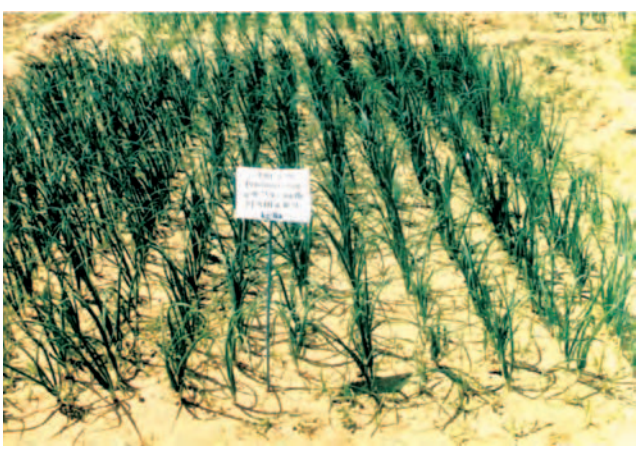
## 4.5 WEED MANAGEMENT

### 4.5.1 Performance of Soybean under Different Tillage Establishment Methods and Weed Management Options

A field experiment was conducted during *kharif* 2008 to study the effect of tillage and crop establishment methods and weed management options on the productivity of soybean and weed dynamics. Maximum seed yield (2.32 t/ha) was recorded in raised-bed planting and conventional tillage. Zero-tillage (flat) planting yielded significantly lower than other systems in terms of seed yield. Application of pendimethalin as pre-emergence (PE) + hand weeding resulted in significantly higher seed yield. Zero-tillage resulted in an energy saving of around 15% in comparison to that of conventional tillage.

### 4.5.2 Weed Management in Transplanted Onion

A field experiment was conducted during *rabi* 2008 to find out a suitable integrated weed management practice for onion. The dominant weed species observed were: *Dactyloctenium aegyptium*, *Elusine indica*, *Cynodon dactylon*, *Cyperus rotundus*, and *Parthenium hysterophorus*. Sequential application of pendimethalin @ 0.75 kg/ha as pre-emergence (PE) followed by pendimethalin @ 0.75 kg/ha as broadcast (sand mix) at 30 days after transplanting (DAT), and fluchloralin @1.0 kg/ha as pre-plant incorporation (PPI) followed by fluchloralin @ 1.0 kg/



**Weed control in onion under sequential application of pendimethalin as pre-emergence followed by pendimethalin @ 0.75 kg/ha as broadcast (sand mix) at 30 DAT**

ha (as broadcast) were on a par with 2 hand weedings. Three hand weedings at 20 DAT, 40 DAT, and 60 DAT resulted in the highest bulb yield (25.53 t/ha owing to the highest weed control efficiency (84.38%) while the lowest bulb yield (2.12 t/ha) was recorded in unweeded plot due to severe weed competition.

### 4.5.3 Bioefficacy and Selectivity of Ready Mix of Mesosulfuron+Iodosulfuron for Weed Control in Wheat

A field experiment was carried out during the year 2008 to study the performance of Atlantis 3.6 WDG (mesosulfuron 3.0 WDG + iodosulfuron 0.6 WDG) for the control of complex weed flora in wheat under various crop establishment techniques. The experimental field was heavily infested with *Phalaris minor, Avena ludoviciana, Chenopodium album, Chenopodium murale, Rumex dentatus, Cirsium arvense, Cannabis sativa* and *Mellilotus indica*. Conventional sowing resulted in the lowest population of weeds which caused significantly higher increase in the grain yield of wheat over weedy check. Conventional sowing had less weeds but weeds grew vigorously in the inter-furrow spaces of the bed planted wheat (Ridge and Furrow).

All weed control treatments significantly reduced the population of weeds, thereby resulting in significant increase in grain yield over that of the unweeded. Repeated weeding recorded the highest grain yield (5.56 t/ha), which was on a par with those of post-emergence application of mesosulfuron + iodosulfuron (24.0 g/ha + 4.8 g/ha) and tank mix application of clodinofop + metsulfuron (60 g/ha + 4 g/ha). The highest WCE was obtained in repeatedly weeded plot (83.40%) followed by 70.04% in tank mix application of clodinofop + metsulfuron.

### 4.5.4 Bioefficacy and Selectivity of Pyrazosulfuron-ethyl for Weed Management in Direct Seeded and Transplanted Rice

A field experiment was conducted during k*harif* 2009 to evaluate the efficacy and selectivity of different new herbicides in aerobic and transplanted rice. The predominant weed flora in the experimental field were: *Echinochloa crusgalli, Echinochloa colona, Leptochloa chinensis, Dinebra retroflexus, Eclipta abla, Ammania baccifera,*

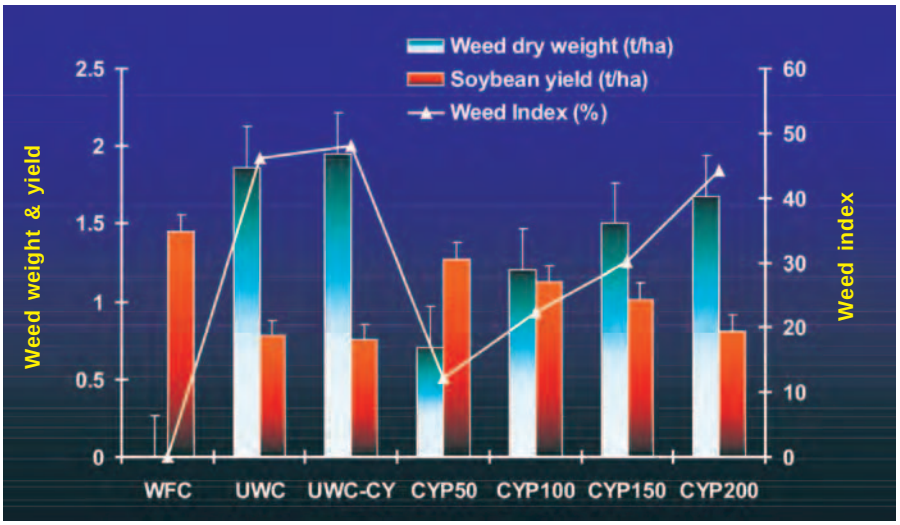
**Effect of crop establishment techniques and weed control treatments on weed density and productivity of rice**

| Treatment | Weed population (No./m$^2$) | Grain yield ( t/ha) | Weed control efficiency (%) |
|---|---|---|---|
| **Planting methods** | | | |
| Direct seeded (dry) | 79 | 3.75 | 42.75 |
| Transplanting | 65 | 3.96 | 52.79 |
| CD (P= 0.05) | 5 | 0.14 | - |
| **Weed control measures** | | | |
| Pyrazosulfuron ethyl (20 g/ha at 10 DAS/DAT) | 84 | 3.85 | 39.00 |
| Pyrazosulfuron ethyl (25 g/ha at 10 DAS/DAT) | 71 | 4.12 | 49.15 |
| Pyrazosulfuron ethyl (20 g/ha at 20 DAS/DAT) | 61 | 4.29 | 56.16 |
| Pyrazosulfuron ethyl (25 g/ha at 20 DAS/DAT) | 49 | 4.49 | 64.25 |
| Butachlor @ 1000 g/ha PE | 84 | 4.00 | 38.89 |
| Repeated hand weeding | 18 | 4.60 | 86.96 |
| Weedy check | 138 | 1.70 | - |
| CD (P= 0.05) | 9 | 0.43 | |

*Marsilea quadrifolia, Cyperus rotundus, Cyperus difformis* and *Cyperus iria.* All weed control treatments significantly reduced the weed density as compared to that of the weedy check. Weed density was comparatively less in transplanted rice as compared to that in direct seeded rice. Repeated weedings (two hand weedings) recorded the highest grain yield (4.60 t/ha) owing to the highest weed control efficiency (86.96%). Among the herbicide treatments, the application of pyrazosulfuron-ethyl @ 20-25 g/ha at 20 days after sowing/transplanting brought the highest increase in the grain yield owing to better weed control that was, however, on a par with that of the pre-emergence application of butachlor @ 1000 g/ha.

### 4.5.5 Economic Threshold Level (ETL) of *Cyperus rotundus* L. (Purple Nutsedge) in Soybean

A field experiment with unweeded control with *Cyperus* (UWC), unweeded control without *Cyperus* (UWC-CY), weed-free check and *Cyperus* densities, viz., 50, 100, 150 and 200 plants per m$^2$ was undertaken.




***Cyperus* dry weight, soybean yield and yield production as affected by *Cyperus*/weed densities**

UWC, UWC-CY and *Cyperus* 200 plants/$m^2$ (CYP200) treatments were comparable with respect to accumulation of weed/*Cyperus* dry weight and reduction of soybean seed yield. These treatments resulted in significantly higher weed dry weight compared to those in other treatments except *Cyperus* 150 plants/$m^2$ (CYP150), and their competition with soybean was of the highest order. The lowest density of *Cyperus*, i.e., 50 plants/$m^2$ also proved to be competitive with soybean causing a reduction in seed yield by 12.1%. It, however, was the least competitive with soybean. The same was corroborated by the weed index value. Using the rectangular hyperbola models, the regression equation for the economic threshold level (T) of *Cyperus rotundus* was worked out to be: [$0.00000236T^2$ - 0.03288 T – 1 = 0], and the economic threshold level (T) was 30 *Cyperus* plants /$m^2$.

## 4.5.6 Herbicide Tank-mix Uses for Efficient Weed Management in Soybean

All the tank-mixes and sequential applications of pendimethalin and imazethapyr brought about a complete control of broad-leaved and grassy weeds. These treatments also resulted in a significant reduction in the dry weight of perennial *Cyperus rotundus*. The tank-mixes of $GA_3$ (400

**Weed dry weight and soybean seed yield as influenced by herbicide tank mixture**

| Treatments | Herbicide dose (kg/ha) | Broad-leaved weed dry weight ($g/m^2$) | *Cyperus* dry weight ($g/m^2$) | Seed yield (t/ha) |
|---|---|---|---|---|
| $GA_3$ (400ppm) + pendimethalin PE followed by imazethapyr at 20 DAS | 1.0+0.1 | 0 | 3.4 | 2.14 |
| $GA_3$ + Tank-mix of pendimethalin & imazethapyr | 0.75+0.1 | 0 | 2.1 | 2.26 |
| $KNO_3$ (6%) + pendimethalin PE followed by imazethapyr | 1.0+0.1 | 0 | 4.0 | 2.32 |
| $KNO_3$ (6%) + Tank-mix of pendimethalin & imazethapyr | 0.75+0.1 | 0 | 1.9 | 2.28 |
| $GA_3$ (400 ppm) + HW at 30 DAS | - | 0 | 5.1 | 2.23 |
| $KNO_3$ (6%) + HW at 30 DAS | - | 0 | 5.6 | 2.24 |
| Unweeded control | - | 187 | 5.5 | 1.06 |
| Weed free check | - | 0 | 0 | 2.32 |
| CD (P = 0.05) | - | - | 0.70 | 0.23 |

ppm) + pendimethalin (0.75 kg/ha) and imazethapyr (0.1 kg/ha) PE, and $KNO_3$ (6%) + tank-mix of pendimethalin (0.75 kg/ha) and imazethapyr (0.1 kg/ha) PE were found superior to their respective sequential applications. The tank-mixes and sequential applications of herbicides were comparable with weed-free check and caused a significant increase in soybean seed yield over that of the unweeded control.

### 4.5.7 Study of Cross-resistance across *Phalaris minor* Retz. Biotypes against Clodinafop-propargyl, Sulfosulfuron and Pinoxaden

*Phalaris minor* biotypes collected from nearly 231 villages of Haryana and Punjab were tested against clodinafop-propargyl (30, 60, and 120 g/ha), sulfosulfuron (16.25, 32.5, and 65 g/ha) and pinoxaden (25, 50 and 100 g/ha) with a control in a (CRD) completely randomized design. The experiment was carried out initially in the growth chamber and then in the green-house of the National Phytotron Facility at IARI.

*Phalaris minor* biotypes showed variable sensitivity to clodinafop-propargyl, which was dose-dependent. Fifteen biotypes showed resistance factors ranging from 5.1 to 41.5 indicating that these biotypes are highly resistant to clodinafop-propargyl with $GR_{50}$ (growth reduction by 50%) values ranging from 90.1 ± 1.95 to 725.6 ± 2.86. Nine biotypes showing resistance factors ranging from 3.94 to 4.85 indicated that these biotypes are resistant to clodinafop-propargyl with $GR_{50}$ values ranging from 69.0 ±1.88 to 84.8 ±1.93, which are greater than those of the recommended dose of 60 g/ha of clodinafop-propargyl. A dozen of *Phalaris minor* biotypes also showed variable resistance to sulfosulfuron and pinoxaden across different doses.

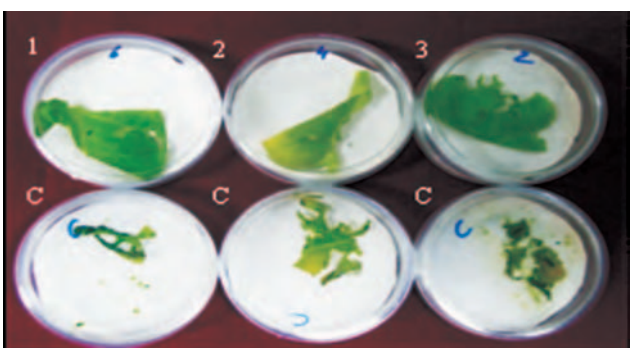
# 5. BASIC AND STRATEGIC RESEARCH (Covers partly NRCPB)

## 5.1 PLANT BIOTECHNOLOGY

### 5.1.1 Transgenic Crops for Biotic Stress Resistance

#### 5.1.1.1 Development of chimeric δ-endotoxin genes for increased efficacy

A chimeric gene *cry1Jb-Jb-Ac* comprising domains I and II of c*ry1Jb* (1.35 kb) and domain III of *cry1Ac* was constructed by PCR amplification of relevant fragments and assembling the same to maintain the correct reading frame for translation of desired protein. The recombinant protein expressed in bacteria was found to be of the expected size (130 kDa) and was successfully activated by trypsin yielding a 65 kDa protease-resistant fragment. The chimeric protein was highly toxic to *Helicoverpa armigera* larvae as assessed by diet overlay assay. Mortality of 70% was observed even at 1 µg/ml. Probit analysis of cry1Jb-Jb-Ac toxicity towards *H. armigera* indicated a high level of toxicity activity at $LC_{50}$ = 767.62 ng/ml. Likewise, another chimeric cry gene *cry1Aa-Ia-Ia* was assembled and mobilized into tobacco. The first instar larvae of *H. armigera* fed on leaf disks cut from transgenic plants suffered heavy mortality (60-65%) indicating the efficacy of the recombinant protein.




**Leaf disc bioassay of *cry1Aa-Ia-Ia* tobacco against *H. armigera*. C: control, and 1, 2, 3: transgenic**

#### 5.1.1.2 Targeting cry protein to endoplasmic reticulum for high level expression

Targeting protein to endoplasmic reticulum can avoid undesirable pleiotropic effects. Therefore, an N-terminal signal peptide essential for targeting and accumulation of proteins to the ER was isolated from *Glycine max* and linked in frame with *cry1Ac* coding sequence to achieve translational fusion. The resulting chimeric *SP-cry1Ac* gene driven by constitutive 35S CaMV promoter and OCS terminator was used to transform tobacco plants through *Agrobacterium* approach. All *SP-Cry1Ac* transgenic plants showed normal development. These *SP-Cry1Ac* transgenic tobacco plants will be subjected to further molecular analysis and insect bioassays against *Helicoverpa armigera.*

#### 5.1.1.3 Gene targeting in rice

Zinc finger nuclease technique was employed for gene targeting in rice. Rice gene coding for *UDP-glucosyltransferase (UGT)*, a key enzyme in anthocyanin synthesis pathway, was selected for targeted gene integration. Transgenic rice plants developed by the integration of *cry1Aabc* and *hptII* expression cassettes in UGT gene will have no functional UDP-glucosyltransferase (UGT) enzyme. Transgenic rice plants with targeted gene integration will be devoid of anthocyanin pigment in rice leaves. It wil make the screening of random gene integration events from gene targeting events easy. For GT, a high frequency regeneration and transformation protocol was standardized in indica rice variety Crossa.

#### 5.1.1.4 Genetic engineering of mustard for aphid tolerance

As previously shown, mustard transgenics producing an alarm pheromone (E)-β farnesene can repel aphids. As β-

farnesene production is dependent on the availability of the precursor farnesyl diphosphate, the *farnesyl diphosphate synthase* (*FPS2*) gene was cloned and mobilized into mustard. Gene pyramiding approach will be used to combine the two genes for high level production of β farnesene. In another strategy to increase β-farenesene levels, β-farnesene synthase and *FPS2* genes were linked with NtrbcS transit peptide to target the proteins to the plastids. Transgenic *A. thaliana* plants carrying these genes were generated to validate the concept before mobilizing the gene into mustard.

In another approach to confer aphid tolerance, RNAi technology was explored. Based on artificial feeding experiments on aphids with synthetic dsRNA oligos, two aphid genes, *COX* and *CuPr* were chosen for RNAi silencing. Hairpin RNAi constructs for these two key genes were designed and plant transformation vectors constructed.

#### 5.1.1.5 Insect tolerance through lectin gene over-expression

Lectin genes from pea and lentil were isolated and cloned in plant transformation vectors. Transgenic tobacco plants carrying pea *lectin* gene were generated through *Agrobacterium*-mediated transformation. Insect bioassay with second instar larvae of tobacco cutworm (*Spodoptera litura*) indicated high mortality of larvae fed transgenic tobacco leaves.

**Transgenic tobacco leaves expressing pea lectin gene show tolerance to tobacco cutworm (lower panel) whereas control leaves (upper panel) were devoured by the larvae**

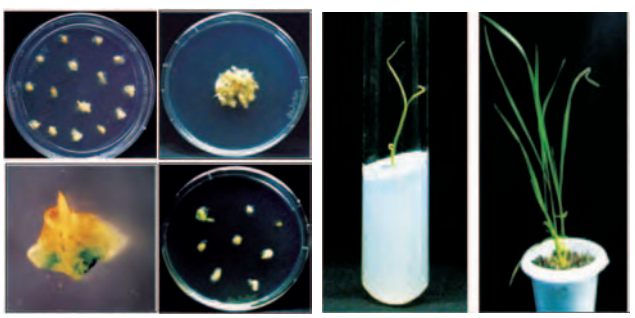
#### 5.1.1.6 Engineering pathogen resistance

A gene coding for metallothionein protein known to adversely affect the growth of fungi was cloned and mobilized into plant transformation vector. Similarly, a full length c-DNA of *XAP-5* gene involved in basal defense in plants was cloned from *B. juncea*. These genes will be used to transform mustard to test their efficacy to confer tolerance to fungal diseases such as *Alternaria* blight and white rust. Transgenic mustard plants carrying another pathogen defense gene *NPR1* were generated and their transgenic status was verified.

### 5.1.2 Development of Transgenic Wheat with Improved Productivity under Abiotic Stress Conditions

#### 5.1.2.1 Development of wheat transgenics for abiotic stress tolerance

Wheat varieties, HD 2894 and HD 2329 were transformed through biolistic approach with gene constructs $P_{AtLEA}$*::TatAPX::NOS* and $P_{AtRD29A}$*::TatAPX::NOS* for improved abiotic stress tolerance. Two transgenics were selected on basta and the regenerated plants were grown in controlled conditions.



**Different stages of wheat regeneration**

#### 5.1.2.2 Cloning of genes and promoters for abiotic stress tolerance

Promoter sequences of rice genes, *Os12LIP*, and *OsWRKY* were amplified from rice varieties Nagina 22 and Pokkali, and cloned in plant transformation vector next to reporter gene *GUS*. Likewise, farnesyl transferase beta subunit, C repeat-binding factor 2 and TabZIP were PCR

amplified and cloned in binary vector. Annexin-like proteins are known to play a role in abiotic stress tolerance in many plants. Expression patterns of six annexin genes were examined in stress tolerant rice variety Nagina 22 through RT-PCR. Two full length c-DNA clones of the annexin genes, *AnnOsI1* and *AnnOsI4* were isolated from Nagina 22. Their capability to confer stress tolerance in other varieties will be tested through transgenic approach.

## 5.1.3 Genomics and Molecular Markers in Crop Plants

### 5.1.3.1 Sequencing of the long (q) arm of tomato chromosome 5

A total of 33 BAC clones forming seven sequence contigs were identified in the minimum tiling path (MTP) of the long (q) arm of tomato chromosome 5. Physical location of 11-seed BACs and 22 extension BACs was confirmed by IL mapping, PCR marker validation and FISH mapping. Shot gun sub-clone and transposon insertion libraries were constructed for the sequencing of identified BACs. Submission of 12 BACs in phase III and 10 BACs in phase II at NCBI GenBank was completed. The sequence data of 30 BACs (3.212 Mbp) in the MTP of chromosome 5 was processed to high quality of international standards. Functional annotation of 2342 predicted genes from 170 tomato BACs was done for ITAG. Using RILs derived from the cross between Pusa 1266 and Pusa Basmati 1 and 166 SSR markers, a QTL *qGN4-1* was identified on chromosome 4. This QTL was co-localized with major QTLs for primary and secondary branches per panicle, and number of panicles per plant. Microarray transcriptome profiling revealed eight genes in the *qGN4-1* region differentially expressed between the two parents during early panicle development.

### 5.1.3.2 Development of EST-SSR in pigeonpea (*Cajanus cajan*) by the use of deep transcriptome sequencing

In all, 43,324 EST unigene contigs were assembled from 1.696 million 454 GS-FLX sequence reads of pooled cDNA libraries prepared from leaf, root, stem and immature seed mRNA of popular pigeonpea varieties, Asha and UPAS 120, and 2412 SSR loci were identified. Primers were synthesized and tested for 407 type I SSR loci ($n \geq 20$ bp), and 275 of these were successfully validated for consistent amplification in 8 diverse pigeonpea varieties. Fifty-six (56) loci were polymorphic. Genetic diversity analysis was done on 22 pigeonpea cultivars and eight wild species by using 20 most polymorphic EST-SSR markers. The number of alleles at these loci ranged from 4 to 10 and the polymorphism information content (PIC) value ranged from 0.46 to 0.72. Neighbor joining dendrogram based on similarity index clearly separated different groups of pigeonpea cultivars and wild species. This is the first comprehensive set of genic SSR markers generated as an important genomic resource for genetic mapping and diversity analysis in pigeonpea.

### 5.1.3.3 Sequencing of chickpea rhizobium *Mesorhizobium ciceri* strain Ca 181

One thousand four hundred (1400) Mbp sequence data (60-fold coverage) were obtained from Solexa sequencing, and 467 Mbp sequence data (20.02 fold coverage) were obtained from 454 GS FLX Titatnium sequencing. Furthermore, a phosmid library of *M.ciceri* Ca181 was prepared in pCC2FOS vector with 25-40 kbp inserts and 1400 clones. For functional screening of the genes in this strain, 500 Tn5 mutants were isolated. *De novo* assembly was done with the 454 sequence data by the use of Newbler assembler. After the assembly, 86 large contigs were formed. Genome was BLASTN searched against *Mesorhizobium loti* and it showed only 35% coverage of the reference genome; the remaining 65% of the genome is unique.

### 5.1.3.4 Identification of genes/QTLs for drought tolerance

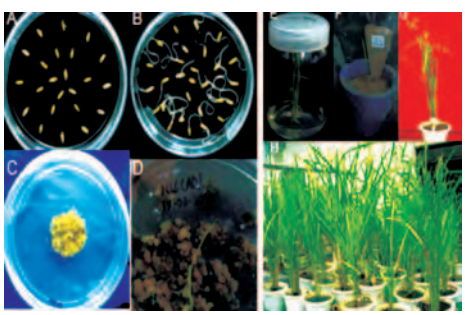
Mapping populations of 209 RILs from the crosses between wheat varieties WL 711 and C 306 were used in this study. All the RILs and the two parents were grown in plastic pipes of 6 inch diameter and 1 meter length. In each pipe, only one plant was grown in control or water stress condition in three replications. Water stress was applied at the booting stage of plants. The agronomic traits were evaluated based on root length, root biomass, shoot biomass and yield/plant. From a set of 586 SSR markers tested, 142 SSRs, 7 ESTs, 2 SNPs and 18 CAPs polymorphic between the parents were obtained. These markers were used to genotype the RIL population.

### 5.1.3.5 Identification of QTLs for sheath blight resistance in rice

Rice variety Tetep was found to be resistant to sheath blight. One hundred twenty-seven RILs were developed from the cross Tetep (resistant) x HP 2216 (susceptible). Combining phenotypic data of multi-location, and multi-year testing RILs with the SSR genotype data (138 SSR markers), a total of 15 markers (two each on chromosome 1 and 7, three on chromosome 9 and seven on chromosome 11) were found to be linked to the sheath blight QTLs. The QTL qSBR11-1 for sheath blight resistance was identified between the marker interval RM1233 (26.45 Mb) and sbq33 (28.35 Mb) on chromosome 11. This region was further narrowed down to marker interval K39516 to sbq33 (~ 0.85 Mb) and a total of 154 genes were predicted including 11 tandem repeats of *chitinase* genes, which may be responsible for sheath blight resistance in the rice line Tetep.

### 5.1.3.6 Cloning of blast resistance gene *Pi-rh* from *Oryza rhizomatis*

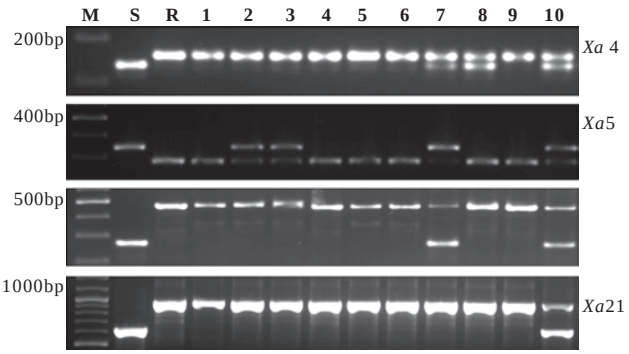
The orthologue of the previously identified blast resistance gene *Pi-k*$^h$ (named *Pi-rh*) (from cv. Tetep) was isolated from the blast resistant wild species of rice, *Oryza rhizomatis* by using allele mining approach. Sequence comparison of *Pi-rh* with *Pi-k*$^h$ revealed 93.45% identity at nucleotide level. *Pi-rh* was expressed constitutively at basal level in the leaves of *O. rhizomatis*, but was upregulated 3.8 fold at 96 h after pathogen attack. Transient expression experiments indicated that the *Pi-rh* protein was extracellular. Gene construct was made in transformation vector and used for transformation of susceptible rice line. Functional validation of cloned *Pi-rh* gene by the use of complementation test showed a high degree of resistance to *M. oryzae* in transgenic plants.



**Development of transgenic rice lines carrying *Pi-rh* gene from *Oryza rhizomatis***

### 5.1.3.7 Marker assisted selection for multiple BLB resistance genes in *basmati* rice

Screening of 1250 RILs from the cross Basmati 370 × IRBB 60 against bacterial blight revealed 34 resistant lines. Marker assisted selection for four XA genes, namely, *Xa4*, *xa5*, *xa13* and *Xa21*, revealed the presence of four genes in 10 recombinants and 3 genes in 14 recombinants. Two recombinants having all the four genes were also found to have aroma. The useful recombinants are being used for a detailed analysis of genetic background as well as grain and cooking quality.




**Ten recombinants (lanes 1-10) having all the four genes for BLB resistance either in homozygous or heterozygous condition. M: 100bp DNA ladder plus, S: B-370, R: IRRB-60**

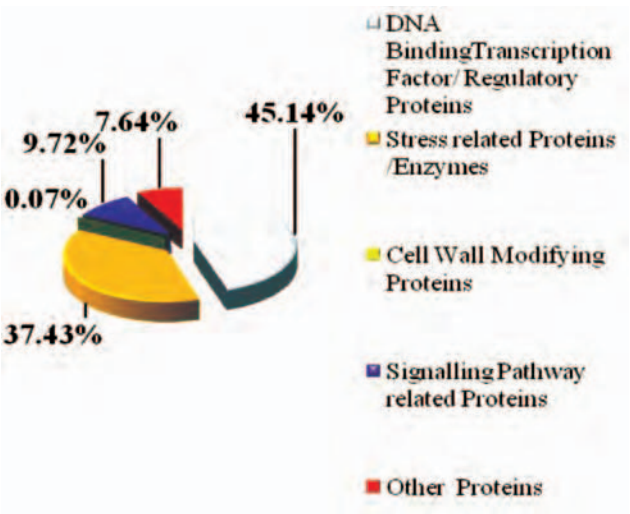
### 5.1.3.8 Generation, characterization and use of EMS induced mutants of upland variety Nagina 22 for yield components and drought tolerance

A total of 3392 Nagina 22 mutagenized lines ($M_2$, $M_3$ and $M_5$ generation), including 347 selected mutants were grown under direct-seeded conditions. Eighty-five out of 1,770 $M_2$ lines segregated for 25 different traits. Out of 463 $M_5$ lines evaluated for drought tolerance under controlled pot culture conditions, 22 were identified as tolerant that recovered upon irrigation after 27 days' stress. Crosses were made between mutants and control for genetic dissection of induced mutations. DNA profiling of 329 selected mutant lines by the use of a set of 24 rice microsatellite markers distributed over 12 rice chromosomes identified 212 (65%) lines identical to Nagina 22, while the rest including 24, which are morphologically identical to Nagina 22 had changes at one or a few of the marker loci tested. A database on "Indian

Initiative on Generation of Rice Mutants" containing the available information on Nagina 22 mutants was created.

### 5.1.3.9 Identification of differentially expressing genes under drought stress in *Sinapis alba* by suppression subtractive hybridization

Suppression subtractive hybridization (SSH) approach was employed to identify differentially expressed genes of *S. alba* under heat/drought stress. A total of 750 recombinant clones containing the differentially regulated transcripts were obtained and sequenced. Homology search through BLAST analysis revealed 144 candidate genes, which were homologous to transcription factors and genes belonging to other metabolic pathways.




**Functional classification of differentially expressing ESTs from SSH library of *S. alba* under moisture stress**

## 5.1.4 Biotechnological Approaches for Increasing Mustard Yield

### 5.1.4.1 Assessment of male sterility inducing cytoplasm on seed yield

CMS lines were reconstituted in three genetic back grounds (DN-1, Pusa Bold and RLM-198) by successive backcrossing (BC5) with CMS sources from *M. arvensis, Diplotaxis catholica, D. erucoides, Erucastrum canariense* and *Trachystoma ballii*. The respective fertility restorer lines of these CMS were also reconstituted following a backcross programme. The CMS lines (15), fertility restorer lines (15) and the three parents were evaluated for seed yield and oil content. CMS lines having *D. catholica* or *T. ballii* cytoplasm showed drastically reduced seed yield as compared to their respective B lines (control). Differences between A-lines of *M. arvensis, D. erucoides* and *E. canariense* and their respective B-lines were, however, non-significant. Performance of fertility restorer (R) lines of the five CMS system revealed no significant difference in seed yield between control and R lines with CMS sources *M. arvensis, D. erucoides* and *E. canariense*. The R lines of *T. balli* and *D. catholica* showed higher seed yield compared to that of the respective A lines but their yield levels were still lower than those of the control lines. Thus, the fertility restorer gene did not help in complete normalization of nuclear-cytoplasmic interaction in CMS lines carrying *T. ballii* and *D. catholica* cytoplasm. The CMS systems *M. arvensis, D. erucoides* and *E. canariense* are suitable for hybrid development.

### 5.1.4.2 Development of CMS lines of cauliflower

Attempts were made to transfer male sterility from (*M. arvensis*) *B. juncea* and (*E. canariense*) *B. napus* to *B. oleracea* var. *botrytis* (cauliflower) by sexual hybridization and back crossing with the objective to develop CMS-based hybrids in cauliflower. The interspecific hybrids were successfully recovered by embryo rescue technique. $BC_2$ generation plants from the crosses were obtained successfully. Some of them have characteristic *oleracea* phenotype.

**CMS *B. oleracea* carrying *E. canariense* cytoplasm**

## 5.1.5 Characterization of Citrus Germpalsm by the Use of DNA Markers

Twenty-five simple sequence repeat markers were used to characterize 30 citrus genotypes from both exotic and indigenous sources. A total of 87 alleles were detected and the banding pattern resolved by each primer pair was in accordance with single locus variation. Out of 25 primer pairs, 20 were polymorphic and produced alleles ranging between 2 and 6 with an average value of 3.95. Cluster analysis separated the genotypes into two groups. From the major group, seedling origin pummelo selection (G1 to G5) formed a separate group from clonal selections of pummelo (G6 to G10). This suggested the hybrid origin of seedling selections of pummelo. Among clonal selections, G9 and G10 had similarity of more than 85% and were grouped in the same cluster. The mandarin selection (G18, G19 and G20) formed a separate group. The dwarf cluster bearing probable hybrid showed affinity with sweet lime and formed a group. This suggested that this dwarf cluster bearing hybrid originated from out crossing of sweet lime.

## 5.1.6 *In vitro* Regeneration in Mango by the Use of Nucellus Tissue

Eight genotypes belonging to two groups, namely, mono-embryonic – Amrapali, Mallika, Dashehari, Chausa, Pusa Arunima and Pusa Surya, and poly-embryonic – Kurukkan and Olour were tested for their ability to regenerate *in vitro*. Nucelli excised from immature 40 to 45-day-old fruitlets were collected for culture. The callusing medium comprised B5 Major + MS (full strength micro + organics) + 200 mg $l^{-1}$ glutamine + 100 mg $l^{-1}$ casein hydrolysate + 100 mgl $^{-1}$ activated charcoal + 60 g $l^{-1}$ sucrose and supplemented with 2 mg $l^{-1}$ 2,4-D. Callus induction was achieved after four weeks. Among poly-embryonic genotypes, Kurukkan gave the highest callusing frequency (85.8%) followed by Olour (83.7%). Amongst mono-embryonic genotypes, the callusing frequency of Amrapali was maximum (82.3%) followed by Pusa Surya (75.3%). Similar trends were noted for somatic embryo induction. Somatic embryogenesis was maximum in Kurukkan (82.5%) followed by Olour (80.7%) compared to mono-embryonic genotypes.

***In vitro* callusing and somatic embryogenesis in mango genotypes**

| Genotype | Callusing (%) | Somatic embryogenesis (%) |
|---|---|---|
| Amrapali | 82.3 | 76.5 |
| Dashehari | 74.9 | 70.5 |
| Pusa Arunima | 72.5 | 69.4 |
| Mallika | 76.5 | 74.2 |
| Pusa Surya | 75.3 | 73.0 |
| Chausa | 56.7 | 51.9 |
| Kurukkan | 85.8 | 82.5 |
| Olour | 83.7 | 80.7 |

## 5.1.7 *In vitro* Regeneration in Grapes

*In vitro* shoot multiplication was achieved in fourteen released and identified grape genotypes including four rootstocks. Two-node repetitive micro-cutting technique was employed. Murashige and Skoog (MS) medium supplemented with 2.0-4.0 mg $l^{-1}$ IBA + 200 mg $l^{-1}$ activated charcoal served as rooting-cum-shoot elongation medium. The data suggested that the ten scion genotypes varied considerably. The shoot multiplication rate was the highest in Pusa Urvashi (9-11 micro-cuttings/subculture) followed by that in Pusa Seedless (9-10 micro-cuttings/subculture). Amongst rootstocks, the highest multiplication rate was noted for H-144 (6-8 micro-cuttings/subcultures) followed by that for 3309 C (3-4 micro-cuttings/subculture). The rootstocks were slightly inferior in their response to scion varieties.

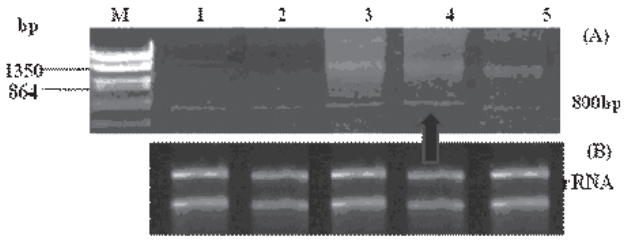
## 5.1.8 Grape Improvement through *In-ovulo* Embryo Rescue

Hand emasculation and pollination were carried out in different cross combinations having seedless x seedless and early maturing seeded x seedless genotypes. Immature ovules excised from developing berries were cultured for 21-23 days. Of the 1,280 ovules cultured, 41 ovules germinated. Twelve plantlets were transplanted for further evaluation.

## 5.2 BIOCHEMISTRY

### 5.2.1 Isolation of *Gm phytase/MIPS* Gene for Engineering its Expression in Soybean Seeds

Soybean contains 60-80% of total seed phosphorous in the form of phytate (*myo*-inositol-1,2, 3,4,5,6-hexakis dihydrogen phosphoric acid) and phytic acid is digested by phytase (*meso*-inositol hexaphosphate phosphohydrolases) during germination releasing the inorganic phosphorus to be utilized by the seedlings. Nearly all the phosphorous translocated to the developing seeds was incorporated into phytic acid, from the third week after flowering until physiological maturity. The rate of accumulation was higher during the initial stages of seed development but decreased with the increase in seed size ultimately constituting 2.7% of the dry weight at full physiological maturity.

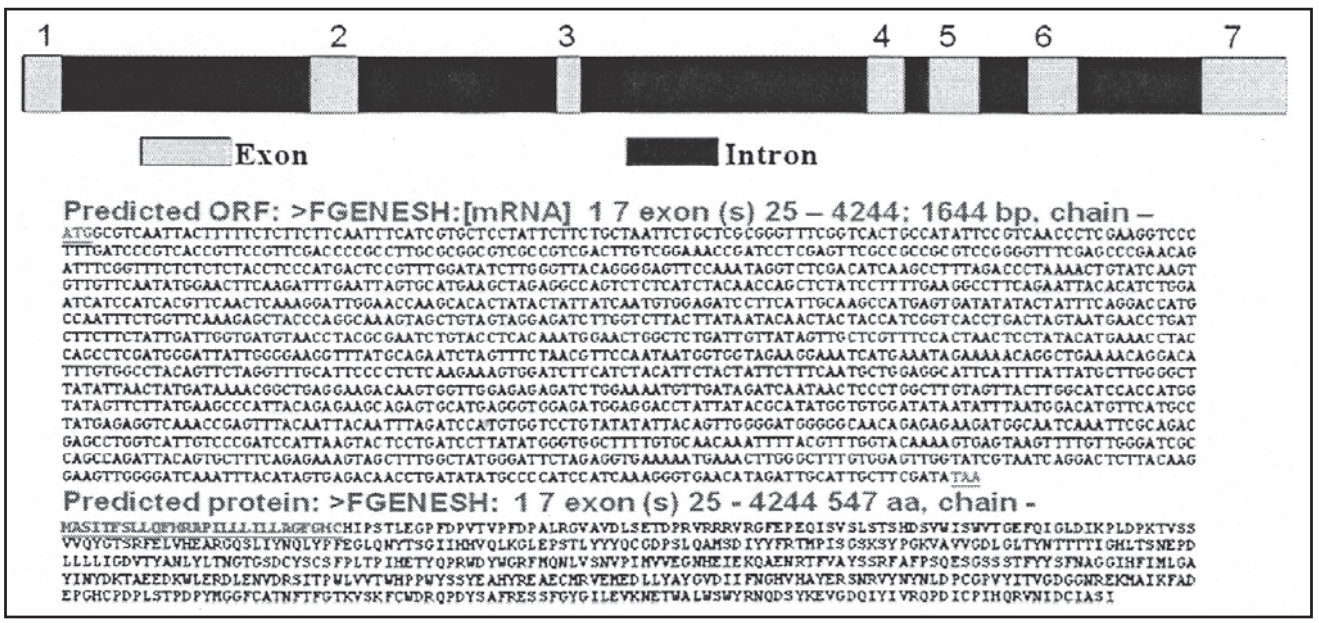



**A: RT-PCR with total RNA from cotyledons of germinating seeds at 5 (lane-1), 7 (lane 2), 9 (lane 3), 11 (lane 4) and 13 (lane 5) days after germination with 800 bp phytase cDNA specific primer pair; EcoRI-HindIII digested lambdo DNA as a MWM (lane M)**

***Phytase* expression in cotyledons of germinating soybean seeds by RT-PCR**

### 5.2.2 Expression studies of *Oleate Desaturase (fad2)* Gene in *Brassica juncea*

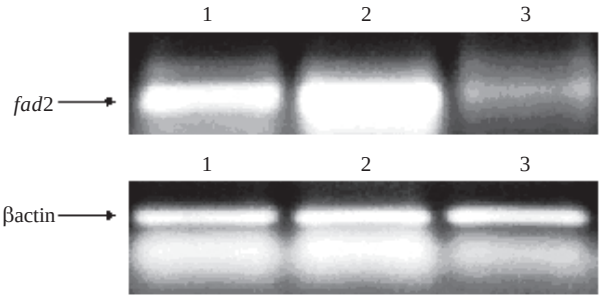
Expression of *fad2* gene from the developing seeds of *Brassica juncea* revealed that the gene was induced at early




**Structure of phytase gene *(SPhy)* from soybean**

A full length genomic sequence encoding *phytase* was isolated, cloned and characterized, and its computational analysis predicted a 547aa long protein of metallophos family. RT-PCR analysis confirmed high transcript levels of phytase gene around 11 days after germination corresponding well with the high phytase activity observed at this stage. A single copy of phytase gene was detected during southern analysis of the genomic DNA.

stages of seed development (15 DAF), peaked in mid maturation stage (30 DAF) and declined as seeds matured (45 DAF). The effect of temperature on *fad2* gene expression through Real-Time PCR showed that the expression of *fad2* gene increased one-fold under low temperature (10 °C) but decreased three-fold at high temperature (32 °C) as compared to that under normal temperature (21 °C). Fatty acid analysis of seed oil in temperature treatments showed




**Developmental expression of *fad2* gene from developing seeds of *Brassica juncea*. Lane: 1 - 15 days after flowering (DAF), lane: 2 - 30 DAF, and lane: 3 - 45 DAF**

that there were significant differences in linoleic and linolenic acid contents between the treatments with the incubation time.

### 5.2.3 Differential Expression of *fad2* Gene in High and Low Erucic Acid lines of *Brassica juncea*

Study of differential expression of *fad2* gene in different lines of *Brassica* having high erucic acid (Pusa Bold) and low erucic acid (LES 1-39 and LES 1- 27) through Real-Time PCR showed that expression of *fad 2* gene was two-fold higher in LES 1-39 and 4-fold higher in LES 1-27 as compared to that in Pusa Bold. Oleic acid pools in high erucic acid line like Pusa Bold were found to be significantly lower (15.9 %) as compared to 38.47 % and 36.75 % in low erucic acid lines LES 1-39 and LES 1-27, respectively. Low erucic acid lines had much lower erucic acid (< 1%) as compared to Pusa Bold (25.48%). Two clones encoding oleate desaturase (*fad 2*) isoforms were sequenced, characterized and deposited in the GenBank with Accession Nos. FJ 696651 and FJ 696652.

### 5.2.4 Studies on Removal of Off-flavour from Soybean by Biochemical and Molecular Tools

Thirty-five EMS-treated soybean mutants were analyzed for fatty acids and lipoxygenase activity. Palmitic, stearic, oleic, linoleic and linolenic acids were the major fatty acids. Linoleic acid was maximum (45% to 58%). Linolenic acid content varied from 4.18% to 7.55%. The off-flavour development was correlated with the content of these polyunsaturated fatty acids as well as lipoxygenase activity, which, however, did not show much variation among the mutants. The total antioxidant capacity of 14 selected soybean mutants was also determined through CUPRAC method and it ranged from 4.55 to 13.88 µmol trolox equivalents/g seeds.

### 5.2.5 Molecular Cloning and Characterization of Small Heat Shock Protein (HSP) Gene from Wheat

An amplicon of ~1 kb was amplified from cDNA of thermo-tolerant wheat cultivar (PBW 175) and was cloned in pGEMT Easy vector. BLASTN homology search showed maximum homology of 98% with HSP26 reported from *Triticum aestivum* L. The amplified gene was grouped under small HSP (sHSPs). The sequence has 5′ UTR region of 23 aa and 3′ UTR region of 69 aa with an open reading frame of 242 aa. This is a complete gene having start codon at 74 bp position and stop codon at 802 bp position. The amplified sequence was characterized for its conserved domain sequence,which showed that it has alpha crystalline domain, which is a signature domain for all sHSPs reported till date. The ACD domain was localized between 160 aa and 240 aa. The sub-cellular localization of the sequence revealed it to be a chlroplastic localized protein coded by nuclear gene. No transmembrane helices were observed in the sequence and it has restriction sites of some of the common restriction enzymes like *Sal*I, *Sac*I, etc.

## 5.3 PLANT PHYSIOLOGY

### 5.3.1 Mechanism of Nitrogen and Carbon Metabolism in two Wheat Genotypes

*Triticale* genotype DT 144 (V1) and wheat (*Triticum aestivum* L genotype PBW 343 (V2) were grown in ambient (370 ± 50 ppm) and elevated $CO_2$ (550 ± 50 ppm) in FACE. Plants of both the genotypes grown in enriched $CO_2$ had higher biomass and chlorophyll content as compared to the ambient grown plants. Decline in the chlorophyll content and lowering of photosynthetic rate correlated with increased protein oxidation. The higher harvest index and yield were due to increase in the number of structures rather than their mean size in the enriched plants. Elevated $CO_2$ increased the content of non structural carbohydrates in flag leaves of wheat. The content of the reducing sugars was much lower than the non-reducing sugars in the flag

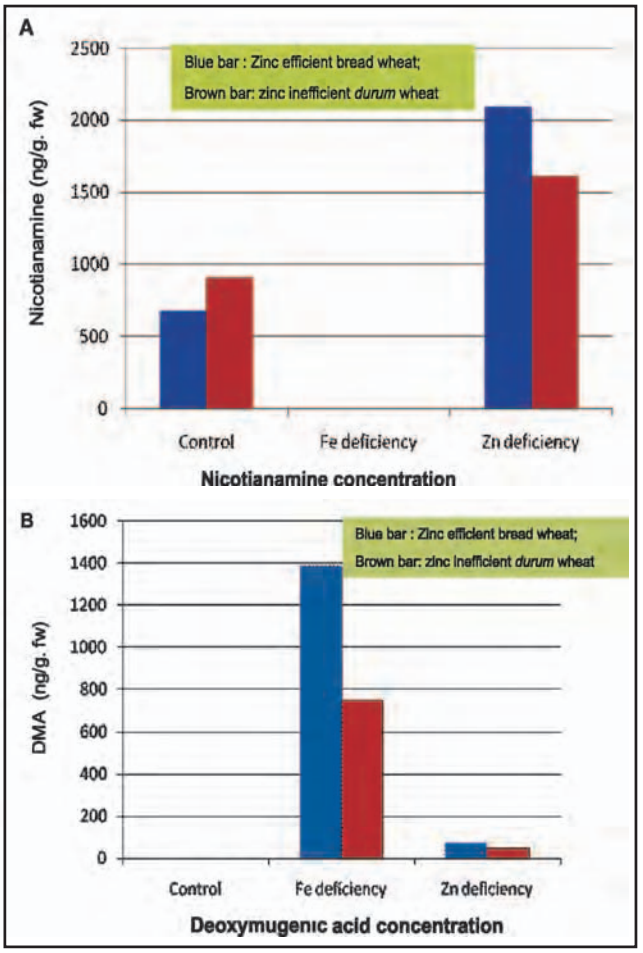
leaves of $CO_2$ enriched plants indicating better mobilization of sucrose from the leaves to the sink tissue. The grains had significantly higher starch content in the $CO_2$ enriched plants. The activity and expression of nitrate reductase (NR) and glutamine synthetase (GS) was up-regulated during the grain filling period in the $CO_2$ enriched plants. The N and total leaf proteins declined in the flag leaves of the $CO_2$ enriched plants on per unit weight basis. The concentrations and distribution patterns of reduced N in plant organs changed in response to rising atmospheric $CO_2$. The critical N concentrations of the total N in the $CO_2$ enriched plants were lower. Grain nitrogen as well as protein declined in the plants under elevated $CO_2$ leading to increased C: N ratio in the grains of $CO_2$ enriched plants. In triticale, N mobilization towards the grains was lower.

### 5.3.2 Physiological and Molecular Bases of Zinc Efficiency in Wheat

An experiment conducted with zinc (Zn) efficient and inefficient wheat lines indicated that root diameter, over other root characteristics, was related to Zn efficiency. Zinc efficient wheat released more phytosiderophore (PS). Nicotianamine levels were correlated to the difference in PS under Fe and Zn deficiency. Phytosiderophore release was induced by Zn only and not by other heavy metals like Ni and Cd.

### 5.3.3 Effect of Salinity on Uptake of Sodium, Potassium and Calcium and Genes of SOS Pathway in *Brassica*

An experiment was conducted with *Brassica juncea* cultivars, CS 52, CS 54, Varuna, Pusa Agrani, and Pusa Jagannath, and *B. campestris* cvs. T 9 and Sagam to study the effect of salinity on the uptake of K, Ca and Na, and expression pattern of genes involved in Na-exclusion. Salinity stress resulted in drastic decline in relative water content (RWC), membrane stability index (MSI), and contents of chlorophyll (Chl) and carotenoids (Car) in all *Brassica* genotypes. However, *B. juncea* genotypes CS 52 and CS 54 were able to maintain relatively higher RWC, MSI and Chl and Car contents. Leaf, stem and root K content and K/Na ratio decreased, and Na content increased with increasing salinity levels. CS 52 and CS 54 were able to maintain comparatively lower Na content and higher K content and K/Na ratio.

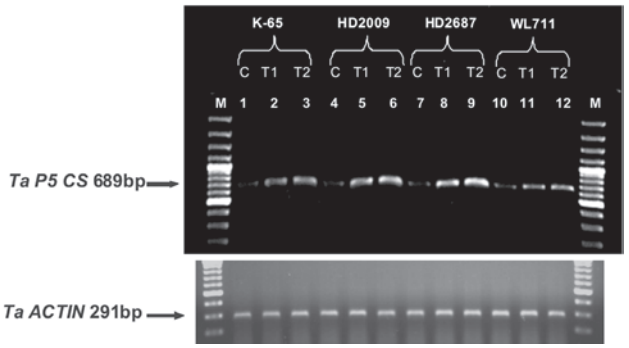



**Root concentration of (A) nicotianamine, and (B) deoxy-mugenic acid (ng $g^{-1}$ FW) in 11 day-old seedlings of bread and *durum* wheat raised on control and iron and zinc deficient solutions**

Expression of genes coding proteins associated with Na-exclusion, viz., *SOS1* (plasma membrane Na/H antiporter), *SOS2*, *SOS3* and *NHX1* (tonoplast antiporter) increased significantly under salinity only in tolerant genotype CS 52 and, to some extent, CS 54. The results suggest that sodium exclusion mechanism in the form of *SOS1*, *SOS2* and *SOS3* and sodium sequestration in vacuole by *NHX1* plays an important role in salinity tolerance in *Brassica* spp.

### 5.3.4 Physiological and Molecular Bases of Salinity Stress Tolerance in Wheat Genotypes

Wheat (*Triticum aestivum* L.) cultivars, Kharchia 65, KRL 19 (relatively tolerant), HD 2009, HD 2687, WL 711 and




**Expression analysis of *pyrrolene 5-carboxylate synthetase* ($P_5CS$) and *actin (TaActin)* genes under salinity stress. (M: 100 bp ladder; C: Control ; T1: 100 mM NaCl ; and T2: 200 mM NaCl)**

HD 4713 *(Triticum durum)* (relatively susceptible) showed decline in RWC, MSI and Chl content under increasing salinity stress at various growth stages. However, the decline was less in Kharchia 65, KRL 19 and HD 2009 at vegetative and anthesis stages. Salinity stress also resulted in reduction in leaf area, and photo system II efficiency in all the genotypes. However, the decline was comparatively less in Kharchia 65, KRL 19 and HD 2009 as compared to that in HD 2687, WL 711 and HD 4713. Salinity stress induced increase in proline content was the highest in Kharchia 65, flowed by HD 2009 and HD 2687, while WL 711 recorded the lowest content. Expression of the *pyrrolene 5-carboxylate synthase* ($P_5CS$) gene also followed the same pattern.

### 5.3.5 Interactive Effects of Urea and Thiourea on Green Gram under Waterlogging

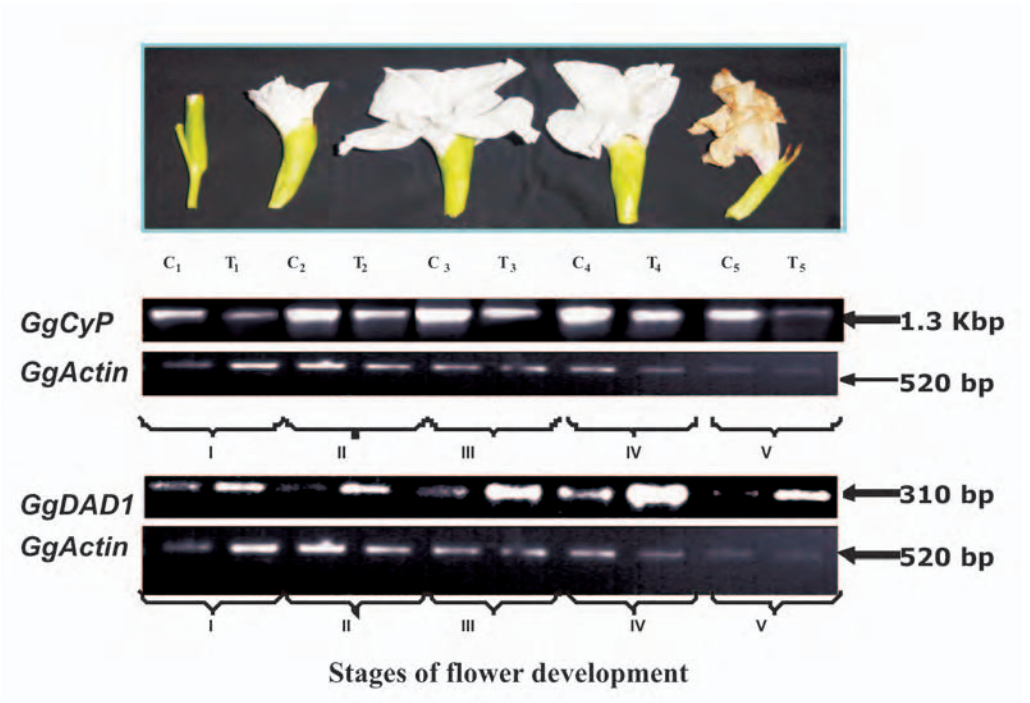
Two green gram genotypes, i.e., MH 96-1 (tolerant) MH 1K-24 (susceptible) were used to study the ameliorative effects of urea and thiourea foliar applications under waterlogging. Foliar application of urea (1%) + thiourea (750ppm) exhibited positive interaction and significantly enhanced the growth, photosynthesis rate, level of photosynthetic pigments (chlorophylls and carotenoids), stomatal conductance, carboxylation efficiency, recovery after waterlogging termination, and grain yield of waterlogged green gram genotypes. The response was more in susceptible genotype (MH 1K- 24) as compared to that in the tolerant genotype (MH 96-1).

### 5.3.6 Screening of Banana Cultivars for Valuable Bioactive Nutritional Compounds

The provitamin-A, β carotenoid, was found to be more in non-edible peel than in pulp. Among the cultivars screened, Nendran showed the highest β carotene both in non-edible peel and pulp. The protein content was also higher in the peel than in the pulp. The activities of various antioxidant enzymes such as SOD, APOX, CAT and GR were the highest in the peel of plantain 'Monthan'. Mineral nutrients like $Ca^{2+}$, $Mg^{2+}$, $Fe^{2+}$, $Zn^{2+}$ and $Mn^{2+}$ were also higher in the peel than in the pulp. Thus, banana cultivars like 'Red Banana', 'Karpuravalli' and plantain cultivars like 'Nendran', and 'Monthan' can be exploited for their bioactive compounds. The gene for phytoene synthase (*psy*) was isolated and characterized. The pattern of *Psy* expression in peel and pulp revealed that the expression was 3-4 times higher in the non-edible peel than in the pulp. In peel, two *Psy* transcript variants were present compared to only one in the case of pulp. Nendran cultivar which showed the highest β-carotene content in pulp also has two isoforms in pulp.

### 5.3.7 Role of Nitric Oxide (NO) in the Regulation of Flower Senescence in Gladiolus

The effect of NO (provided by sodium nitropruside: 100 ppm) was studied on delaying the senescence in gladiolus cultivar Snow Princess. The vase life of flower spikes was significantly increased and fresh weight retained for longer duration by treatment with NO than with control (distilled water). Spikes kept in vase solution containing NO maintained higher membrane stability and lower lipid peroxidation and lipoxygenase activity as compared to those kept in control. The expression of *GgCyP1* was down-regulated by NO during the course of flower development. The expression increased gradually during early stages of flower development and started declining from incipient senescent stage onwards in both control and treated florets but the decrease in expression was more prominent in control than in NO treated florets. However, *GgDAD1* expression was up-regulated by NO treatment during the course of flower development. The expression of this gene increased




**RT-PCR analysis of *GgCyP1* and *GgDAD1* gene expression at different developmental stages in gladiolus as affected by nitric oxide (NO) (100 ppm)-source-SNP. Gladiolus partial actin gene (*GgActin*) was used as control**

gradually from bud to incipient senescent flower stages and decreased in fully senescent stage in both control and treated florets but the treated floret maintained higher expression of these genes compared to that in the control at terminal senescent stage of gladiolus floret.

### 5.3.8 Delaying Ripening for Better Post-harvest Management of Tomato (*Solanum lycopersicon* L.) Fruits by 1-Methyl-cyclopropene (1-MCP)

1-Methylcyclopropene (1-MCP) is a highly effective gaseous inhibitor of ethylene action in the plant tissues. It binds to the ethylene receptor thereby preventing the ethylene-mediated signal transduction cascade. The present study showed that treatment with 0.3 µl $l^{-1}$ of 1-MCP for 24 h was the most effective in delaying the ripening of tomato fruits (of any variety) harvested either at green mature or breaker stage even at relatively higher storage temperature of about 25 $^0$C and 30 $^0$C.

The treatment was also highly effective in delaying the ripening for 5-10 days for a fruit lot representing a mixture of fruits at different ripening stages (green mature, breaker and turning). Results imply prospects for the use of 1-MCP in delaying the fruit ripening and better post-harvest management of tomato even at relatively higher ambient temperatures that prevail in most of the tropical and sub-tropical countries.

**Control** **Treatment**

**Effect of 1-MCP treatment (0.3 µl $l^{-1}$ for 24 h) on the ripening of tomato fruits harvested at green mature stage (10 days after treatment)**

**Effect of 1-MCP treatment (0.3 µl $l^{-1}$ for 24 h) on post-harvest life (%) of tomato fruits at different days after treatment**

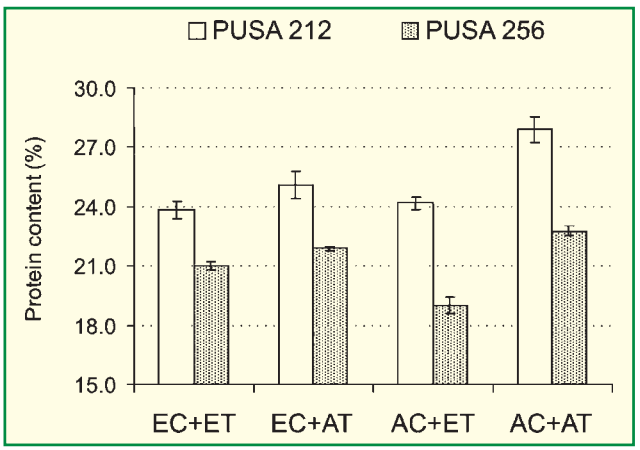
| Variety (V)/ Treatment (T) | Fast ripening type | | | | | Slow ripening type | | | Mean (T) |
|---|---|---|---|---|---|---|---|---|---|
| | Pusa Ruby | Pusa Early Dwarf | Pusa Sheetal | Pusa Uphar | Pusa Gaurav | Pusa 120 | Pusa Selection 8 | Pusa Rohini | |
| **14 days after treatment** | | | | | | | | | |
| Control | $55^{ab}$ | $40^{bc}$ | $68^{a}$ | $40^{bc}$ | $11^{de}$ | $31^{bcd}$ | $9^{e}$ | $32^{bcd}$ | $35.7^{a}$ |
| Treatment | $0^{f}$ | $16^{cde}$ | $0^{f}$ | $7^{e}$ | $0^{f}$ | $3^{f}$ | $0^{f}$ | $0^{f}$ | $3.2^{b}$ |
| Mean (V) | $27.5^{ab}$ | $28.0^{a}$ | $34.0^{ab}$ | $23.5^{ab}$ | $5.5^{c}$ | $17.0^{bc}$ | $4.5^{c}$ | $16.0^{bc}$ | |
| Significant at $P < 0.01$V = **, T = **, V x T = ** | | | | | | | | | |
| **18 days after treatment** | | | | | | | | | |
| Control | 57 | 51 | 89 | 47 | 13 | 48 | 18 | 32 | $44.4^{a}$ |
| Treatment | 36 | 21 | 55 | 23 | 2 | 5 | 0 | 0 | $17.7^{b}$ |
| Mean (V) | $46.5^{b}$ | $36.0^{bc}$ | $72.0^{a}$ | $35.0^{bc}$ | $7.5^{d}$ | $26.5^{cd}$ | $9.0^{d}$ | $16.0^{d}$ | |
| Significant at $P < 0.01$V = **, T = **, V x T = NS | | | | | | | | | |

## 5.3.9 Comparative Response of *Kabuli* Type versus *Desi* Type Chickpea Genotypes to High Temperature Conditions

Performance of 4 *Kabuli* (viz., Pusa 1003, Pusa 1088, Pusa 1053, and Pusa 1108) and 4 *desi* (viz., BGD 72, Pusa 256, Pusa 362 and Pusa 1103) chickpea genotypes was investigated under high temperature conditions and terminal high temperature stress. Under high temperature conditions, *desi* type chickpea genotypes performed better than *Kabuli* type in terms of crop growth rate, membrane stability index (MSI), relative water content (RWC%), photosynthesis, canopy temperature depression (CTD), partitioning to economic sink and grain yield. MSI, RWC and CTD showed close association with high temperature tolerance. It is speculated that these traits may be used as simple screening criteria for high temperature tolerance in chickpea.

## 5.3.10 Effect of Elevated $CO_2$ and Temperature on the Protein Content of Chickpea Cultivars

Two cultivars of chickpea (Pusa 212 and Pusa 256) were grown under four different environmental conditions in four open top chambers, viz., elevated $CO_2$ and elevated temperature (EC+ET), elevated $CO_2$ and ambient temperature (EC+AT), ambient $CO_2$ and elevated temperature (AC+ET) and ambient $CO_2$ and ambient temperature (AC+AT). The



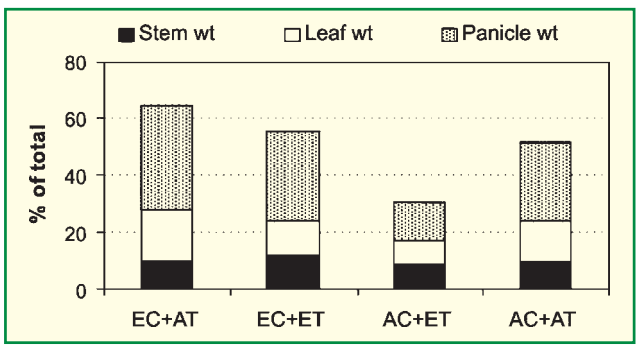

**Protein content in chickpea seeds under elevated $CO_2$ and temperature**

protein content in seeds for both cultivars was reduced between 4% and 17% under elevated temperature and/or increased $CO_2$ concentrations as compared to that under ambient temperature and $CO_2$ grown plants.

## 5.3.11 Effect of Elevated $CO_2$ and Temperature on Partitioning, Yield and Cooking Quality of Rice Crop

Rice crop (Pusa 44) grown in the open top chambers to study the interactive effects of elevated $CO_2$ and temperature revealed that total dry matter and yield per plant were the

highest in elevated $CO_2$ (550±50) with ambient temperature treatment (EC+AT) and the lowest in ambient $CO_2$ with elevated temperature treatment (AC+ET). The increased yield under elevated $CO_2$ was mainly due to increased panicle weight, spikelets per panicle and spikelet density. Elevated $CO_2$ increased the assimilate partitioning to seeds in rice crop. Elevated temperature, however, reduced the assimilate partitioning to seeds in rice crop and the lowest panicle weight was obtained in AC+ET.




**Dry matter distribution in rice under elevated $CO_2$ and temperature**

Rice hybrid PRH 10 and its parental rice genotypes, PRR 78 (male parent) and PUSA 6B (female parent) were evaluated for the impact of elevated $CO_2$ (600 µmol $mol^{-1}$) and temperature (3 °C above ambient) at panicle initiation stage (50-55 days after transplanting) and anthesis stage (90-95 days after transplanting) for 10 days duration in open top chambers (OTCs). Among the three genotypes, PRR 78 showed maximum increase in the rate of photosynthesis under high $CO_2$ condition. Pusa 6B showed further increase in photosynthesis when exposed to high temperature during both panicle initiation as well as anthesis stages. Elevated $CO_2$ exposure showed no effect on spikelet fertility but exposure to high temperature during anthesis caused significant reduction in spikelet fertility in all the rice genotypes. Grain yield increased in elevated $CO_2$ grown plants of PRH 10 and Pusa 6B but no significant changes occurred in PRR 78. Exposure to high temperature during anthesis stage was critical in all the genotypes and resulted in lower grain yield in both ambient and high $CO_2$ exposed plants. PRR 78 was observed to be most sensitive to high temperature in terms of reduction in spikelet fertility and grain yield.

Among the quality parameters like slenderness of the grain, elongation of the grain after cooking and aroma of cooked rice, the length/breadth ratio was not affected by $CO_2$ treatment. The elongation ratio of the cooked grain improved in the female parent Pusa 6B, but declined in the male parent PRR 78 and remained unchanged in the hybrid PRH 10. Aroma declined in the grains harvested from plants of all the genotypes exposed to higher levels of $CO_2$. Alkali spreading value in the hybrid and female parent Pusa 6B decreased and hence the gelatinization temperature increased resulting in firmer cooked rice under high $CO_2$. It may be concluded that high $CO_2$ adversely affected traits like aroma and gelatinization temperature.

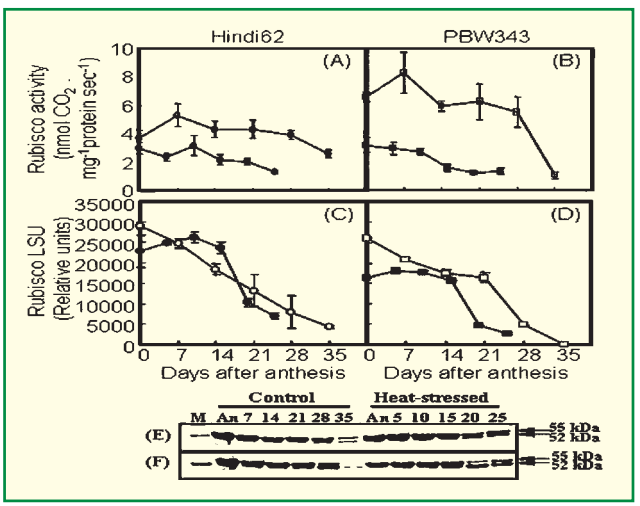
## 5.3.12 Effect of High Temperature Stress on Monocarpic Senescence in Wheat: Involvement of Serine Proteases

The present study was undertaken to understand the mechanism of heat tolerance during monocarpic senescence under field conditions in Hindi 62 (heat tolerant) and PBW 343 (heat susceptible) under late sown condition. There was a faster rate of senescence under heat-stress environment (HSE) in both the genotypes. Hindi 62 maintained cooler

**Effect of high $CO_2$ on cooking quality traits of rice hybrid (PRH 10) and its parental lines (AC=Ambient $CO_2$, HC= High $CO_2$)**

| Quality traits | PRH-10 | | PRR 78 | | Pusa 6B | | CD at 5 % |
|---|---|---|---|---|---|---|---|
| | AC | HC | AC | HC | AC | HC | |
| L/B ratio | 4.30 | 4.33 | 4.04 | 4.03 | 4.58 | 4.61 | 0.058 |
| Elongation ratio | 1.74 | 1.74 | 1.63 | 1.48 | 1.59 | 1.74 | 0.040 |
| Alkali spreading value | 5.58 | 5.33 | 2.67 | 3.37 | 5.0 | 4.3 | 0.47 |
| Aroma | 0.75 | 0.62 | 1.22 | 1.25 | 0.96 | 0.82 | 0.14 |
| Amylose % | 20.0 | 21.0 | 15.7 | 15.8 | 22.6 | 22.7 | 0.38 |

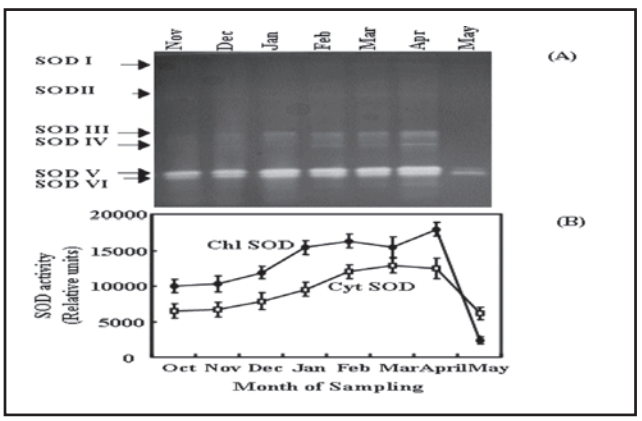
canopy under high temperature compared to PBW 343. The tolerance for high temperature in Hindi 62 was clearly evident in terms of slower green leaf area degradation, higher stomatal conductance, and higher stability in maximum PS II efficiency, rubisco activity and content compared to those of PBW 343. Both the genotypes exhibited lower endopeptidase activity under HSE as compared to that under non-stress environment (NSE), and this difference was more apparent in Hindi 62. Serine proteases are the predominant proteases responsible for protein degradation under NSE as well as HSE. Flag leaf of both the genotypes exhibited high molecular weight endoproteases (78 kDa and 67 kDa) isoforms up to full grain maturity, which were inhibited by specific serine protease inhibitor in both the environments.




**Effect of high temperature on Rubisco activity (A, B); and Rubisco LSU content (C, D) of wheat genotypes, Hindi 62 (A and C) and PBW 343 (B and D) during grain development. Immunoblots showing effect of high temperature on Rubisco LSU degradation in wheat flag leaf of Hindi 62 (E) and PBW 343 (F). Hindi 62: o – normal sown environment; • - heat-stress environment; PBW 343: – normal sown environment; ■ - HSE, heat-stress environment**

## 5.3.13 Purification and Characterization of Thermostable Monomeric Chloroplastic-Cu/Zn Superoxide Dismutase from *Chenopodium murale*

A thermostable chloroplastic-Cu/Zn superoxide dismutase (Chl-Cu/Zn SOD) was purified to homogeneity by using minimal steps from *Chenopodium*. Incubation of lysed chloroplasts at 70 °C for 1 h reduced the interference of cytosolic SOD isoforms and reduced the protein content by 75%. Chloroplastic SOD was purified from the heat stable fraction by gel filtration chromatography. The purified enzyme had a native molecular weight of 24 kDa, a half-life of 47.9 min at 80 °C and showed a single band at 24 kDa on SDS-PAGE .The N-terminus contained the conserved amino acids of Chl-Cu/Zn SOD. The Chl-Cu/Zn SOD protein and its activity were enhanced under very high temperatures, high light intensities and in water stress/recovered *C. murale* plants under controlled environment conditions. Chl-Cu/Zn SOD was also one of the predominant isoforms throughout the growing period in field grown plants and it declined during senescence. The Chl-Cu/Zn SOD activity increased with the increase in ambient temperature and peaked in April with a 45 °C Tmax. These results clearly indicate that the chloroplastic Cu/Zn SOD is stably expressed under extreme environmental conditions. The presence of stable monomeric chloroplastic Cu/Zn SOD might help the plants to maintain the cellular homeostasis under adverse environmental conditions.




**SOD activity across developmental stages in *Chenopodium murale*, where it faces extreme temperatures from 5 °C to 45 °C. A: native PAGE showing SOD activity, B: relative SOD activity as determined by scanning the gels**

## 5.3.14 Sprout Inhibition of Red and White Onion Types

The effect of *gamma* irradiation (0, 0.10 and 0.15 kGy) on post harvest shelf life and sprouting of red and white onions showed that a dose of 0.10 kGy was sufficient to yield 100% sprouting inhibition without any spoilage even beyond 6 months of storage at room temperature. Red onions

**Effect of *gamma* irradiation on post harvest shelf life of onions (values in parenthesis indicate % spoilage)**

| Treatment | Days after irradiation | Bulb sprouting (%) | | Bulb weight (% weight loss over zero time) | |
|---|---|---|---|---|---|
| | | Red onion | White onion | Red onion | White onion |
| **Control** | 0 | 0 | 0 | - | - |
| | 70 | 50 (17) | 67 (21) | 32 | 34 |
| | 120 | 100 (30) | 100 (42) | 55 | 61 |
| | 160 | 100 (59) | 100 (68) | 70 | 82 |
| **0.10 kGy** | 0 | 0 | 0 | - | - |
| | 70 | 0 | 0 | 18 | 18.8 |
| | 120 | 0 | 0 | 22 | 25 |
| | 160 | 0 | 10 (15) | 25.1 | 29 |
| **0.15 kGy** | 0 | 0 | 0 | - | - |
| | 70 | 0 | 0 (17) | 23 | 40.8 |
| | 120 | 0 | 0 (32) | 32 | 50 |
| | 160 | 0 (5) | 0 (41) | 39 | 55 |

showed no spoilage at 160 days of harvest as compared to 17% spoilage in white onion treated with 0.1 kGy.

### 5.3.15 Thermostability of Phytase from Chickpea Seeds as Affected by *Gamma* Irradiation

*Gamma* irradiation (0, 0.2, 0.5, 3 and 5 kGy) increased the seed phytase activity in chickpea. No phytase activity was recorded at incubation temperatures above 45 °C in unirradiated seeds. *Gamma* irradiated seeds, irrespective of dose, showed an increase in phytase activity at 65 °C which declined at 90 °C but was significantly higher than that of the unirradiated control. A dose of 3 kGy treatment was most effective in maintaining phytase activity at higher incubation temperatures. This clearly suggests an improvement in thermotolerance of seed phytase by *gamma* irradiation.

### 5.3.16 Effect of *Gamma* Irradiation on Physiological, Biochemical and Yield Characteristics of Wheat (*Triticum aestivum* L.)

*Gamma* irradiation improved the grain yield by increasing the plant vigour, leaf area, tiller number, spikes per plant, stem thickness and number of developing grain sinks. The increase in yield was negatively correlated with 1000-grain weight, which could be due to inadequate supply of photosynthates from source to all the developing sinks, which were appreciably higher in irradiated wheat plants. Irradiated plant had higher concentration of both macro- and micro-nutrients in the plant tissues but not in grains. The protein content increased in the irradiated grains. Changes in the protein profile were evident with the appearance of new bands. β-carotenes increased in irradiated grains.

### 5.3.17 Physical Energy (Magnetic Field and *Gamma* Radiation) Effects on Grain Quality, Germination, Plant Growth and Release of Root Exudates in Wheat (*Triticum aestivum* L.)

Magnetic stimulation of plant vigour was caused by a favourable increase in nutritional attributes owing to improved root exudation that modified the rhizosphere favourably. Protein content of grains did not change significantly in response to magnetic field. However, a distinct difference in the amino acid profile of magnetized and non-magnetized seeds was noted. The concentrations of methionine increased at 50 mT and 100 mT but, declined to negligible levels at 150 mT. Glutamine on the other hand, declined upon magnetic treatment in a dose dependent manner. Proline accumulation was induced upon magnetic treatment. Magnetic field was able to bring in a favourable change in source-sink relationship as evident from an increase in carboxylation efficiency of the source and root to shoot translocation index. The effect of *gamma* energy

on root exudation was more pronounced than the effect of magnetic energy.

### 5.3.18 Effect of *Gamma* and Magnetic Energies in Mitigating Abiotic Stresses in Wheat

An experiment was conducted to study the interactive effect of magnetic field and water availability on seed germination, seedling establishment and related enzymatic changes. A higher yield of magnetized plants could be attributed to an increase in the number of grains per ear and 1000-grain weight. Most of the grain quality traits, as affected by magnetic fields, were maintained even in next generation when compared with those of the parental seed material. Magnetic field improved drought tolerance of wheat under low moisture availability as evident from an increase in the rate of seed germination due to stimulated α-amylase activity and subsequent seedling establishment and vigour. The effect of *gamma* irradiation on imparting water, salinity and micronutrient stress tolerance was investigated in wheat in farmer's field. *Gamma* irradiation improved seedling vigour of seeds under all the abiotic stresses. The tolerance characteristic was related to a higher activity of superoxide dismutase. A greater tolerance of irradiated seedlings to iron deficiency was related to their ability to produce significantly larger amounts of phytosiderophores.

### 5.3.19 Effect of Vernalization on Grain Yield and Related Characters in Wheat

Significant yield increase (28-45%) was realized through fortification of reproductive phase by vernalization under normal sown (November 15-20) conditions. Out of a total increase of 20-23% in above-ground biomass, grain weight increased by 15-17%, grain number by 3.6-17.0%, and harvest index by 6-8% as compared to those of the control.

## 5.4 GENETICS

### 5.4.1 Wheat

#### 5.4.1.1 Genetics of rust resistance

Genetic analysis of stem rust resistance in genotype WR 95 revealed a single recessive gene for rust resistance. Analysis of monosomic $F_1$s failed to identify the chromosome due to hemizygous ineffectiveness of the gene. Work was initiated for molecular mapping of the gene. The WR 95 was screened with molecular markers of stem rust resistance genes *Sr*22, *Sr*24, *Sr*25, *Sr*26, *Sr*31, *Sr*36 and *Sr*38.None of these genes could be detected in WR 95. Another genetic stock Sel.T3336 was identified with rust resistance genes *Lr*24/*Sr*24 and *Sr*26.

### 5.4.2 Rice

#### 5.4.2.1 Marker aided improvement of PRH 10 for resistance to bacterial blight (BB)

PRH 10 is a widely cultivated superfine grain aromatic rice hybrid in India. This hybrid and its parental lines Pusa 6B (maintainer) and PRR 78 (restorer) are susceptible to bacterial blight disease caused by *Xanthomonas oryzae* pv. *oryzae*. By the use of marker assisted foreground and background selection, two bacterial blight resistance genes, namely, *xa13* and *Xa21* were transferred in the parental lines of PRH 10 (Pusa 6B and PRR78). The plants of $BC_2F_5$ families of both the backcross series were highly resistant to bacterial blight. The extent of donor segments in the improved versions of Pusa 6B was estimated to be <0.97 Mb and <2.15 Mb in the genomic regions flanking *xa13* and *Xa21*, respectively, while in the case of improved versions of PRR 78, the donor segment on carrier chromosome was estimated to be <2.07Mb and <3.45Mb in the genomic regions of *xa13* and *Xa21*, respectively.

Agronomic performance and grain and cooking quality attributes of selected improved parental lines were similar to or better than the respective, recurrent parents. Improved

**A field view of bacterial blight resistant PRH 10**

Data on yield and yield related components and BB resistance of newly developed hybrid combination in comparison with PRH10

| Details | DFF (days) | PH (cm) | NT | PL (cm) | FG/P | SF (%) | TW (gms) | Y/P (g) | BB Score (cm) |
|---|---|---|---|---|---|---|---|---|---|
| PRH 10 | 85 | 110.60 | 15.80 | 27.40 | 175.60 | 90.34 | 23.24 | 21.07 | 14.39 |
| F1-26 | 86 | 108.25 | 18.00 | 27.50 | 180.25 | 92.99 | 23.21 | 23.05 | 1.92 |
| F1-27 | 84 | 106.80 | 15.60 | 25.40 | 182.80 | 89.78 | 24.32 | 24.34 | 2.48 |
| F1-28 | 85 | 104.20 | 13.60 | 26.00 | 170.80 | 90.32 | 22.50 | 20.03 | 2.08 |
| F1-32 | 83 | 108.00 | 18.40 | 28.40 | 175.80 | 95.12 | 22.43 | 22.35 | 2.20 |
| F1-37 | 87 | 112.60 | 20.20 | 28.40 | 185.40 | 90.40 | 24.22 | 26.12 | 2.14 |
| CD at 5% | 2.8 | 4.50 | 2.6 | 1.5 | 5.5 | 1.5 | 3.5 | 3.5 | |

PH: plant height; NT: number of tiller; PL: panicle length; FG/P: filled grain/panicle; SF: spikelet fertility; TW: 1000-grain weight; Y/P: yield/plant; DFF: days to 50% flowering

version of Pusa 6B and PRR 78 were intercrossed and combinations as good as or better than PRH10 with resistance to bacterial blight were identified.

## 5.4.3 Maize

### 5.4.3.1 Polymorphic studies with InDel markers

A set of 48 maize land race accessions were analyzed by the use of 155 InDel markers. Out of the 155 InDel markers screened on 48 landraces, polymorphism was recorded for 45 markers. A total of 109 alleles were detected, at an average of 2.7 alleles per marker. Another set of 48 Indian maize landraces, especially from Himachal Pradesh, were also characterized by the use of 42 fluorescent-labelled SSR markers.

### 5.4.3.2 Allele mining

Allele mining in *Tb1* gene influencing prolificacy was undertaken. Several SNPs (including transitions and transversions) and InDels were observed. The prominent InDels included a 3-bp InDel of CTG at position 165-168, single-base InDels (of T) at positions 121 and 152, besides a 9-bp InDel suggesting significant nucleotide diversity in the *tb1* alleles of the prolific Sikkim primitives as compared to that of the normal maize genotypes.

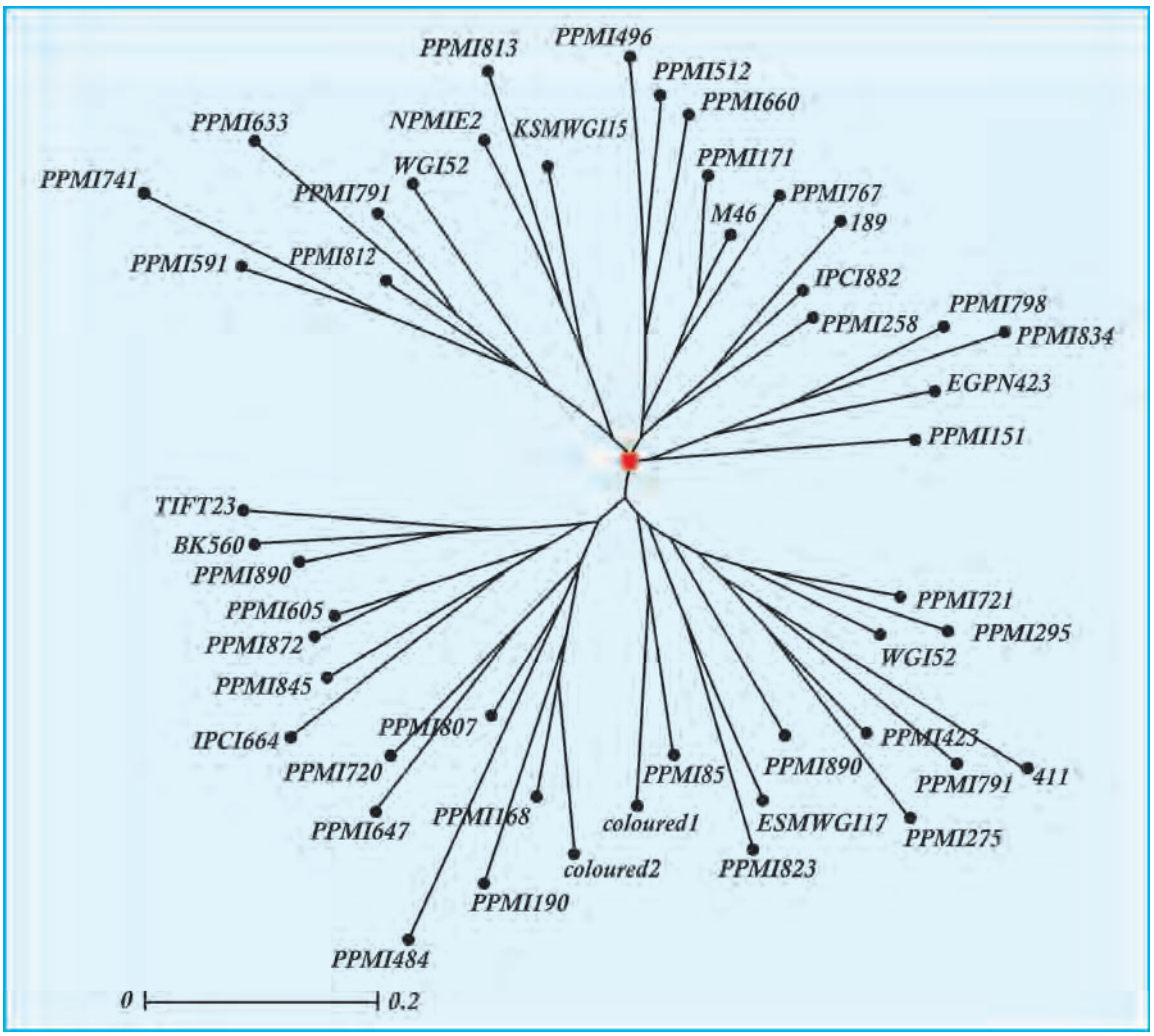
### 5.4.3.3 Diversity analysis

Nucleotide sequence diversity in the *Yellow1* (*Y1* or *psy1*) gene and in the 5′ UTR region of the *su1* (*sugary1*) gene were analyzed in a selected set of maize inbred lines, and was related with functional diversity for the target traits. Four haplotypes out of 14 were identified to be particularly 'informative' with respect to mean carotenoid content, while three putative haplotypes detected in the 5′ UTR region of the *su1* gene, were identified as 'informative haplotypes'.

## 5.4.4 Pearl Millet

### 5.4.4.1 Molecular marker assisted selection for downy mildew resistance and economically important traits

A total of 48 elite inbreds were used for molecular characterization studies. These consisted of both downy mildew resistant and susceptible inbreds. DNA polymorphism between the inbred lines was investigated by the use of SSR markers. Of the total 135 SSR primers used for the study, only 34 of them were found to be polymorphic. Elite pearl millet restorers were evaluated for diversity and 5 distinct groups could be formed on Darwin tree.




**Darwin tree showing molecular diversity among 48 elite inbreds of pearl millet**

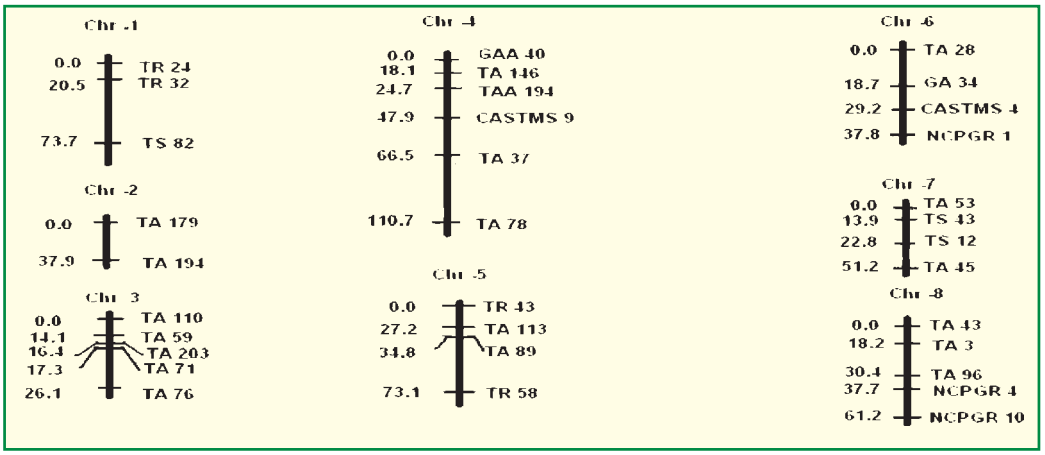
## 5.4.5 Chickpea

### 5.4.5.1 Development of molecular linkage map of chickpea

A molecular based $F_2$ linkage map of chickpea was developed from a *desi* × *Kabuli* cross of BGD 112 and FLIP 90-166 by the use of Sequence-tagged Microsatellite Markers (STMS). A total of 250 STMS markers were used to study the parental polymorphism and 49, which showed polymorphism were used for genotyping $F_2$ lines. Linkage analysis revealed 8 linkage groups mapped by 33 loci by these markers covering a distance of 471.1 cM of map distance with an average marker density of 9.6 cM at a LOD of 3.0. The molecular map using *desi* × *Kabuli* cross throws insights into variability and diversity that can be utilized directly by the breeders.

### 5.4.5.2 Development of mapping populations

Advancement of mapping population of the crosses, BGD 112 × SBD 377, BGD 112 × Flip-90-166, SBD 377 × Pusa 1103 and Pusa 362 × BGD 112 were taken up. In addition, a new mapping population development using Pusa 372 × PG 0515 was initiated for yield traits and advanced to $F_2$. Also a target induced local lesions in genomics (TILLING) population of 10000 individuals using ICC 4958 is being developed and is in $M_3$.




**Molecular linkage map of chickpea**

### 5.4.5.3 Genetics of flowering time in chickpea in a semi-arid environment

Inheritance of time of flowering was studied in several early × late and early × early crosses under field conditions. The $F_2$ segregation analysis established the role of duplicate dominant genes with cumulative but unequal effect in the inheritance of flowering time in chickpea. There are several genes for flowering time in chickpea. The model proposed would convincingly explain the magnitude of genetic variability for flowering time that exists in the world chickpea germplasm collection.

## 5.4.6 Pigeonpea

### 5.4.6.1 Conversion of superior lines into A lines

In pigeonpea, with respect to $A_2$ cytoplasm, 2 lines were in $BC_3$, 2 lines in $BC_6$, and 12 lines in $BC_2$, and with respect to $A_4$ cytoplasm, 29 lines were in $BC_2$ stage.

## 5.4.7 *Brassica*

### 5.4.7.1 Genetics of white rust resistance in different species and allelic relationship studies

Mode of inheritance of white rust resistance gene in indigenously developed resistance source and allelic relationship of genes for white rust resistance in two different sources, viz., Bio YSR and NPC 12 from *Brassica juncea* and *B. carinata*, respectively, was studied. The inheritance pattern of resistance genes in donors when crossed with two widely cultivated, highly susceptible cultivars, Varuna and Bio-902 (Pusa Jai Kisan), indicated the presence of a single dominant gene for white rust resistance. A cross between the resistant sources from *B. juncea* and *B. carinata* segregated in 15:1 (resistant: susceptible) ratio in $F_2$ generation indicating the involvement of two different genes governing white rust resistance in these sources. For allelic relationship studies in four sources of white rust resistance,

**The pedigree and trait of the mapping populations being developed in *Brassica***

| Pedigree | Gener-ation | Size | Trait |
|---|---|---|---|
| LES 39 × EC 597318 | F 2 | >1000 | Glucosinolates |
| LES 1-27 × EC 597318 | F 2 | >1000 | Glucosinolates |
| Varuna × LES 39 | F 2 | >250 | Erucic acid |
| NPJ 93 × LES 1-27 | F 2 | >250 | Erucic acid |
| LES 39 × LES 1-27 | F 2 | >250 | Erucic acid |
| Varuna × Bio YSR | F 3 | 299 | White rust |
| Bio 902 × Bio YSR | F 3 | 193 | White rust |
| Bio 902 × BEC 144 | F 3 | 215 | White rust |
| NPJ 102 × BEC 144 | F 4 | 107 | Maturity, height, seeds/ siliqua |
| Varuna × BEC 144 | $F_{15}$ | 192 | White rust, maturity, seed colour, size, plant height, plant type |

viz., Bio-YSR (indigenous), BEC 144 (exotic), BEC 286 (exotic), and JM 1 (indigenous) on the basis of their $F_1$, backcross and $F_2$ phenotyped data, it was concluded that the same gene is governing the white rust resistance in all of these four donors.

## 5.4.8 Soybean

### 5.4.8.1 Development of regression model

A regression model was developed for the prediction of photo-thermo sensitivity of soybean by taking inverse of days to flowering (R) as response variable; and mean temperature (T, mean of maximum and minimum temperatures of the growing season) and mean sunshine hours (S) as explanatory variables. A fixed effect linear regression model (R = 0.127 – 6.58E-03S – 2.43E-03T**)** for the two seasons and 32 genotypes resulted in R-square value of (0.947). The effect of sunshine hours was found to be almost 2.7 times that of temperature on the rate of response to flowering.

## 5.4.9 *Drosophila melanogaster*

### 5.4.9.1 Molecular genetic analysis of *stambhA*

INO80 knockouts in *Drosophila* were obtained and the expression of Hox genes- *Antp*, *Ubx*, *Scr* and *AbdB* was studied. *Antp* was up-regulated while *Scr*, *Ubx* and *AbDB* were down-regulated. Over-expression of *UAS wg* did not rescue *DWnt4AL7*. However, over-expression *UAS Wnt4* by the Armadillo Gal4 driver rescued *AL7*. This shows that *DWnt4* is expressed in the Armadillo (B catenin) domain. INO 80 embryos show severe homeotic transformation of segments A 5-A 8 towards A1. Thus, INO 80 is a member of the Pc/ trithorax group of chromatin modifiers. SUMO protein shows different pattern specific distribution in imaginal tissues. SUMO mutants do not enhance the *vg1* phenotype but greatly enhanced the *Gla* phenotype. Chromosome 3rd was isogenised. It has been noted that a chromosome with Yeast FRT sequences on the right arm of chromosome 3 is linked to the INO 80 null. Around 250 genotypes of *Drosophila* are being maintained for research as well as teaching purposes in IARI.

## 5.4.10 Gene Effects, Combining Ability and Heterosis for Fodder Yield and Other Traits

Twenty-one genotypes of six parents were analyzed for gene effects of variance, combining ability effects and standard heterosis for fodder yield and other traits in barley. Among the parents, BHS 352 and HBL 276 were identified as good general combiners for fodder yield, days to 50% heading and spikelets/ear, whereas the parent HBL 113 was found to be good general combiner for tillers/plant, ear length and biological yield. The predominance of non-additive components of genetic variance (H1, H2) along with positive values of additive component (D), high *per se* performance, significant *sca* effects and significant standard heterosis in top ranking hybrid HBL 276 × HBL 113 suggested the scope for improvement of fodder yield, tillers/plant, ear length, biological yield and grain yield through bi- parental mating.

## 5.4.11 Molecular Breeding of Vegetable Crops

In cauliflower, **b**ased on DNA fingerprinting of 16 SI lines with 32 RAPD and 38 SSR primers, 13 lines were identified. None of the markers could identify the lines cc-22, VV and cc-32E. The genotype 395aa was found to be diverse from molecular markers analysis. Out of the 32 RAPD primers, 25 showed maximum polymorphism percentage in primer SK-14 (50%) and out of the 38 SSR primers, 3 showed polymorphism. The SSR markers, namely, BoREM-lb, Bo DCTD-1 and Bo AB-20TR can be used for testing genetic purity of hybrids derived from SI lines. In tropical carrot, the extent of genetic variability in 40 elite indigenous breeding lines was studied with 48 DNA markers consisting of 16 ISSRs, 10 URPs, 16 RAPD and SSR markers. Forty-eight markers amplified a total of 591 bands, of which 569 were polymorphic (0.96) and the amplicon size ranged from 200 to 3500 base pairs (bp) in ISSR, RAPD and URPs markers and from 100 to 300 bp in SSR markers. The ISSR marker system was found to be most efficient with (GT)n motifs as the most abundant SSR loci in the carrot genome. UPGMA analysis of the combined data set of all the DNA markers obtained by four marker systems classified 40 genotypes in two groups with 0.45 genetic similarity with high Mantel matrix correlation (r = 0.92).

## 5.5 AGRICULTURAL PHYSICS, REMOTE SENSING AND GIS

### 5.5.1 Soil Physics

#### 5.5.1.1 Assessing soil physical quality in long-term fertilizer experiment through single value indexing

The slope of the soil water retention curve at the inflection point (S) was evaluated in a long-term experiment in maize-wheat rotation on a sandy loam soil, Delhi. It was hypothesized that changes in major soil physical properties under long-term fertilizer and organic manure application can effectively be translated into soil functionality for crop growth and can be quantified by S. Better aggregation was found with 100% NPK + FYM, and aggregation indices (mean weight and geometric mean diameter of aggregates) were positively and significantly correlated with soil organic carbon in 8-4 mm size aggregates. Transmission and storage pores were more abundant in manure-treated plots improving the water retention capacity of soil. The effects of 150% NPK or 100% NPK + sulfur were better compared with those of 100% NPK indicating that the recommended NPK was sub-optimal to maintain the favourable soil physical health. Close associations of S with soil physical parameters was obtained indicating potential of S in capturing the changes in soil physical environment through fertilizer and manure applications.

#### 5.5.1.2 Effect of mulches on soil physical properties and processes in wheat

Experiments were conducted at IARI farm to study the effects of two types of mulches, viz., rice husk and transparent polyethylene, two irrigation treatments, i.e., 2 and 5 irrigations, and three nitrogen levels, viz., 60, 120 and 180 kg N/ha on wheat. Transparent polyethylene mulch was most efficient in conserving surface moisture, closely followed by rice husk, in top layers (0-15 cm), while rice husk showed the best performance in conserving moisture in deeper layers. The application of mulch reduced the water fluxes throughout the root zone compared to the water fluxes of un-mulched plots. In the top layer (0-15 cm), the temperature moderation up to 2 °C and 1 °C was recorded under polyethylene and rice husk mulches, respectively. Nitrogen fluxes were reduced under mulched condition even when temperature changes were up to 2 °C. Nitrate nitrogen was conserved for longer period under more steady state condition of soil profile in mulched plots than under dynamic condition of soil water and temperature in un-mulched plots.

### 5.5.2 Remote Sensing and GIS

#### 5.5.2.1 Hyper spectral discrimination of water stress in chickpea (*Cicer arietinum* L.)

A field experiment was conducted in sandy clay loam (*Typic Haplustept*) soil at IARI research farm, New Delhi to monitor the soil moisture stress in *desi* chickpea through conventional and hyper spectral remote sensing approach. Seeds pre-exposed to a static magnetic field of 100 mT for 1 h enhanced the plant root growth, and was taken as one of the treatments. Terminal drought stress was characterized by very low soil moisture content (<15% v/v), which restricted the crop growth and development as evidenced by significantly low leaf area index, biomass accumulation, vegetation indices and ultimately low seed yields. Crop growth between 78 days and 118 days after sowing was identified as the most susceptible period to soil moisture stress. Root growth parameters at peak growth stage under extreme water stressed condition showed significantly higher values for each parameter. The magnetically treated chickpea could extract about 12-13% more residual moisture because of enhanced root growth, and alleviated the stress. The effect of critical soil moisture stress on plant water content was clearly distinguished by spectral reflectance indices, of which the water band index in the near infrared and canopy-air-temperature difference in thermal infrared regions of spectra was able to characterize the plant water status. This study generated useful information on soil-plant-water relations in chickpea with special emphasis to terminal drought stress appearance and its identification through remote sensing. The magnetically treated seeds had significantly improved root parameters, and could be a viable option in augmenting the chickpea yield.

### 5.5.2.2 Validation and correction of available MODIS LAI product for Indian region for use in agricultural applications

Available crop biophysical parameters, mainly, leaf area index (LAI) in spatio-temporal scale is crucial for better monitoring of crop growth. The study was carried out for LAI product of wheat crop at its peak growth stage in trans-Gangetic plains of India and validation was performed for a portion of the study area. LAI map of LISS-III was generated through validated regression model of its NDVI with ground measured LAI values. The LAI product generated at 24 m resolution was aggregated to 1 km resolution for comparison between aggregated LISS-III-LAI, and MODIS LAI. The comparison indicated significant positive correlation between LISS-III-derived LAI and MODIS LAI (with $R^2$ value 0.63). The study revealed that MODIS LAI product yields under-estimated values. Many pixels of MODIS LAI product were having very low LAI, which was very much contrary to that of ground observations. However, it needs to be recorded that LAI is a spatially heterogeneous quantity, and associated with high uncertainty in field observations and other procedures. Additional studies covering more sites and vegetation types are underway which may bring better realistic MODIS LAI product for its operational use.

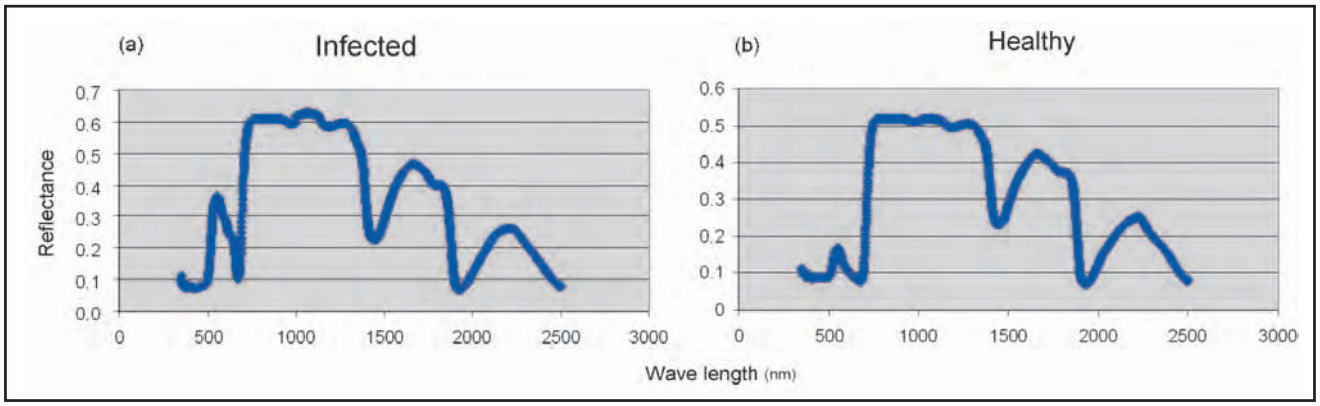
### 5.5.2.3 Quantitative assessment of soil properties by the use of proximal hyperspectral remote sensing

Retrieval of soil chemical and physico-chemical properties from remote sensing was a challenge till the development of hyperspectral remote sensing. In this study, the ability of hyperspectral data in visible (VIS) and near infra red (NIR) regions for the prediction of soil properties (mineralizable nitrogen (N), available phosphorous (P) and potassium (K), extractable manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), $CaCO_3$, soil organic carbon (SOC), electrical conductivity, pH, soil texture, bulk density, particle density and hydraulic conductivity) in the farmers' fields of Jalandhar (Punjab) was evaluated. Visible and near-infrared (350-2500 nm) reflectance spectra of 85 soil samples were obtained from a portable spectroradiometer (ASD, FS3) in the laboratory. Reflectance and its mathematically derived other forms such as absorbance, and their first as well as second derivatives were used for model development following the stepwise regression approach. Best bands were identified for different soil properties through correlation analysis for developing prediction models. Results indicated that the models developed by using derivatives of the spectral data were able to predict some selected properties with reasonably higher accuracy while reflectance and absorbance values did not yield convincing results. Based on $R^2$ of the predicted models, the first derivative of absorbance was found suitable for the model predicting nitrogen while its second derivative was best for Mn, Fe, and Zn prediction models. The second derivative of reflectance was selected for the prediction of P and Cu, and the first derivative of reflectance was better for K prediction. The highest predictability (adjusted $R^2$) was 0.93 recorded for $CaCO_3$ while the lowest 0.68 was obtained for N. Prediction evaluation indices such as Ratio Prediction Deviation (RPD) confirmed that N, P, K, Mn, Fe, $CaCO_3$, SOC, EC, sand, silt and clay were predicted well (having high RPD and $R^2$ values) except Zn, Cu, pH, BD, PD and Ks.

## 5.5.3 Agricultural Meteorology

### 5.5.3.1 Detection of YMV infected leaves through hyper spectral sensors

Three soybean cultivars, viz., JS 335 (V1), Pusa 9712 (V2) and Pusa 9814 (V3) were sown on July 7 (D1: normal) and July 22 (D2: late) to study the crop phenology and thermal time requirements. The cultivar JS 335 was susceptible to *Yellow vein mosaic virus* (YMV). Reflectances of YMV infected and healthy leaves were measured through hyper spectral sensors in the wavelength range of 350-2500 nm. Reflectance of a healthy leaf was significantly lower than that of a diseased leaf in the whole spectrum. The YMV infected leaf showed a reflectance (0.36) significantly higher than that of a healthy leaf (0.18) at 550 nm in visible range. Similarly, in the near infra red (NIR) region, there was significant difference in reflectance of diseased and healthy leaves in the wavelength band of 1000 nm. These two bands (550 nm and 1000 nm) may be useful to detect YMV infected soybean crop and estimate its area from the space through remote sensing.




**Reflectance of virus infected (a) and healthy (b) leaves of soybean**

### 5.5.3.2 Weather-based agro-advisory services

Weather-based agro-advisories for farmers of Delhi and surrounding villages are sent twice a week by the Agro-advisory Unit located in the Division of Agricultural Physics of IARI since 1993. The advisories based on the forecast data are prepared by the expert team from different disciplines and disseminated to the farmers through telephone, E-mail and speed-post. Agro-advisory service bulletin is published in local Hindi newspapers (*Dainik Jagaran* and *Haribhoomi*) and uploaded at IARI website (*www.iari.res.in*). Weather forecast for maximum and minimum temperatures, rainfall, cloud cover, wind speed, maximum and minimum relative humidity for the next five days received from India Meteorological Department, Regional Meteorological Centre, Agromet Advisory Unit, Safdarjung Airport, New Delhi are also given in the bulletin.

# 6. SOCIAL SCIENCES AND TECHNOLOGY TRANSFER

## 6.1 AGRICULTURAL ECONOMICS

### 6.1.1 Emerging Issues in Food and Nutritional Security

Continued growth of agriculture sector is important not only for ensuring national food and nutritional security but also for the role it plays in enhancing the purchasing power of the rural population. The Planning Commission has set a growth target of 4 per cent per annum for the agriculture sector, which has remained elusive so far. For maintaining self-sufficiency in foodgrain production, the country needs to produce at least another 20 MT of additional foodgrains. Also globally, there is a need to produce 40 per cent more cereals to feed the growing population in 2020. There will be deficit in many developing countries and, therefore, food import may double by 2020. This implies that any shortfall in production may deplete the food stocks leading to price rise. In case the shortfall occurs in large countries like China and India, there may not be adequate stock to meet the import demand. Therefore, a policy of self-reliance in food production coupled with increased storage is suggested. The study does not envisage any problem of disposing the stocks in international market, if required.

#### 6.1.1.1 Government support for food production

There was some complacency in terms of public investment during the 1990s and, as a result, there was significant slowdown of agricultural growth since the mid-1990s. This was corrected, to some extent, recently and real public investment maintained an uptrend resulting in positive agricultural growth, including in foodgrain production. However, there is a need to sustain this uptrend in public investment and take appropriate measures to increase the efficiency of public investment. Surface irrigation is one area where most of the public investment has been made. Institutional reforms can help modernize this and other sources of surface irrigation, e.g., irrigation tanks. The study suggests the diversion of part of the input subsidies to long-term investment to contribute to higher food grain production. Delivery of farm inputs and services is another area, which needs government attention. There is increasing participation of private sector in delivery of inputs like fertilizer, seeds, pesticides, etc., which needs to be encouraged. However, there is a lot of information asymmetry and quality problems in input markets, which need to be addressed through appropriate regulatory measures. Improved seed needs special attention because of its immediate impact on crop productivity as also early flow of protected varieties into farmers' seed system. Planting material for horticultural crops needs adequate attention of the government as not many players are active in this area. Farmers require not only planting material but also reliable information to make varietal choice involving long-term investment decisions.

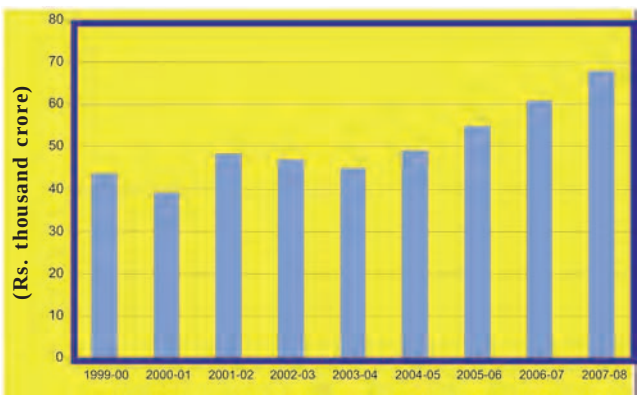
Bridging the yield gap which varies between 60% and 100%, depending upon crop and region, is a high payoff option. The gap is especially high in the eastern region, both for rice and wheat, and bridging it will contribute to substantial increase in foodgrain production. For dryland areas also, the yield gap is an issue and raising the yield level through water conservation measures is more appropriate to increase the productivity of cereals and pulses. For this effective participation of farming community in watershed development is needed to ensure its success. Revitalization of state extension system with more resources, accountability to stakeholders and linkages with NARS also needs immediate attention.

Current policy of government intervention in foodgrain markets should continue; in fact, its need will be felt more in the years to come. This is because private trade is not well developed in large parts of the country and farmers should

be ensured remunerative price for their produce. Variability in foodgrain production may increase because of erratic weather events and the year-to-year changes in foodgrain production in absolute quantity may be quite high. This implies the need for more storage requiring more resources to create storage capacity and carrying stocks. The need for such an intervention is underscored by the likely shortfall in rice production in 2009-10. In order to minimize the cost, the feasibility of community food storage should be explored.

### 6.1.1.2 Agricultural diversification

The trend of agricultural diversification towards high value commodities will intensify after the revival of the economy from the current slowdown. The demand for Indian agricultural products in world market will further intensify this trend. This raises the question of foodgrain security versus diversification, and a rational approach could help realize both these objectives. Self-sufficiency in foodgrain production is a must given the global food scenario and, therefore, foodgrain production should be increased. This will be mainly yield driven. Increase in yield of food grains is also essential to release some area for high value commodities which are in high demand. In addition, there is considerable area under rice-fallow in eastern region which could be brought under cultivation by adopting better moisture management practices. Technological options like single cross hybrids in maize, hybrid rice, system of rice intensification, water saving technologies (drip and sprinkler irrigation), IPM in pulses and site-specific nutrient management can contribute significantly to yield improvement of foodgrain crops.




**Trend in gross capital formation in agriculture in India, 1999-00 prices**

### 6.1.1.3 Agricultural growth scenario and strategy

Agricultural growth in the country has missed the target rate of 4 per cent per annum. The growth for the crop sector was 2.25 per cent during IX Plan and 2.46 per cent during X Plan. Among the crop groups, commercial crops have registered a growth rate more than 3 per cent. This is equal to the growth rate observed for livestock products. The growth for fisheries was 2.6 per cent and 3.2 per cent in IX and X Plans, respectively. As regards the long term trends, cereals showed an impressive growth until 1980s but it slowed down in 1990s. The combined growth of pulses and oilseed was more than 5 per cent during 1980s owing to technology mission on oilseeds. Livestock and fisheries have high growth since 1980s, but the growth of fruits and vegetables accelerated in 1990s owing to the growth in their demand because of high income level and urbanization.

The opportunities and incentives for private investment in agriculture started with the investment in input sector but the size of agriculture sector has grown so much that government alone cannot serve the sector now. Attractive incentives are emerging in the areas of R&D, supply of modern inputs like seed, information dissemination, livestock health services, marketing and agro-processing.

Higher investment in agriculture alone cannot realize the goals; there should be new ways or institutional innovations to realize higher economic efficiency and address the key constraints like shrinking resources, small size of production, global competitiveness and environmental security. This can take place when farmers have the capacity and skill to understand the growing opportunities and pool their resources to realize the benefits of economy of scale through institutional innovations. However, improving farmers' access to markets, technologies and credit is essential and the private sector could be a useful ally of the government and farmers' organizations in this responsibility. A proper mix of polices relating to investment, innovations and incentives will provide the much needed push to this reform process. Although these reforms are important for all the aspects of Indian agriculture, but immediate attention on marketing and agro-processing can generate income and provide incentives to the farmers.

### 6.1.2 Impact of Liberalization on Indian Agricultural Trade

India's trade in agricultural commodities has shown significant changes and dynamism during the last one-and-a-half decade after the initiation of economic policy reforms and trade liberalization. Policy changes to liberalize trade were taken in the context of emerging changes in multilateral trade disciplines and rules subsequent to the formation of the World Trade Organization (WTO). A comprehensive analysis of the pattern of growth, instability and intensity of trade of major agricultural commodities helped to explain the structural changes in exports and imports.

Exports of *basmati* rice from India increased at 7.37 per cent per annum during 1990-91 to 2007-08. The exports of non-*basmati* rice which were low and irregular prior to the liberalization, increased rapidly after liberalization and grew at an annual rate of around 14 per cent during the period. This may be because India has been traditionally exporting only *basmati* rice and exports of non-*basmati* rice have picked up only in recent years. The main markets for non-*basmati* rice are Asian countries and developing economies. Besides non-*basmati* rice, poultry and dairy products, other cereals, groundnut and floricultural products registered a high rate of growth of exports during the post-reforms period. However, the growth rate of exports of total agricultural and allied products to the world was low but significant. A high degree of instability in exports of non-*basmati* rice, pulses, groundnut, raw cotton including waste, and miscellaneous processed items was observed. A similar analysis of the growth and instability of agricultural imports into India clearly indicated substantial inflow of edible oils to India. A high instability was also observed for imports of edible oils and cotton though, these commodities exhibited high growth rate.

Comparative advantage and competitiveness of India's exports of major agricultural commodities in relation to other leading world exporters was assessed. India has a comparative advantage in commodities like tea, coffee, rice, castor oil, cashew nuts, spices, oil meals, tobacco, ground nuts and pulses. However, in the exports of wheat, sesame, sugar, vegetables, meat, fruits, dairy and marine products, India cannot boast of a comparative advantage.

### 6.1.3 Implications of Labour Migration on Rural Economy of Indo-Gangetic Plains

A study examined the magnitude and determinants of migration, its implication on structural and socio-economic condition of farm households of Indo-Gangetic Plains of India. The study identified that low wages, lack of adequate employment and seasonal nature of work availability were the major push factors for out-migration. Though the income inequality was found lower in migrant households as compared to that in non-migrants, the returns and economic efficiency in wheat and paddy cultivation were significantly higher on non-migrant households than on the migrants. The study also highlighted that migration has increased the drudgery of the female members of the migrant families. The drudgery index ranged from 0.70 to 0.80 for migrant households as compared to 0.45 to 0.58 for non-migrant households in the study area. However, migration had contributed positively towards empowering the female members of the migrant households in terms of enhancing their decision making role in various farm-household activities. Increased involvement of women in migrant household was seen in decision making regarding sale of farm produce, storage of seed, hiring of labour, children's education, purchase and sale of livestock, farm input use and crops/variety selection. However, the empowerment score for the traditionally male dominating decisions of capital investment and purchase and sale of land was found still relatively low. Other social changes felt due to migration by the family of non-migrants include shortage of labour in the locality, reduction in social harmony and decrease in attachment with villagers due to migration.

### 6.1.4 Management of Peri-urban Agriculture

***Peri-urban agriculture in Delhi.*** India's two cities, Mumbai and Delhi are expected to be the largest cities with 26.4 and 22.5 million people, respectively, by 2025. Sharp rise in demand for food articles including fruits and vegetables in Delhi led to widen the gap in their requirement and production. Rapid urbanization and growth of trade and industry have reduced the contribution of agriculture sector significantly in Delhi's economy. The share of agriculture and allied activities in the Gross State Product had declined

sharply from 1.40 per cent in 1999-2000 to 0.81 per cent in 2006-07. The requirement and availability of food items were calculated for Delhi and a big gap was observed. Delhi produced only one per cent of its requirement for foodgrains. In the case of vegetables, fruits and milk, it was only 5.2%, 0.59% and 11.70%, respectively.

***Profitability and annual net returns.*** The benefit–cost analysis showed that high value vegetables were highly profitable (1:1.96) followed by seasonal vegetables (1:1.63) and cereals (1:1.12). These high value vegetables contributed more than three-fourths of the total farm returns. The farmers grew cereals as their staple food, while they sold their horticultural crops for increasing their income.

***Technical and economic efficiencies.*** Small and marginal farmers were found to be more efficient than medium and large farmers in terms of technical and economic efficiencies. Technical efficiency of 0.90% and economic efficiency of 0.87% were observed for cereals. These were 0.92% (technical efficiency) and 0.85% (economic efficiency) for horticultural crops and 0.98% (technical efficiency) and 0.95% (economic efficiency) for high value crops. Geographical location, easy availability of inputs and regulated markets, and willingness of farmers to adopt high-tech methods were found conducive to increase their technical and economic efficiencies.

### 6.1.5 Input Use and Productivity in the Rice-Wheat Cropping System

Water use and net irrigated area by different sources in the Rice Wheat System of the Indo-Gangetic Plains (IGP) revealed that surface water irrigation declined by 8.7% while ground water irrigation increased by 279% during the last four decades. While the canal supplies increased marginally (6.36%) and tank irrigation declined by 29%, tube well irrigation showed a tremendous increase. Such an exorbitant increase of ground water irrigation in IGP implied that the demands for water from the rice-wheat system exceeded that available from rain and canal supplies, and such excessive withdrawal of ground water could be unsustainable in long run. As annual water extraction rate exceeds the recharge rate, the likely adverse impacts are: declining per capita availability of water, water stress, water quality issues, salinity/alkalinity, and poor soil health. Policies targeting water and energy pricing, conjunctive water use and conservation can lead to sustainable agriculture in IGP.

Fertilizer consumption in IGP from 1975 to 2009 showed a positive trend with a huge increase particularly in *kharif* season (1297%) when rice crop is predominantly grown. NPK consumption showed an increase of 691% for N, 1265% for P, and 546% for K during the corresponding period. Such excessive uses of fertilizers have environmental concerns and can worsen water quality. Need-based application of fertilizers can be advocated to sustain crop production in the rice-wheat system of IGP.

The average productivity of rice in IGP region is 3.66 tonne per hectare. However, a wide variation has been witnessed among IGP states as far as rice productivity is concerned. It runs as high as 5.44 tonne per hectare in Punjab and as low as 2 tonne per hectare in Bihar. Regional disparity and low yield of rice in such disadvantaged states dampen the overall performance in IGP region. It is important to identify the production constraints in rice crop in the states like Bihar and Uttar Pradesh so that rice productivity can be improved and regional disparity can be reduced. Growth rate of rice production has shown a decline (0.90%) during 2000-08 from 5.6% during 1980-90, and a decrease in yield growth rate has been witnessed from 2.45% to 1.89% during the corresponding period. Decomposition of sources of growth in rice production in IGP revealed that the yield effect was more in states like Bihar (114%) and West Bengal (97%) whereas the area effect was significant in Punjab (58%) and Haryana (83%). To arrest the recent deceleration in growth rate of rice production in IGP region, it is important to put in place appropriate policies for technology push and institutional reforms.

### 6.1.6 Co-integration of Horticultural Markets

A study examined the different aspects of vegetable marketing in some selected APMC vegetable markets in the country. These APMC markets were established to improve the marketing efficiency. The study was conducted with the objectives (i) to ascertain the pattern of price of major fruits and vegetables in APMC markets in India, (ii) to analyze the

market integration of major fruits and vegetable markets, and (iii) to observe the relationship between arrival price and price of these commodities in APMC markets. The seasonality of price was analyzed through ratio to trend technique and it was observed that onion price had more or less similar pattern across the country with one or two markets showing some deviation. The integration among different horticultural markets was examined using Johanson co-integration analysis. The results showed that major vegetable markets are well integrated while small markets are weakly integrated. However, the market integration, in general, has improved over the years.

### 6.1.7 Artificial Neural Networks for Time Series Forecasting

During the last decade, several non-linear time series models such as the bilinear model, the threshold autoregressive (TAR) model and the generalized auto regressive conditional heteroscedasticity (GARCH) model were developed. But, these non-linear models are still limited in the sense that an explicit relationship for the data series at hand has to be hypothesized with little knowledge of the underlying law.

In this study, two particles swarm optimization (PSO) based multi-layer feed forward neural networks were developed using real financial time series data. The prediction ability of these PSO based neural networks was compared with a standard back-propagation (Levenberg-Marquardt algorithm) trained network with respect to usual performance measures such as the mean squared error (MSE), and the mean absolute error (MAE) for three forecasting horizons that are ten days ahead, thirty days ahead, and sixty days ahead. The data series was divided into three parts: training set, validation set and testing set for conducting the experiment in order to determine the best neural network structure.

Out of 40 neural network structures, a model with eight input nodes and six hidden nodes provided the best test result. In order to eliminate the effect of initial value and to increase the possibility of obtaining the true global minima, the Institutes' scientists trained each network 20 times by using different initial weights to select the best model for prediction with the given data set. Results clearly show that both PSO based training algorithms provide better forecasting ability with respect to the MSE and MAE across all the three forecasting horizons in comparison to the standard neural network. Further, neural network model based on Trelea II uniformly provided better forecasting accuracy than Trelea I with respect to performance measures across all the three forecasting horizons except for the 60 days period with the MAE.

## 6.2 AGRICULTURAL EXTENSION

### 6.2.1 Cyber Extension Model

#### 6.2.1.1 Agro-information, input and output behaviour of farmers

The information, input and output behaviour of the farmers were studied and the information needs of the farmers were identified and prioritised. A survey among 60 farmers of villages under Sidhauli block of Sitapur district of Uttar Pradesh revealed that major sources of farm information were progressive farmers (53.3%) and input dealers (41.6%). Radio and television were also used by 31.6% and 21.6% farmers, respectively.

The investigation further revealed that a large number of farmers were the owners of modern information and communication technologies. Radio was owned by 91.6 per cent farmers, while 81.6 per cent of farmers had mobile phones. However, only 3.3 per cent of farmers owned computers. The awareness of respondents about improved farm technologies was found to be poor. Only 36 per cent of farmers had heard about improved varieties of different crops of IARI. The percentage of farmers who had awareness about IPM, drip Irrigation, bio-fertiliser and bio-pesticides was 26.6, 33.3, 41.6 and 38.3, respectively. With regard to mass media usage for seeking farm information, it was found that 76.7 per cent of the farmers listened to radio everyday for farm information while only 30 per cent of farmers read newspapers daily. Television and newspapers were used twice in a week for seeking information by 61.7 and 56.7 per cent of farmers, respectively. Internet services were accessed once or twice in a year by the farmers mainly for seeing the results of board examinations. In the case of mobile phones, some service providers sent short message service (SMS)

consisting of price of agricultural commodities in local market, which was used by 5 per cent of farmers.

The market related information was mostly accessed through input dealers (65%) followed by radio (60%) and progressive farmers (50%). It was observed that farmers were willing to pay for quality information which could lead to substantial economic returns. It was observed that majority of the farmers were willing to pay for information about market price (91.6%) followed by information about weather (76.6%).

An investigation into the information need of the farmers revealed that most of the farmers (above 90%) needed farm information related to areas such as pest and disease management, improved crop varieties, availability of quality seed and market price. Further, farm information was also needed by a large number of farmers (about 61.6% to 76.7%) in areas related to weather forecasting at local level, disease management in livestock, availability of inputs and availability of quality planting material. The other areas in which farmers needed information related to rejuvenation of orchards, insect-pest management in mango and farm credit/subsidy schemes or crop insurance. It was noted that only 19 per cent of the farmers needed information about post harvest management and value addition of fruits and vegetables. This might be due to their ignorance about post harvest management and value addition.

#### 6.2.1.2 Dissemination of IARI technology through post office

An action research was initiated for dissemination of IARI technologies through post office. The IARI wheat varieties, HD 2733 and HD 2824 were sent by post to 78 farmers, particularly the *village pradhans* of the Sidhauli block under Sitapur district in the state of Uttar Pradesh, to find out how far the post offices could be used to create awareness among the farmers about improved technologies and information packages. Each farmer was sent a parcel of 10 kg of IARI wheat variety seeds. The study showed that 83 per cent of the farmers received the seed of wheat (variety HD 2733 and HD 2824) sent through post office within 4-6 days of despatch from IARI. All the farmers, who received the seed had sown the seed.

A preliminary assessment of the performance of IARI wheat varieties (HD 2733 and HD 2824) showed that the farmers were very happy to receive the quality seeds, and the crop growth was good. The farmers also found the extension literature supplied to them as useful. The *village pradhans* showed willingness to multiply the seeds of IARI varieties and to share them with other farmers. It was clear that sending seed through post office could be an effective mechanism of dissemination of technology if the farmers are motivated and an institutional mechanism is made for seed multiplication and distribution to the neighbouring villages.

### 6.2.2 Analyzing Extension Models and Strategies for Sustainable Agricultural Development

#### 6.2.2.1 Analysis of innovative extension approaches

Documentation of existing extension models revealed several innovative initiatives taken up in various states for effective dissemination of information and technology as well as capacity building of farmers. Farmers' Field School (FFS) has been deployed as an effective means for educating the farmers about new technology in the states of Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab, Tamil Nadu, and Uttar Pradesh. Case analysis of Farmers' Field School *(Rayatu Kshetra Pathshala)* at village Chage of Chikkaballapura district in Karnataka revealed that a group of 30 registered farmers along with the collaborator farmer, Shri Krishnamoorthy, learnt about the cultivation of tomato with better water use efficiency and eco-friendly management of insect pests. In the case of tomato (var. US 618), the farmers learnt that with the use of wider spacing (90 cm x 60 cm), application of *Trichoderma*, bio-fertilizers (PSB), planting of marigold as trap crop, balanced fertilizer application, use of broad bed and furrow irrigation method and adoption of IPM practices (use of yellow sticky boards, pheromone traps, application of neem seed kernel extracts and plant products chemicals) in place of their own practices of using closer spacing (60 cm x 30 cm), imbalanced fertilizer application, single furrow irrigation and over-irrigation and improper plant protection, the yield could be increased by 14-15 per cent with 30-40 per cent reduction in cost of cultivation, reduction in number of irrigation by 25 per cent

and enhanced water use efficiency of about one t/ha-cm as against about 0.750 t/ha-cm in the case of farmers' practice. The knowledge scores on components of integrated management of tomato obtained by administering a knowledge test among the 30 farmers participating in the FFS and 30 non-participating farmers randomly drawn from the village where FFS was conducted and 30 farmers randomly drawn from non-FFS village were subjected to Kruskal-Wallis test, which revealed that the mean knowledge scores of the three sets of farmers were significantly different. It could be concluded that as a result of participation in FFS, the participating farmers were different from non-participating farmers with respect to knowledge about integrated crop management of tomato. Of the 30 participating farmers, six women members volunteered to act as collaborators. This reflects that besides enhancement in technological know-how and do-how, the Farmers' Field School concept facilitates empowerment process and increases self-esteem of farmers besides complementing other extension methods. This is also an appropriate method to strengthen and foster grassroots experimentation orientation among farmers. One farmer in Bangalore rural district in Karnataka started experimentation with aerobic rice cultivation by the use of drip irrigation system, through which he could reduce the seed rate by 50 per cent as compared to that under SRI method and he also expects to reduce the irrigation water requirement by 60-70 per cent. Farmers' feedback for the limitations and constraints in Farmers' Field School were identified as low attendance of participating farmers sometimes due to engagement with agricultural operations and dependence of small farmers on wages, time consuming school process, lack of inputs, and lack of female trainers.

Disseminating agricultural information through schoolchildren was found to be a novel method adopted by Haryana, where farmers were benefited with the information on early sowing of wheat and seed treatment with fungicide and bio-inoculants. An intervention was made at village school at Sahjadpur, Sonepat in Haryana wherein the school children were sensitized towards food security, environment, and rural development; motivated to be knowledge workers for parents and other farmers in village; and educated about the Green Revolution and the contribution of agricultural science and the modern varieties of IARI. Demonstrations were proposed through school children for practical learning about agricultural science and community work.

### 6.2.2.2 A case study on precision farming extension components

A case study was undertaken to investigate the major components of precision farming extension as well as its impact. Precision farming was started in 2004 by Tamil Nadu Agricultural University, Coimbatore, in Dharampuri and Krishnagari districts of Tamil Nadu in 400 hectares of land. The major focus of this extension approach was to prepare farmers for market-led agriculture and promote hi-tech horticulture with in-built precision farming elements. The key precision farming technologies identified are as follows:

**(i) Drip and fertigation system:** One of the major components of precision farming extension was drip and fertigation system to ensure water economy and precise application of soluble fertilizer in root zone. This helped in realising an ideal soil moisture regime of 60 per cent and an aeration of 40 per cent. This also aided in keeping the surface of the soil dry which resulted in less weed growth and lower incidences of plant diseases. Lower weed infestation also led to reduction of labour expenses. **(ii) Community nursery:** Community nurseries were adopted to produce uniform seedlings which were raised in net houses. **(iii) Field preparation:** Chisel ploughing was recommended once in two years to ensure better aeration to root zones and drainage in the case of excess field moisture. **(iv) Other crop production technologies**: The other crop production technologies included the use of high yielding or hybrid seeds, integrated plant protection method, and effective weed management. **(v) Social technology**: The major social technologies included cluster approach for mobilizing farmers to help in collective marketing. Farmers were also mobilised to form 'precision farmers' association'. Farmers were also encouraged to establish 'agro service centres' for supply of quality inputs.

### 6.2.2.3 Impact of precision farming extension approach

The precision farming extension technologies were provided to the farmers through financial assistance. The

cost of complete package of technology was about Rs.1.1 lakh per hectare. As a result of this precision farming extension, there was an increase in yield of all the crops by 60-80 per cent. Further, there was a labour saving up to 50 per cent. The farmers also got a profit margin of Rs. 1 lakh to 4 lakhs per hectare of major horticultural crops.

### 6.2.3 Constraints in Technology Adoption and Yield Gap in Pulses and Cereals

**Yield gap analysis for chickpea (var. BGD 72) during *rabi* 2009-10**

| State | Area (ha) | Yield (t/ha) | | | Yield gap-I (t/ha) (C-A) | Yield gap-II (t/ha) (A-B) |
|---|---|---|---|---|---|---|
| | | Demo. (A) | Check (B) | Research Station(C) | | |
| Uttar Pradesh | 4.0 (10) | 1.36 | 0.75 | 3 | 1.64 | 0.61 |
| Madhya Pradesh | 3.0 (2) | 1.00 | 0.71 | 3 | 2.00 | 0.29 |
| Maharashtra | 2.0 (2) | 1.88 | 1.35 | 3 | 1.13 | 0.52 |
| Bihar | 1.0 (5) | 0.96 | 0.70 | 3 | 0.74 | 0.26 |
| **Total/Average** | **10.0** (19) | 1.30 | 0.88 | 3 | 1.38 | 0.42 |

Figures in parentheses indicate the number of demonstrations conducted

A study aimed at analyzing the yield trend as well as identifying the yield gaps of important pulse and foodgrain crops besides delineating the constraints in adoption of the improved technologies. The profitability demonstrations of chickpea (var BGD 72) were laid out in ten hectares in four states, namely, Uttar Pradesh (4 hectares), Madhya Pradesh (3 hectares), Maharashtra (2 hectares) and Bihar (one hectare). With comparative yield data of demonstration plots, research station plots and farmers' plots, yield gaps were analyzed. The average yield gap-I for chickpea was observed as 1.38 t/ha while, the average yield gap-II was relatively lower, i.e., 0.42 t/ha. The profitability analysis of chickpea showed that the net profit in BGD 72 was higher than that of the farmers' variety in Maharashtra and Bihar.

The profitability demonstrations of IARI wheat varieties (HD 2733, HD 2851, HD 2329, and WR 544) were also laid out in the states of Madhya Pradesh, Uttar Pradesh, Maharashtra and Bihar in farmers' field at different locations. An average yield gap-I of 1.38 t/ha was observed in wheat, while the average yield gap-II was 0.97 t/ha. As evident from the demonstrations and yield gap analysis what are more critical, include concerted efforts of adaptive research to standardize appropriate package of practices to reduce the yield gap-I and educating the farmers about improved varieties and production management technologies for reducing the yield gap-II. The profitability analysis of wheat and chickpea showed that the net profit in chickpea was higher than that in wheat.

**Yield gap analysis for improved varieties of wheat**

| State | Area (ha) | Yield (t/ha) | | | Yield gap-I (t/ha) (C-A) | Yield gap-II (t/ha) (A-B) |
|---|---|---|---|---|---|---|
| | | Demo. (A) | Check (B) | Research Station(C) | | |
| Madhya Pradesh | 8.00 (11) | 2.18 | 1.61 | 5 | 2.82 | 0.57 |
| Uttar Pradesh | 7.20 (15) | 4.47 | 2.82 | 5 | 0.53 | 1.65 |
| Bihar | 0.80 (1) | 4.20 | 3.50 | 5 | 0.800 | 0.70 |
| **Total/Average** | **16.00 (27)** | **3.62** | **2.64** | **5** | **1.38** | **0.97** |

Figures in parentheses indicate the number of demonstrations conducted

A comparative analysis of demonstrations showed that per hectare average yield of chickpea (0.20 t/ha) was much lower than that of wheat (0.36 t/ha). However, the profitability analysis of IARI wheat and chickpea varieties revealed that even with the same level of the cost of production (Rs 15,000/ha), the net profit from chickpea (Rs. 45,000/ha) was higher than the net profit from wheat (Rs. 24,600/ha). The B: C ratio too was higher for chickpea (4.00) than for wheat (2.64). The

demonstrations amply showed and communicated to the farmers that cultivation of chickpea was more profitable than wheat.

### 6.2.4 Enhancing Entrepreneurship among Rural Youth

#### 6.2.4.1 Success factors and impact of interventions

Case studies of selected entrepreneurs were studied to delineate facilitative factors, innovations generated and best practices followed by them to succeed as entrepreneurs. Constraints and problems of farmers in developing agri-enterprises were also probed into.

***Best practices of seed production enterprises***. Three cases of wheat and soybean seed producers from Dhar, Dewas and Hathod districts and a case of potato-wheat-soybean seed producer of Hathod district of Madhya Pradesh revealed their best practices as: (a) crop diversification and cultivation of high yielding varieties; (b) quality seed production of wheat varieties, namely, GW 366, HI 1544 (Purna), HI 8498 (Malawshakti), HI 1531(Harshita), and HI 8663 (Poshan), soybean varieties: JS 93-05, JS 95-60, and NRC 7, and potato varieties: Chipsona, Safed Lakar, and Surya; (c) development of innovative technology and farming methods; (d) effective linkages with other agencies; (e) utilization of marketing channels; (f) knowledge and information seeking behaviour of the farmers; and (g) adequate knowledge and skills before taking up an enterprise.

Some of the innovative methods used by the farmers included under leaf sprayer for soybean; bund former in combination with seed drill which was used for building irrigation channels along with sowing; use of a rod behind tractor after ploughing for leveling the field instead of the usual plank considering the soil quality of the region where rod is more effective; innovative duck foot kind of structure for making ridges for irrigation to be used simultaneously with seed drill; converting big drum into a sprayer to be used with tractor; and using thin tyres for tractor when spraying.

***Best practices of growers of high value crop of Meghalaya (Turmeric).*** A member of Laryntih Self Help Group, Smt. Demmon Pala, aged about 34 years and a mother of six children from Mowkyndeng village, witnessed a vast change after taking up cultivation of turmeric. She is a member of a self help group, which is a part of an SHG Federation called L.I.F.E (Laskein Federation of SHGs) for the cultivation and processing of Lakadong turmeric in Jaintia hills. Lakadong is considered to be one of the finest varieties of turmeric in the world with high curcumin content (6.8-7.5 per cent as recorded by ICAR). The slicing of turmeric was done by hand which is time consuming often leading to drudgery and inefficiency. The method of drying too was not hygienic and wholly dependent on the availability of sunlight. By learning about mechanisation with exposure trip to a processing plant in Kerala, a demonstration unit was set up and the SHG Federation contributed 10 per cent of the total cost of this unit. The unit is being run by trained members of the Federation and they could increase production from 70 million tonnes to 700 million tonnes.

The best practices they followed were: improvement in the quality that fetched better market price; learning from others' experience (the skills for processing of turmeric learnt from Kerala); organic certification and AGMARK certification.

***Facilitative factors for success of agricultural entrepreneurs.*** Case analyses revealed acquisition of adequate knowledge by farmers as the most important facilitative factor in entrepreneurship development followed by their ability to assess opportunity to capitalize on farmers' own innovativeness. The third rank was attributed to farmers' self-involvement in day-to-day enterprise activities and their passion to do things in an excellent manner. Urge for excellence has earlier been reported to be one of the critical components for entrepreneurship development. Other factors, which were found to be facilitative, were: farmers' problem solving ability, perseverance and determination of entrepreneurs, quality of products, optimum utilization of available resources, special incentives and schemes for rural enterprises' continuous progress.

***Inhibitive factors for success of agricultural entrepreneurs.*** Case analyses revealed lack of entrepreneurial competencies among farmers as the most important inhibitive

**Training needs of SHG members in management skills**

| Training need areas | Perceived mean scores and rank | | | | |
|---|---|---|---|---|---|
| | Tamil Nadu (n=100) | Andhra Pradesh (n=100) | Orissa (n=50) | Bihar (n=40) | Overall perceived mean scores |
| Leadership | 2.44 (X) | 2.96 (VIII) | 4.4 (II) | 2.45 (IX) | 3.06 (XI) |
| Planning | 2.81(IV) | 4.59 (III) | 4.06 (III) | 3.09 (II) | 3.64 (II) |
| Time management | 2.94 (II) | 4.79 (II) | 3.56 (IV) | 2.92(VII) | 3.55 (III) |
| Team building | 2.77(V) | 5.0 (I) | 3.42 (VI) | 2.76 (VIII) | 3.49 (IV) |
| Motivation | 2.70 (VII) | 5.0 (I) | 3.46 (V) | 2.30 (X) | 3.37 (VII) |
| Decision making | 2.58 (IX) | 3.78(VII) | 5.0 (I) | 3.59 (I) | 3.74 (I) |
| Coordination | 2.86 (III) | 2.89 (IX) | 5.0 (I) | 3.04 (IV) | 3.45 (VI) |
| Conflict management | 2.34 (XI) | 4.3 (V) | 3.06 (VIII) | 2.98 (VI) | 3.17 (IX) |
| Accounting | 3.07 (I) | 4.5 (IV) | 3.3(VII) | 3.05 (III) | 3.48 (V) |
| Record keeping | 2.67 (VIII) | 4.3 (V) | 2.92 (X) | 1.93 (XI) | 3.30 (VIII) |
| Handling meeting | 2.72 (VI) | 3.82 (VI) | 3.02 (IX) | 3.02 (V) | 3.15 (X) |

factor in the success of agri-enterprises followed by getting critical technical guidance at the opportune time. The third rank was attributed to timely availability of inputs and market information and lack of avenues. Other factors, which were found to be inhibitive were : high cost of inputs, fluctuating demand, climate fluctuation and pest- disease attack, lack of infrastructure, technical specifications and food quality standards.

## 6.2.5 Training Modules for Enhancing the Effectiveness of SHGs

An assessment of the training needs of self-help group members was conducted for the development of capacity building training module. Using the snowball sampling technique, a total of 290 self-help group members drawn from Coimbatore district of Tamil Nadu, Prakasham district of Andhra Pradesh, Puri district of Orissa and Nalanda district of Bihar were subjected to training need assessment in the areas of management, communication and entrepreneurial skills through self anchoring scale having a continuum of very high to very low with respective weightage of 5 to 1. Among the management skills, training need in "leadership" assumed second rank for the SHG members of Orissa, while "planning" assumed second rank for the SHG members of Bihar. "Time management" got second rank as training need for the members of Tamil Nadu and Andhra Pradesh and fourth rank in the case of Orissa. Training need in "team building" and "motivation" assumed first rank in the states of Andhra Pradesh while "decision making" and "coordination" assumed first rank in Orissa. Training need in "accounting" got first and third ranks for the members of Tamil Nadu and Bihar, respectively. Based on overall mean scores across the states, the training needs according to their descending order of ranks were: decision-making, planning, time management, team building, accounting, coordination, motivation, record keeping, conflict management, handling meeting and leadership.

Among the entrepreneurial skills, "enterprise selection" with perceived mean score of 4.16 and "marketing skills" with perceived mean score of 3.21 assumed first and second ranks, respectively, in the state of Tamil Nadu while "floriculture" and "seed production" obtained first rank in Andhra Pradesh and Orissa. Training need in "food processing" had first rank in Bihar while it had second rank in Andhra Pradesh and Orissa. According to overall perceived mean scores across the states, the ranks of the training need areas in descending order were: food processing, seed production, biogas application, enterprise selection, bee keeping, floriculture, mushroom cultivation, entrepreneurial management, risk taking and marketing.

## 6.2.6 Visioning, Policy Analysis and Gender (V-PAGe)

An impact analysis of Pusa 1121, a *basmati* rice variety of IARI was done. *Basmati* rice export is worth Rs. 3000 crore for India. India exported 1.8 million tonnes of *basmati* in 2009-10. There was approximately 60 per cent of area increase in Punjab and 40 per cent area increase in Haryana

**Training needs of SHG members in entrepreneurial skills**

| Training need areas | Perceived mean scores and rank | | | | |
|---|---|---|---|---|---|
| | Tamil Nadu (n=100) | Andhra Pradesh (n=100) | Orissa (n=50) | Bihar (n=40) | Overall perceived mean scores |
| Risk taking | 2.31 (V) | 3.32 (VII) | 3.39 (IX) | 2.30 (IX) | 2.83 (IX) |
| Enterprise selection | 4.16 (I) | 3.12 (VIII) | 4.13 (VI) | 2.43 (VII) | 3.46 (IV) |
| Marketing | 3.21 (II) | 2.01 (IX) | 2.94 (X) | 2.70 (VI) | 2.75 (X) |
| Entrepreneurial management | 3.12 (III) | 3.73 (IV) | 3.58 (VIII) | 2.40 (VIII) | 3.20 (VIII) |
| Mushroom cultivation | 2.23 (VII) | - | 4.65 (V) | 3.00 (IV) | 3.29 (VII) |
| Bee keeping | 2.27 (VI) | 3.42 (VI) | 4.81 (III) | 2.92 (V) | 3.36 (V) |
| Floriculture | 2.13 (IX) | 4.12 (I) | 4.0 (VII) | 3.08 (III) | 3.33 (VI) |
| Seed production | 2.13 (IX) | 3.60 (V) | 5.0 (I) | 3.52 (II) | 3.56 (II) |
| Biogas application | 2.17 (VIII) | 3.96 (III) | 4.75 (IV) | 3.08 (III) | 3.49 (III) |
| Food processing | 2.43 (IV) | 3.98 (II) | 4.85 (II) | 4.18 (I) | 3.86 (I) |

over the previous year's area under cultivation of Pusa 1121. It was sold at Rs. 25-30 thousands per tonne in 2009-2010. It was observed that the average area under cultivation of Pusa 1121 had increased from less than 0.2 ha to more than 1.6 ha between the years 2006 and 2009. The per hectare returns from Pusa1121 were very high. The per hectare returns were more than Rs. 70,000 per ha. The cost was approximately Rs. 30,000 per ha for the states of Punjab, Haryana and UP. The B/C ratio was more than 2.5 for the states of UP and Punjab and about 2 for Haryana.

### 6.2.7 Training for Human Resource Development for Extension

The Institute conducted one summer school of ICAR on **"**Tools & Techniques for Planning, Monitoring, Evaluation & Impact Assessment of Extension Programmes" and two winter schools on "Gender Empowerment in Agriculture" and "Capacity Building of Extension Professionals for Effective Training", benefiting 73 extension professionals in updating their knowledge and skills. Under CAS programme, a three-week training programme was conducted on "Entrepreneurship Development in Agriculture" while under the Centre for Advanced Faculty Training scheme of ICAR, a three-week training on "Methodological Advances in Extension Research" was conducted to upgrade the knowledge and skills of extension researchers in quantitative and qualitative measurements. The Institute also conducted an orientation training for SAARC scientists about "New Dimensions of Agricultural Research and Extension" and a model training course sponsored by the Directorate of Extension, Ministry of Agriculture on "Management Skills of Extension Professionals". In all, 146 extension professionals of ICAR institutes, SAUs and KVKs were trained.

## 6.3 TECHNOLOGY ASSESSMENT AND TRANSFER

### 6.3.1 Assessment of Agricultural Technologies in Peripheral Districts of NCR

Under a project being implemented in five districts (Sonipat, Faridabad, Aligarh, Palwal and Jhajjar) of Haryana, two districts (Aligarh and Bulandshahr) of UP, and Najafgarh block of NCT of Delhi, a cluster of 2-4 villages was selected at each project location to carry out the transfer of technology (TOT) activities. Progressive farmers in the project locations were also associated with the programme.

In *rabi* 2008-09, a total of 207 demonstrations on wheat (HD 2851, HD 2932, WR 544, PBW 550, HD 2824, and HD 2687), onion (Pusa Red), mustard (Pusa Jaikisan, Pusa Bold, and JD 6), lentil (L 4076), and gram (BGD 72) were conducted in the operational areas. In Sonipat district, a wheat variety HD 2932 gave the highest average yield of 5.11 t/ha with a B:C ratio of 2.31. Pusa Jagannath variety of mustard performed well and gave a B:C ratio of 2.22 in comparison to

the B:C ratio of 1.99 of Pusa Bold. In Faridabad district, all the three wheat varieties (HD 2851, WR 544, and HD 2687) under demonstration performed better than the local check and registered 4.1 per cent to 8.3 per cent increase in yield over the local variety. HD 2851 was the top yielder with an average yield of 5.20 t/ha. Mustard varieties, JD 6 and Pusa Jaikisan gave average yields of 1.80 t/ha and 2.10 t/ha, respectively, as against 1.65 t/ha of the local check (Rohini). In Aligarh and Palwal districts, wheat variety HD 2851 performed best while mustard variety Pusa Jagannath in Aligarh and Pusa Jaikishan in Palwal district performed best. Lentil variety L 4076 gave 2.25 t/ha as against 1.20 t/ha of control check. In Palwal district, among wheat varieties demonstrated, HD 2851 outperformed other varieties, viz, WR 544 and HD 2687 and gave 6.1% higher yield. Mustard variety Pusa Jaikisan outperformed all other varieties with an average yield of 2.10 t/ha followed by Pusa Bold with 2.00 t/ha as against 1.65 t/ha of the control. In Jhajjar district, wheat variety PBW 550 outperformed HD 2851, HD 2932, WR 544 and HD 2824 and gave 69.01% higher yield with a B:C ratio of 3.05. In Bulandshahr, Pusa Agrani variety of mustard gave an average yield of 2.25 t/ha and a B:C ratio of 2.45.

During *kharif* 2009**,** a total of 334 demonstrations on paddy (Pusa 1121, P 1460, PRH 10 and PB 1), *moong* (Pusa Vishal and Pusa Ratna), *arhar* (P 991 and P 992), bottle gourd (Pusa Naveen), and *bhindi* (Pusa A 4) were conducted in operational areas of Sonipat, Palwal, Faridabad, Rohtak, Ghaziabad, and Bulandshahr districts. In Faridabad and Palwal districts of Haryana, Pusa 1121 was the first choice of farmers owing to high yield and high market rate. In Ghaziabad district (UP), paddy varieties PRH 10, P 1460 and PS 4 gave average yields of 6.71, 4.85 and 3.84 t/ha, respectively, in comparison to 3.68 t/ha yield of local check (Sarbati). Pigonpea varieties P 991 and P 992 gave average yields of 2.18 and 2.16 t/ha, respectively, in comparison to 1.25 t/ha yield of the local check (*desi*). *Moong* (Pusa Vishal), bottle gourd (Pusa Naveen), and okra (Pusa A4) yielded higher than the local checks. At Rohtak and Sonipat districts (Haryana), paddy variety PRH 10 outperformed the other varieties (Pusa 1460, PB 1, and Pusa 1121). Farmers preferred PRH 10 for early maturity and higher yield and Pusa 1121 for higher market rate. In Baghpat district (UP), paddy variety PB 1 and in Aligarh district (UP), PRH 10 were identified as the most suitable varieties. Pigonpea (P 991) and *moong* (Pusa Vishal) performed well in Aligarh amd Bulandshahr.

During *rabi* 2009-10, 274 demonstrations on wheat (HD 2733, HD 2894, DBW 17, WR 544, PBW 550, HD 2824, HD 2932, SKAF 645, HD 2851, HD 2329, and HD 2987 (BS)), mustard (Pusa Bold, Pusa Jaikisan, JD 6, Pusa Tarak, Pusa Vijay, Pusa Jagannath, NRCDR, and Hybrid PM 6), cauliflower(PSB and K 1), cabbage(Golden Acre), lentil (L 4076), marigold (Pusa Narangi) and gladiolus (Pusa Kiran, Pusa Jyotsna were conducted in the adopted villages of Palwal, Ghaziabad, Rohtak, Sonipat, Baghpat, and Gurgaon.

### 6.3.2 Outreach National Extension Programme for Developing Integrated Models for Market-led Agriculture

A national extension programme was taken up in collaboration with 11 ICAR institutes/SAUs for quick and wider spread of IARI varieties and production technology to a large number of farmers in far off locations in different parts of the country. Collaboration was taken up with Marathwara Agricultural University, Parbhani, and Mahatma Phule Krishi Vidyapeeth, Rahuri in Maharashtra; BHU, Varanasi, IIVR, Varanasi and CIRG, Mathura in Uttar Pradesh; MPUA&T, Udaipur; and National Centre for Rapeseed and Mustard, Bharatpur in Rajasthan and University of Agricultural Sciences, Bangalore and Dharwad in Karnataka, BAU, Ranchi in Bihar, NAU Navsari (Gujarat) and CCSHPKVV, Palampur (Himachal Pradesh). In *rabi* 2008-09,

**Wheat demonstration in Palana Khurd, a tribal village of Udaipur, Rajasthan**

**IARI scientists observing the performance of a pigeon pea crop at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra under a collaborative extension programme**

in all, 287 demonstrations were conducted on varieties of wheat, gram, mustard and lentil. At MPUA&T, Udaipur, wheat variety HD 2884 gave higher average yield of 5.00 t/ha, which was 79.86% higher in comparison to that of the local check variety. Gram variety (BGD 72) recorded 130% higher yield as compared to the local variety. In MPKV, Rahuri, of 12 demonstrations on wheat varieties, HI 8498 and HI 8663 performed better. At IIVR, Varanasi, a total of 60 demonstrations on wheat (Kundan, HD 2851 and WR 544), gram (BG 1103 and BGD 128), and mustard (Pusa Bold) were conducted. Among wheat varieties, HD 2894 gave the highest yield of 5.06 t/ha followed by HD 2851 (5.01 t/ha).

During *kharif* 2009, at CIRG, Mathura, farmers perceived that in water stress condition, PC 334 variety of *bajra* and Pusa Vishal of *moong* were better and preferred these varieties for their bold seed and high economic returns. Pusa 1121 variety of paddy attracted the farmers for its high aromatic, super fine grains and high market price. At DRMR, Bharatpur (Rajasthan), feed/fodder obtained from pearl millet variety PC 383 was sweet in taste. The farmers liked the taste of the *dal* prepared from the *moong* variety Pusa Vishal. Owing to moisture stress, the true potential of this variety could not be harnessed. There was very good fruiting in this variety and farmers harvested the fruit pods twice.

At NAU, Navsari, Gujarat, pigeonpea variety Pusa 992 recorded 5.55% – 32.30% increase in grain yield over that of the local variety BDN 2. At BHU, Varanasi, paddy varieties, PRH 10, P 1121 and P 1460 gave less than potential yields due to low rainfall and inadequate irrigation. P 1121 was less preferred owing to breakage during milling and inadequate facilities in the area for milling. At UAS, Banglore (Karnataka), among all vegetable varieties, *palak* variety Pusa Bharati was found more acceptable by the farmers on the basis of its yield, better market price, broader leaves and rapid growth.

During *rabi* 2009-10, demonstrations on wheat varieties, HI 1500, HI 1531 and HI 1454, mustard varieties, Pusa Jaikisan, Pusa Bold and Pusa Tarak, Lentil variety L 4076, and gram variety BGD 72 were conducted. At CIRG, Mathura, overall average yields of wheat varieties were higher except WR 544 as compared to those of the local varieties. However, WR 544 is a late sown variety and can grow in limited irrigation facility. Farmers like it owing to its good *chapati* quality and attractive grains. However, owing to sudden rise in temperature at maturity, yield reduced up to 300-500 kg/ha. JD 6 and Pusa Agrani varieties of mustard proved a bonus crop in between early *kharif* and late *rabi* crops (1st week of September to mid December) and farmers preferred them for bold seed and high yields (46% and 63.7%, respectively). Pusa Jaikisan variety also attracted the farmers

**Results of demonstrations of IARI varieties under NEP during *rabi* 2009-10**

| Location | Name of crop | Variety | No. of demo. | Average Yield t/ha | | % increase in yield |
|---|---|---|---|---|---|---|
| | | | | Test variety | Local | |
| MPUAT, | Wheat | HD 2932 | 2 | 3.25 | 2.76 (Lok 1, Raj 3765) | 17.5 |
| Udaipur | | HD 2894 | 3 | 3.75 | | 35.57 |
| (Rajasthan) | | HD 2864 | 1 | 3.21 | | 16.0 |
| | Mustard | Pusa Agrani | 10 | 1.82 | 1.67 (T 59) | 8.85 |
| | | Pusa Bold | 5 | 1.94 | | 16.02 |
| UAS, Dharwad* | Wheat | HI 1531 | 8 | 0.67 | 0.52 | 28.65 |
| | | HI 8663 | 10 | 0.60 | 0.49 | 21.10 |

*contd...*

**Results of demonstrations of IARI varieties under NEP during *rabi* 2009-10** *(Concld.)*

| Location | Name of crop | Variety | No. of dem. | Average Yield t/ha | | % increase in yield |
|---|---|---|---|---|---|---|
| | | | | Test variety | Local | |
| BAU, Ranchi (Jharkhand) | Wheat | HI 1500 | 10 | 1.83 | 1.11 | 64.66 |
| | | HI 1531 | 11 | 1.75 | | 57.37 |
| | | HI 1454 | 12 | 2.33 | | 109.62 |
| | Mustard | Pusa Bold | 10 | 0.83 | 0.67 | 24.48 |
| | | Pusa Jaikisan | 10 | 0.86 | | 28.36 |
| | Lentil | L 4076 | 9 | 1.48 | 0.74 | 100.00 |
| | Gram | BGD 72 | 4 | 1.56 | 0.69 | 123.18 |
| MAU, Parbhani (MS) | Wheat | HI 8498 | 4 | 2.47 | 2.17 (Lok1) | 13.38 |
| | | HI 8663 | 4 | 3.53 | 2.88 | 22.46 |
| | | SKF-PS 645 | 1 | 2.38 | 2.00 | 19.00 |

*Owing to floods, the crop yield was badly affected.

because of its more economic yield. At DRMR, Bharatpur (Rajasthan), among wheat varieties assessed, profuse tillering was observed in HD 2733. Grain size of HD 2851 was found bold and attractive and responsive to heavy manurial application. Yield potential of PBW 550 was found good but grain size and texture of grains were poor. The yield of onion variety Pusa Red was high and this variety was preferred for its bold size and copper colour. Carrot variety Pusa Rudhira was preferred for its soft, juicy, long, and light red coloured roots having good yield potential. Lentil variety L 4076 was preferred by farmers for its bold attractive grain and high yield.

### 6.3.3 Participatory Seed Production of Improved IARI Varieties of Paddy and Wheat

During *rabi* 2008-09, 34.2 tonnes of wheat seeds of HD 2851, HD 2894 and WR 544 were produced at Rakhra, Patiala in Punjab. During *kharif* 2009, 93.15 tonnes of paddy seeds of P 44, P 1121, P 1460, P 1401, P 2511 and PB 1were produced at Patiala, Faridabad and Bulandshahr. During *rabi* 2009-10, wheat seeds of 405.9 tonnes of varieties, HD 2987, HD 2329, HD 2851, HD 2733, HD 2894, DBW 17, WR 544, DBW 17, HD 2932 and PBW 550 were produced at Ghaziabad, Aligarh, Patiala, Faridabad and Bulandshahr. In addition, 100 kg seeds each of mustard (Pusa Agrani) and pea (Pusa US 10), 800 kg of barley (Raj 2552), 1.8 tonnes of *moong* (Pusa Vishal and Pusa Ratna), 200 kg of *jowar* (PC-9), and 5.0 tonnes of potato (K. Bhahar, K. Surya, K. Chips 16-3, Kufri Anand, and Kufri Pukhraj) were produced at Bulandshahr.

### 6.3.4 Water Management Technologies for Sustainable Crop Production

In order to assess and transfer selected water management technologies to the end users for enhancing water and nutrient use efficiency and improving soil-health for sustainable agricultural productivity, the demonstrations were conducted on the use of biogas technology (80 biogas plants), SRI technology (35 demonstrations), bed planter (30 demonstrations), aqua-ferti-seed drill (20 demonstrations) and laser leveller (240 acres-45 in *kharif* 2009 and 195 in *rabi* 2009-10).

### 6.3.5 Front Line Demonstrations on Wheat and Maize

A total of 70 demonstrations (62 for grain and 8 for cob) on maize varieties, 30V-92, NMH 589, NMH 666 and 30R-77 were conducted in villages of Ghaziabad, J.P.Nagar, Aligarh and Bulandshahr districts in UP during *kharif* 2009. The grain yield of variety 30 R-77 was the highest (3.92 t/ha) followed by that of NMH 666 (3.87 t/ha) in comaprision to the local yield of 2.50 t/ha. Two varieties, NMH 666 and 30 R-77 demonstrated for cob gave an average increase in cob yield by 47.61 and 34.61 per cent, respectively, over that of the local check. Fifty-one FLDs covering an area of 21 ha on wheat were conducted during *rabi* 2009-10 in the farmers' field on three different components: (i) Newly released wheat varieties (DBW 17 and PBW 550), (ii) application of bio-fertilizer (Azotobacter+PSB) in newly released varieties, and

(iii) zero tillage at different locations (Ghaziabad, Baghpat, Aligarh, G.B. Nagar (UP) and Faridabad (Haryana). Varieties DBW 17 and PBW 550 gave average yields of 4.41 and 4.25 t/ha, respectively, in comparison to that of the local check (4.10 t/ha). Treatment of these varieties with bio-fertilizer (Azotobacter+PSB) and use of zero tillage resulted in an increase in yield ranging from 2.33 to 6.32 per cent over that of control.

### 6.3.6 Partnership under Non-Government Organisations

The Institute undertook a partnership programme with select NGOs for feasibility trials and promotion of agricultural technologies in their operational locations, a first of its kind in public-private partnership for agricultural transformation. Under this programme, 27 NGOs of repute from 16 states of the country were involved since *rabi* 2009-10 to assess and disseminate IARI technologies in their operational areas. Under this initiative, two workshops were organized. A toll free service (phone) was launched by IARI to facilitate communication with NGO partners.

### 6.3.7 Organisation of *Krishi Vigyan Melas*

#### 6.3.7.1 *Pusa Krishi Vigyan Mela* (2009)

The Institute organized a four-day *Pusa Krishi Vigyan Mela* on the theme "IARI Technologies for Farmers' Prosperity and Food Security" from February 23 to 26, 2009. Technologies developed at IARI for farmers' prosperity and food security were displayed in a huge thematic *pandal*, where some progressive farmers shared their useful experiences of IARI technologies with the visiting farmers. Different project directorates, divisions, centres and units of the Institute demonstrated their technologies in their respective stalls. Besides IARI, 8 state agricultural universities, 21 ICAR institutes including some livestock based research institutes, 35 private companies, 8 public sector undertakings, 25 organizations for flower show, and 15 NGOs/societies participated in the *mela* to demonstrate their technologies/products, for display or sale. Twenty-six progressive farmers from extension operational areas of the Institute also put up their stalls for display and sale of their farm produce. A total of 170 stalls, besides thematic pandals, displayed the latest agricultural technologies/products.

More than one lakh visitors from different parts of the country covering farmmen and farmwomen, students, extension workers, entrepreneurs and others visited the *mela*. Seeds of high yielding varieties of different crops worth rupees 25 lakhs were sold through Pusa Seed Sale Counter during the *mela* period. Many farmers from extension operational areas of the Institute putting up their stalls in the *mela* also sold truthfully labeled seeds of high yielding varieties produced on their fields through Farmer Participatory Seed Production Programme of IARI.

#### 6.3.7.2 *Pusa Krishi Vigyan Mela* (2010)

Pusa Krishi Vigyan Mela 2010 on the theme "Agricultural Technologies for National Prosperity" was organised from March 4 to 6, 2010. An area of around 5 acres was covered to display exhibits in 205 stalls. Besides IARI (34 stalls), state agricultural universities (4), ICAR institutes (23) including some livestock based research institutes, KVKs (4), private companies and NGOs (65), and public sector undertakings (5) participated in the *mela* to demonstrate their technologies/products for display or sale. Thirty-five progressive farmers from extension operational areas of the Institute also put-up their stalls for display and sale of their farm produce. Farmers were provided free of cost consultancy services at the *mela* site by various agricultural experts.

More than 1,00,000 visitors from different parts of the country including farmmen, farmwomen, students, extension

**Hon'ble Union Minister of Agriculture, Consumer Affairs, Food & Public Distribution, Shri Sharad Pawar visiting the thematic *pandal* at the venue of *Pusa Krishi Vigyan Mela* (2010)**

workers, entrepreneurs and others visited the *mela*. A few foreigners from Uganda and Nepal also visited the *mela*. Three technical sessions were utilized for farmers-scientists-industry interface on different themes. More than 5000 farmwomen and farmmen from different parts of the country participated in the Women Empowerment Workshop. Seeds of high yielding varieties of different crops worth Rs. 22 lakhs were sold through Pusa Seed Sale Counter during the *mela* period.

### 6.3.8 Off-campus Exhibitions

The CATAT and ATIC organized/participated in various agricultural exhibitions for display/sale of IARI technologies, products, services and publications. During the period, these centres participated in 12 exhibitions, of which 5 were at regional level, 4 at national level and 3 at international level.

### 6.3.9 Training of Farmers and Extension Workers

During the reported period, 42 training programmes were organised. The training programmes covered areas of production technology of various crops, water conservation technology, development of agricultural entrepreneurship, organic faming and vermicompost, use of biotechnology and GM seeds, rainfed farming, horticultural and post harvest technology, etc. Various interaction sessions with farmers, were also conducted. About 980 extension workers, agricultural officers, progressive farmers, etc., were trained. Training programmes were sponsored by various agencies like ATMA, Delhi Govt., Farm Schools of Bijnor and Saharanpur, Kisan Call Centre, State Institute for Rural Development (SIRD), Guahati, etc.

### 6.3.10 Agricultural Technology Information Centre (ATIC)

The ATIC is providing a single window delivery system for agricultural products, services and technologies to the farmers/entrepreneurs, etc. Besides, the ATIC is providing farm advice to the farmers through Pusa Helpline (011-25841670), exhibitions, farm literature and letters. Information and advisory needs of the visitors are also being catered through information museum, plant clinic, farm library and exhibits related to agriculture implements, seed samples, and bio-fertilizers displayed in the Centre.

Live demonstrations on the latest varieties of wheat, mustard, vegetables, horticultural crops and medicinal plants, and green manure were conducted.

About 13,685 farmers/entrepreneurs, development department officials, students, NGO representatives, etc. from 22 states of India visited the Centre and its stalls in various exhibitions during the year for farm advisory, diagnostic services, purchase of technological inputs/products and trainings. Maximum number of farmers visited the Centre to purchase or enquire about seeds/varieties (9,052), horticultural and medicinal plants related information (5,120), plant protection related information (2,348), information on agro-based enterprises (904), and information related to farm literature (3,242), dairy (486), agricultural implements (644) and other agricultural aspects (1077).

Besides farmers, industry has shown a lot of interest in IARI research products. The Centre is providing a mechanism for getting direct feed-back from the technology users to the technology generators. The Centre has also developed functional linkages with various agencies working for the farming community to effectively cater to the information needs of different stake holders.

### 6.3.11 Krishi Vigyan Kendra (KVK), Shikohpur, Gurgaon

#### 6.3.11.1 Front line demonstrations

During the period, 80 demonstrations (*rabi* 2008-09 and *kharif* 2009) covering 39.7 ha on oilseeds, pulses and cereal crops were organized in the farmer's fields in 9 villages of 4 blocks of Gurgaon district.

The average yields of mustard, gram, wheat, barley, pea, *arhar, moong* and *bajra*, were 02.253, 1.960, 5.028, 4.960, 7.100 (green pods), 1.746, 0.975, and 3.377 tonnes per hectare, respectively. The comparative results revealed that the average yield of mustard, gram, wheat, barley, pea, *arhar, moong* and *bajra* increased by 14.71%, 19.69%, 0.56%, 63.42%, 6.63%, 10.50%, 13.37% and 6.36%, respectively, over that of the farmer's existing practices.

During *rabi* 2008-09, the KVK organized seven demonstrations on wheat (covering 3.00 ha) sponsored by the Directorate of Wheat Research (DWR), Karnal.

**Details of front line demonstrations organized by the KVK**

| Season | Crop | Varieties | No. of demons-trations | Area (ha) |
|---|---|---|---|---|
| ***Rabi*** 2008-09 | Mustard | Pusa Jagannath | 30 | 19.50 |
| | Gram | Pusa 1103 | 03 | 1.00 |
| | Wheat | HD 2851 | 10 | 4.00 |
| | Barley | BH 393 | 10 | 4.00 |
| | Pea (for green pods) | Azad P-1 | 04 | 1.20 |
| | | **Total** | **57** | **29.70** |
| ***Kharif*** 2009 | *Arhar* | Pusa 991 | 08 | 4.00 |
| | *Moong* | Pusa Vishal | 05 | 2.00 |
| | *Bajra* | 9944 (Proagro) | 10 | 4.00 |
| | | **Total** | **23** | **10.00** |
| | | **Grand Total** | **80** | **39.70** |

### 6.3.11.3 On-farm testing

During the period, 19 on-farm trials (OFTs) were conducted on different field/farm based problems and 2 trials were conducted on animal based problems.

### 6.3.11.4 Agricultural extension activities and farm advisory services

For speedy dissemination of technologies among the farming community, the KVK organized various extension activities in the villages of Gurgaon district, and at the KVK campus. During the period, 2 *kisan melas*, 18 field days on different crops, 3 farmers' fairs-cum-field days, 1 World Food Day celebration, 2 honey days, 1 animal health day-cum-clinical camp, 31 method demonstrations, 22 group meetings/ discussions, 9 camps/campaigns, 42 lectures by the subject matter specialists of the KVK, 15 programmes on TV/radio,

**Details of sponsored front line demonstrations organized by the KVK**

| Season/ Year *Rabi 2008-09* | Theme of FLDs | Name of variety | No. of demos-trations | Area (ha) (t/ha) | Avg. yield | Increase overcontrol | |
|---|---|---|---|---|---|---|---|
| | | | | | | (kg) | (%) |
| | (i) New variety | DBW17 | 05 | 2.00 | Demo- 5.207<br>Local -5.039 | 168 | 3.33 |
| | (ii) Use of biofertilizers (*Azotobactor* and PSB) | DBW17 | 02 | 1.00 | Demo- 5.242<br>Local -5.001 | 241 | 4.82 |

* Bio-fertilizers used –

**Details of trainings organized for different target groups**

| Type of training with target groups | No. | No. of beneficiaries |
|---|---|---|
| Vocational trainings for rural youth | 07 | 144 |
| Day long on/off campus trainings for practicing farmers | 64 | 1320 |
| In-service (refresher course) trainings for field extension functionaries | 04 | 54 |
| Collaborative trainings | 06 | 149 |
| **Total** | **81** | **1667** |

### 6.3.11.2 Trainings for different target groups

The major objectives of on-campus and off-campus trainings were to generate opportunities for income and employment; to provide technical knowhow to the practicing farmers; and to update the knowledge of in-service personnel.

**Details of OFTs conducted in farmers' fields**

| Title of OFTs | No. of trails |
|---|---|
| Evaluation of new herbicide molecule for weed control in wheat | 04 |
| Management of pod borer in gram | 04 |
| Balanced fertilization in wheat | 04 |
| Stem rot management in mustard | 04 |
| Effect of plant hormones on regulation of flowers/yield in marigold | 03 |
| Worm problems in calves | 01 |
| Imbalanced feeding | 01 |

12 press releases on the KVK activities, 166 field visits of scientists/SMS in farmers' fields, and 433 visits of farmers at the KVK for scientific/farm advice were the important activities organized by the Kendra.

*Krishi Vigyan Patrika*, a quarterly newsletter of the Kendra (in Hindi) continued to provide the latest technologies to the farmers at the appropriate time at their doorsteps.

# 7. EMPOWERMENT OF WOMEN AND MAINSTREAMING OF GENDER ISSUES

## 7.1 GENDER EMPOWERMENT THROUGH SELF-HELP GROUPS

### 7.1.1 Empowerment of Women

Collective action was employed as an effective means for gender empowerment. A study conducted by the Institute on women self-help groups (SHGs) showed that they had taken up community action for their betterment.

The SHGs had promoted community action initiatives among the members. Of the four states, namely, Tamil Nadu, Andhra Pradesh, Orissa and Bihar, under study, Orissa was found to be the leading state in taking up community activities like water supply, education related activities, health and sanitation related activities, veterinary care, campaign on social issues and women related issues by higher percentages (94, 68, 82, 64, 72 and 76 respectively) of members. The next state to follow was Bihar with respective percentages of 15, 42.5, 67.5, 50, 50 and 82.5 for the above activities and for improving village road (35%).

The SHGs had also led to improvements in the personal finance of the members, to a great extent, for the majority of SHG members in Tamil Nadu (98%), Andhra Pradesh (96%) and Orissa (86%) and, to a moderate extent, for the majority of members in Bihar (55%). Except for Orissa (64%), the share of SHG members in family income had increased, to a moderate extent, for a majority of members of Tamil Nadu (92%), Andhra Pradesh (85%) and Bihar (70%). Similarly, the involvement of SHG members in financial decision at home increased by a moderate extent because of SHG for a majority of members in Tamil Nadu (81%), Andhra Pradesh (74%), Orissa (56%) and Bihar (65%).

## 7.2 CAPACITY BUILDING OF FARM WOMEN

Rural women are playing a significant role not only in homestead activities but also in agricultural development and allied fields. Women have proven that they can be good entrepreneurs and development managers in any kind of activities. The KVK, Shikohpur is playing a vital role in empowering rural women of Gurgaon district by organizing various need-based self-employment and income generating activities.

**Community action undertaken by SHG members**

| Community activity | Percentage | | | |
|---|---|---|---|---|
| | Tamil Nadu (n=100) | Andhra Pradesh (n=100) | Orissa (n=50) | Bihar (n=40) |
| Water supply | 32 | 43 | 94 | 15 |
| Education related activities | 54 | 26 | 68 | 42.5 |
| Health and sanitation related activities | 12 | 19 | 82 | 67.5 |
| Veterinary care | 16 | 17 | 64 | 50 |
| Improving village road | 0 | 13 | 0 | 35 |
| Campaign on social issues | 15 | 37 | 72 | 50 |
| Women related issues | 13 | 23 | 76 | 82.5 |

The important programmes and activities organized by the KVK for rural women during the period (January, 2009 to March, 2010) are as under:

| Name of programme & activities | No. of activities | No. of participants |
|---|---|---|
| **Vocational trainings** | | |
| • Dairy farming | 02 | 62 |
| • Dress designing & training | 02 | 60 |
| • Preservation of seasonal fruits & vegetables | 02 | 60 |
| **Total** | **06** | **182** |
| **Agricultural extension and farm advisory services** | | |
| • Celebration of women in agriculture day | 01 | 160 |
| • Day long trainings in villages | 24 | 318 |
| • Lectures delivered by subject matter specialists in trainings organized by line departments | 05 | 82 |
| • Method demonstrations | 05 | 110 |
| • Visit of farmwomen in agril. exhibition/fairs | 02 | 145 |
| **Total** | **32** | **815** |

### 7.2.1 Impact of Capacity Building and Agricultural Extension Activities

The interventions made by the KVK created several positive impacts on rural women as listed below:

- After getting vocational trainings, the rural women were able to save/earn Rs. 3000-3500/- per month by stitching the garments for their family members and other needy neighbours.
- Some rural women started their own training centers and provided trainings to needy girls/women on tailoring in their own villages and earned Rs. 200/- per month from each trainee.
- Through active participation in village trainings and in extension activities, the farm women were able to do farm work, including dairy farming, with the application of improved technologies earning more income.
- Some SHGs of rural women, trained in preservation of fruits & vegetables were engaged in value addition activities by making and marketing different types of pickles, *murabba*, and squashes, and established their own successful business.
- The most distinct impact of women empowerment activities related to the creation of a sense of security and self reliance among rural women.

### 7.2.2 Women's Participation in Seed Production

Sixty-five farmwomen from Begampur and Jhinavari villages of Karnal district, Haryana were given trainings on quality seed production of wheat variety DBW 17. The women visited IARI Regional Station, Karnal on February 26, 2010 and were shown the latest agricultural technologies at wheat seed production plots. Through active participation in seed village scheme trainings on different aspects of quality seed production, their level of understanding of seed production as a whole improved.


**Rural girls performing a Haryananvi folk dance during a *kisan mela* organized by the KVK**

# 8. POST-GRADUATE EDUCATION AND INFORMATION SYSTEM

## 8.1 POST-GRADUATE EDUCATION

### 8.1.1 Admission during the Academic Session 2009-2010

The Post Graduate School of IARI provides national and international leadership in human resource development. It continues to attract a large number of students seeking admission to various PG courses in all five streams of admission, namely, open competition, faculty up-gradation, ICAR in-service nominees, departmental candidates, and foreign students.

The admissions to the Ph.D. programme are made on the basis of candidates' performance in a national level entrance examination, conducted in different parts of the country followed by an interview and academic records. While the admissions to the M.Sc. programme are made on the basis of an 'All-India Entrance Test' conducted by the Education Division of the ICAR. The foreign students are admitted through DARE, Ministry of Agriculture.

During the academic year 2009-2010, 272 students were selected for admission to M.Sc. and Ph.D. courses as per details given below.

| Category | M.Sc | Ph.D. | Total |
|---|---|---|---|
| Open competition | 109 | 142 | 251 |
| Foreign students* | 10 | 11 | 21 |
| Total | 119 | 153 | 272 |

***Foreign students admitted from: Iran, Nepal, Rwanda, Sudan, Sri Lanka, Syria and Vietnam.**

The total number of students on roll were 714 (243 M.Sc. and 471 Ph.D.) including 49 students (17 M.Sc. and 32 Ph.D.) from 11 foreign countries, namely, Bangladesh, Egypt, Ethiopia, Iran, Libya, Nepal, Rwanda, Sudan, Sri Lanka, Syria and Vietnam.

### 8.1.2 Convocation 2009

The 47th Convocation of the Post Graduate School of the IARI was held on February 13, 2009. Dr. K. Kasturirangan, Director, National Institute of Advanced Studies, Bangalore and Member of Parliament (Rajya Sabha) was the chief guest. The chief guest in his inspiring and informative convocation address, emphasized that agriculture has played a seminal role in shaping both the material and moral well being of humankind. Dr. Kasturirangan mentioned that although our country chose the path of rapid industrialization after independence, agriculture continued to be the lynchpin of our economy cohesively holding together the diverse parts of our society. The chief guest also highlighted the fact that among the other dimensions of modern agricultural endeavors, two of the important ones related to bio-security and the increasing influx of genetically modified foods.

Dr. S.A. Patil, Director, IARI presented the significant research achievements of the Institute during the year 2008.

**A Ph.D. student receiving her degree certificate from Dr. K. Kasturirangan, Director, National Institute of Advanced Studies, Bangalore and Member of Parliament (Rajya Sabha) at the Convocation. Also seen in the picture is Dr. S.A.Patil, Director, IARI**

Dr. H.S. Gaur, Dean & Joint Director (Education), IARI highlighted the important role being played by the Institute in human resource development in terms of post-graduate teaching, short-term training courses and modernization of PG laboratories, lecture halls, hostels, dispensary, etc. The chief guest released 13 IARI seed varieties which include two varieties each of carrot and wheat, one variety each of rice, pearl millet, chickpea, pigeon pea and five varieties of mustard. Dr. Mangala Rai, Secretary, DARE and DG, ICAR released 9 IARI publications including a CD on 'Advances in Post Graduate Research for Improving Agricultural Growth and Prosperity' in the form of e-book.

At this convocation, 71 M.Sc. and 91 Ph.D. students were awarded degrees. Dr. Kaushik Majumdar (Agricultural Chemicals) and Mr. Raghu B.R. (Genetics) were awarded the 'Best Student of the Year 2008' award for Ph.D. and M.Sc., respectively. In addition, five recipients each of Ph.D. and M.Sc. degrees were awarded the 'IARI Merit Medals' for their outstanding academic performance. Five faculty members, namely, Dr. T.B.S. Rajput (Water Science & Technology), Dr. (Ms.) Dolly Wattal Dhar (Microbiology), Dr. R.D. Gautam (Entomology), Dr. (Ms.) Irani Mukherjee (Agricultural Chemicals) and Dr. (Ms.) Radha Prasanna (Microbiology) were awarded 'Best Teacher Award' for their outstanding contributions to teaching.

The 3rd Rao Bahadur Dr. B. Viswanath Award for the biennium 2006-07 consisting of a cash prize of Rs. one lakh, a citation and certificate was awarded to Dr. V.P. Singh, former Principal Scientist, Division of Genetics, IARI, New Delhi and Vice President, KRBL, Ghaziabad for his outstanding research contributions to the improvement of rice varieties. The 13th Dr. B.P. Pal Memorial Award for the year 2008 consisting of a cash prize of Rs.10,000/-, a gold medal and a commendation certificate was awarded to Dr. Vinod, Senior Scientist, Division of Genetics, IARI, New Delhi for his outstanding research contribution to 'Genetics of Rust Resistance and Identification of New Genes in Wheat'.

The 9th Hari Krishna Shastri Memorial Award for the year 2008 consisting of a cash prize of Rs.25,000/- and a commendation certificate was awarded to Dr. K.C. Bansal, Professor of Molecular Biology & Biotechnology, NRCPB, New Delhi for his outstanding research contribution on (i) generation of transgenic tomato and mustard for improved tolerance to abiotic stress, and (ii) isolation of fruit-specific promoter.

The 39th Lal Bahadur Shastri Memorial Lecture was delivered on February 12, 2009 by Dr. T. Ramasamy, Secretary, Department of Science and Technology, Government of India on the topic 'Science for Managing Creative People'. Dr. M.V.Rao, Former Special Director-General, Indian Council of Agricultural Research, New Delhi presided over the function. In his informative and thoughtful lecture, Dr. Ramasamy emphasized that even today, the best way of managing the creative people was to follow the Lal Bahadur Shastri model of functioning.


**Dr. T. Ramasamy, Secretary, Department of Science and Technology, Government of India (seated second from left) delivered the 39th Lal Bahadur Shastri Memorial Lecture**

## 8.1.3 Convocation 2010

The 48th Convocation of the Post Graduate School of IARI was held on February 13, 2010. Her Excellency the President of India, Smt. Pratibha Devisingh Patil was the chief guest. Hon'ble Union Minister of Agriculture, Consumer Affairs, Food & Public Distribution Shri Sharad Pawar and Hon'ble Minister of State for Agriculture, Consumer Affairs, Food & Public Distribution Prof. K.V. Thomas also graced the occasion. In the convocation address, Her Excellency the President of India, highlighted the importance of agriculture in India. She said that in our country agriculture provided employment to around 60% of


**Her Excellency the President of India, Smt. Pratibha Devisingh Patil and other dignitaries at the 48th convocation of IARI**

the workforce and contributed about 18% to our GDP. She also mentioned that India supported about 18% of global population and over 15% of livestock, on less than 5% of the world's water resources and about 3% of global land. She suggested in her address that IARI should continuously strive for excellence, constantly review their own performance through self appraisal and see how to involve organizations like National Innovation Foundation, which were working to support grassroots innovation and traditional knowledge in research activities.

Dr. H.S. Gupta, Director, IARI presented the significant research achievements of the Institute during the year 2009. Dr. H.S. Gaur, Dean & Joint Director (Education), IARI highlighted the important role being played by the Institute in human resource development in terms of post-graduate teaching, short-term training courses, creation/updating of student amenities, etc. The Hon'ble Union Minister of Agriculture, Consumer Affairs, Food & Public Distribution released 7 IARI seed varieties including 3 varieties of wheat. The Hon'ble Minister of State for Agriculture, Consumer Affairs, Food & Public Distribution released the journal of IARI Post Graduate School 'Pusa AgriScience'.

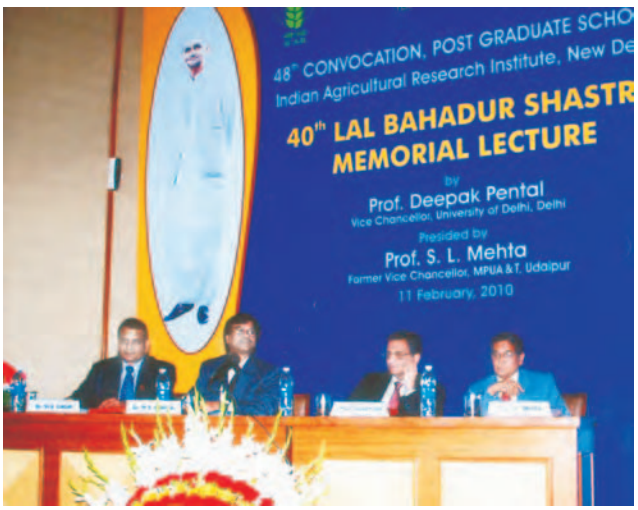
At this convocation, 75 M.Sc. and 69 Ph.D. students were awarded degrees. Dr. Mridhul Chakraborti (Genetics) and Mr. Santosh H.B. (Genetics) were awarded the 'Best Student of the Year 2009' for Ph.D. and M.Sc., respectively. In addition, five recipients each of Ph.D. and M.Sc. degrees were awarded the 'IARI Merit Medals' for their outstanding academic performance. Five faculty members, namely, Dr. A.D. Munshi (Vegetable Science), Dr. Y.S. Shivay (Agronomy), Dr. S.D. Singh (Environmental Sciences), Dr. D.K. Singh (Agricultural Engineering) and Dr. V.T. Gajbhiye (Agricultural Chemicals) were awarded the 'Best Teacher Award' for their outstanding contributions to teaching.

Dr. A.K. Singh, Deputy Director-General (NRM), ICAR, New Delhi received the 10th Hari Krishna Shastri Memorial Award for his outstanding research contribution in the area of Natural Resource Management (Water Management). Dr. Srinivasa Rao Cherukumalli, Principal Scientist, CRIDA, Hyderabad received the 16th Sukumar Basu Memorial Award 2007-08 for his outstanding research contributions in the area of soil science. Dr. K.V. Prasad, Sr. Scientist, Division of Floriculture & Landscaping, IARI received the 14th Dr. B.P. Pal Memorial Award for the year 2009 for his outstanding

**A Ph.D. student receiving her degree certificate from Her Excellency the President of India, Smt. Pratibha Devisingh Patil at the convocation. Also seen in the picture is Dr. H.S. Gupta, Director, IARI**

research contributions to "Developing New Varieties of Chrysanthemum and Roses through Induced Mutation and Tissue Culture".

The 40th Lal Bahadur Shastri Memorial Lecture was delivered by Dr. Deepak Pental, Vice-Chancellor, University of Delhi on February 11, 2010 on the emerging topic 'Achieving the Elusive Second Green Revolution – Can Research and Development Help?'. Dr. S.L. Mehta, former Vice Chancellor, MPUAT, Udaipur presided over the function. In his impressive and informative lecture, Dr. Pental emphasized the need for the application of modern science and technology for the improvement of crops, and consolidated multidisciplinary efforts in crop breeding for improving the productivity and quality related traits. He cited the example of China where phenomenal growth in productivity of important crops had taken place during the past decade through application of science led technologies. Dr. Pental emphasized on the establishment of centres for improvement of each crop with adequate funding and infrastructure support. He suggested employing more scientists for specific breeding programmes and related sciences and training of young scientists in cutting edge technologies.




**Dr. Deepak Pental, Vice-Chancellor, University of Delhi (seated third from left) delivered the 40th Lal Bahadur Shastri Memorial Lecture**

## 8.1.4 Training Programmes

The Institute organizes several national and international short-term training courses (regular, *ad hoc* and individual) and refresher courses in specialized areas for the scientists of National Agricultural Research System (NARS) under the programmes like "Centres of Excellence" and "Centres of Advanced Studies". Some special training courses are also organized for the benefit of farmers and extension workers.

**Important training programmes organized**

| Topic/name of the training course | Dates | No. of trainees |
|---|---|---|
| **Division of Agricultural Chemicals** | | |
| • Pesticide residue analysis | March 16-20, 2010 | 11 |
| **Division of Agricultural Economics** | | |
| • Sustainable agricultural development for food security | January 8-28, 2009 | 17 |
| • Climate change, environmental sustainability and agricultural development | March 9-29, 2010 | 14 |

| Topic/name of the training course | Dates | No. of trainees |
|---|---|---|
| **Division of Agricultural Engineering** | | |
| • Micro irrigation | (i) February 26, 2009 | 32 |
| | (ii) March 4-5, 2009 | 78 |
| | (iii) March 7-8, 2009 | 79 |
| | (iv) June 24-25, 2009 | 45 |
| | (v) June 26-27, 2009 | 35 |
| • Water management in agriculture and modern techniques of irrigation | (i) August 20, 2009 | 64 |
| | (ii) August 21, 2009 | 51 |
| | (iii) August 22, 2009 | 47 |
| **Division of Agricultural Extension** | | |
| • Vegetables production techniques for the farmers of Rajasthan under NAIP | January 5-11, 2009 | 22 |
| • Entrepreneurship development in agriculture (under CAS, ICAR) | January 5-25, 2009 | 23 |
| • Capacity building and project orientation | (i) January 27-February 3, 2009 | 39 |
| | (ii) February 4-11, 2009 | 36 |
| • Fruits production and nursery management for the farmers of Rajasthan under NAIP | February 25-March 3, 2009 | 18 |
| • Horticulture production technology at Palana Khurd (Udaipur) | March 24, 2009 | 40 |
| • Entrepreneurship development in agriculture for the farmers of Rajasthan under NAIP | March 25-30, 2009 | 26 |
| • Horticulture crop production technology at Masotia (Banswara) | March 26, 2009 | 50 |
| • Vegetables production technology at Sagwadia (Banswara) | March 27, 2009 | 45 |
| • Latest agricultural production technologies for higher production and income | May 20-26, 2009 | 30 |
| • Intermediate course for officers of Military farm, Meerut | May 25-28, 2009 | 12 |
| • Latest agricultural production technologies for higher production and income | June 3-9, 2009 | 30 |
| • Agricultural production technology for higher income for progressive farmers of Arwal district of Bihar | June 17-23, 2009 | 30 |
| • Water storage and water conservation for state extension Officers and farmers of Govt. of NCT, Delhi | July 2, 2009 | 30 |
| • Latest agricultural production technologies for higher production and income | July 14-20, 2009 | 30 |
| • Tools and techniques for planning, monitoring, evaluation and impact assessment of extension programmes | July 21-August 10, 2009 | 25 |
| • Use of biotechnology and genetically modified seeds for farmers and field staff | August 25, 2009 | 30 |
| • Dry land farming for farmers | August 26, 2009 | 30 |
| • Latest agricultural production technologies for higher production and income | September 7-12, 2009 | 30 |
| • Management skills for extension professional | December 16-23, 2009 | 19 |
| • Capacity building of extension professional for effective training | January 8-28, 2010 | 25 |
| • Methodological advances in extension research | February 5-25, 2010 | 18 |
| **Division of Agricultural Physics** | | |
| • Remote sensing applications in agriculture with special emphasis on hyper spectral remote sensing | March 30 - April 23, 2009 | 21 |
| • Remote sensing, geographical information system and global positioning system | August 25- November 20, 2009 | 25 |
| • Remote sensing applications in agriculture with special emphasis on management of crop physical environment | March 23 - April 16, 2010 | 20 |
| **Division of Agronomy** | | |
| • Spices and aromatic plants | January 16-17, 2009 | 200 |
| • Quantitative and qualitative improvement in crop production systems and soil health through INM | May 25 – June 15, 2009 | 19 |
| • Multicriteria decision making and optimization methodology for sustainable farming system | October 20-November 9, 2009 | 23 |
| **Division of Genetics** | | |
| • Patents at National Institute of Intellectual Property | March 2-6, 2009 | 15 |
| • Quality enhancement: Conventional and molecular approaches | July 15- September 4, 2009 | 26 |
| • Molecular marker assisted breeding for crop improvement | February 15 -24, 2010 | 25 |

| Topic/name of the training course | Dates | No. of trainees |
|---|---|---|
| **Floriculture and Landscaping** | | |
| • Improved production technology of flower crops | May 8-14, 2009 | 25 |
| **Division of Microbiology** | | |
| • SAARC training on *Rhizobium* biofertilizer technology for sustainable agriculture | March 15-30, 2009 | 07 |
| • Blue green algae | April 18- May 8, 2009 | 19 |
| • Microbes mediated crop residue management and their utilization for sustainable crop production | August 2-13, 2009 | 16 |
| • Bioprospecting for microorganisms with agriculturally important traits using polyphasic approaches | November 17-December 7, 2009 | 18 |
| **Division of Post Harvest Technology** | | |
| • Appropriate post harvest technology for fresh fruits and vegetables | March 16-22, 2010 | 14 |
| **Division of Plant Physiology** | | |
| • Post-harvest physiology of fruits and flowers | January 27- February 16, 2009 | 25 |
| • Photosynthetic efficiency and crop productivity under climate change scenario | August 25-September 14, 2009 | 21 |
| **Division of Plant Pathology** | | |
| • Biodiversity, taxonomy, conservation and characterization of fungi | January 28- February 17, 2009 | 16 |
| • Molecular diagnostics for fastidious prokaryotes, viruses and viroids | February 20- March 13, 2009 | 20 |
| • Mushroom cultivation | September 14-19, 2009 | 31 |
| **Division of Seed Science and Technology** | | |
| • Plant variety protection and its significance on hybrid vegetable seed production | February 19-21, 2009 | 20 |
| • Principles and procedures of DUS testing of vegetable crops including indigenous cucurbits | November 3-7, 2009 | 12 |
| **Division of Soil Science and Agricultural Chemsitry** | | |
| • Soil testing, plant analaysis and water quality assesmeent | September 4-24, 2009 | 5 |
| **Nuclear Research Laboratory** | | |
| • Applications of ionizing and non- ionizing energies in agriculture | November 4-24, 2009 | 18 |
| **Vegetable Science** | | |
| • Hybrid seed production of vegetable crops | (i) March 23-24, 2009 | 10 |
| | (ii) March 26-27, 2009 | 10 |
| • Shakiya phasalon ka unnat evam sankar beej utpadan | April 20-16, 2009 | 22 |
| • Vegetable variety development and evaluation | September 15- October 14, 2009 | 7 |
| **Centre for Protected Cultivation Technology** | | |
| • Protected cultivation of horticultural crops | (i) July 4 -10, 2009 | 30 |
| | (ii) July 13- 19, 2009 | 30 |
| | (iii) August 1-7, 2009 | 25 |
| | (iv) November 30- December 5, 2009 | 8 |
| | (v) December 7-12, 2009 | 7 |
| | (vi) February 04 -06, 2010 | 50 |
| | (vii) February 22 -26, 2010 | 25 |
| **Seed Production Unit** | | |
| • Aloo evum sabji phaslon ka beej utpadan | April 14-20, 2009 | 50 |

### 8.1.6 Post-Graduate Faculty

The main strength of the Institute is its faculty of 462 members in 23 disciplines, of whom 288 are recognized as research guides. During the period under report, 67 new scientists were inducted in the PG faculty and 31 faculty members were inducted as research guides. The out-sourced guest faculty is also invited to take part in the teaching programmes of their respective subjects, where sufficient faculty is not available for teaching the courses.

### 8.1.7 Internet Facilities for IARI Students and Faculty

Provided internet and intranet facility to the IARI faculty on their desk and also in several classrooms. On-line and wi-fi connectivity to the post-graduate students was also provided at the hostels and guest houses for trainees and visiting faculty. As an important initiative, the day-to-day functioning of the PG School was computerized by adding online submission of roster cum registration forms, PPW and trimester results, student and faculty data-bases, etc. The course schedule along with contents and suggested reading was made available on intranet system. The PG School Calendar, containing PG School by laws, courses and their contents and various formats being used by PG students and faculty, was put on IARI website in Hindi and English.

### 8.1.8 Modernization of PG Laboratories and Lecture Halls

In most of the Divisions new equipments were purchased/repaired, and computer facilities updated. New text books were procured in divisional libraries, and teaching facilities modernized by adding audio-visuals, LCD projectors and multi-media systems. Laboratory manuals were prepared in each teaching discipline for practical courses.

### 8.1.9 Students' Extra Curricular Activities

The Institute makes conscious efforts to encourage the students to take part in sports, music, debates, cultural and other extra-curricular activities for overall personality development. The students participated in inter University sports and debate competitions and won a number of prizes. IARI students are known worldwide for their academic and professional excellence. This year, IARI students won the over-all championship of ICAR inter-deemed university sports meet held at NDRI, Karnal. Various cultural programmes were also organized throughout the year. The Post-Graduate Students Union also arranged health check-up, fresher's welcome and other social functions. The Institute has zero-tolerance to ragging.

## 8.2 INFORMATION AND DATABASE

### 8.2.1 Bioinformatics

#### 8.2.1.1 Wheat informatics

A web based application on 'Wheat Informatics' was developed that enabled users to retrieve general, scientific and bioinformatics on wheat. This application is user-friendly and helps students, researchers and farmers to know the details of the crop.

### 8.2.2 Agri-Informatics

#### 8.2.2.1 Consortium for e-Resources in agriculture (CeRA)

The CeRA was established in November 2007 for facilitating the accessibility of scientific journals to all researchers/teachers in the National Agricultural System. Following are the specific achievements during the period under report.

- For smooth functioning of CeRA, three committees, namely, Steering, Monitoring, Negotiation and Working were constituted and, six meetings held.
- Subscriptions to publishers, namely, Elsevier, Taylor & Francis, Nature, Indian Journals, and Thomson Reuters (for web of science), were made effective in addition to the existing subscriptions to Springer Verlag, Annual Reviews, CSIRO and Informatics for facilitating 24x7 online access of agriculture-based journals to all researchers in NARS.
- A web-based software developed in 2008 for facilitating the online access and with the URL www.cera.jccc.in, was updated. All institutions in NARS were provided the access through respective IP address(es).

- About 1600 articles were sent to various users under a Document Delivery Request (DDR) System.
- Nine awareness-cum-monitoring workshops of CeRA were organized at Calcutta, Karnal, Ranchi, Chennai, Coimbatore, Hyderabad, Bangalore, Thiruchinapalli and Port Blair covering 15 Institutions in NARS.
- During the period, more than 9,78,000 articles were downloaded from CeRA subscribed publishers. Assuming a cost of US $ 5 per article (the normal average download cost being US $25 per article), the Consortium had recovered about Rs 19.56 crores, not to mention the easy online availability. It is to be noted that the subscription cost during January 2009- March 2010 is about 8.8 crores.

#### 8.2.2.2 AGROWEB - digital dissemination system for Indian Agricultural Research (ADDSIAR)

As per the guidelines developed by the Agroweb Team on uniformity in the websites of ICAR institutes, the website of IARI was developed. It was launched by Dr. S. Ayyappan, Secretary, DARE and Director-General, ICAR on 19 March, 2010. Web-based information system of M.Sc./Ph.D. students admitted during the past decade with year-wise updating was developed and incorporated with the internet of the Institute.

#### 8.2.2.3 RKMP digitization of library resources in NARS

A prototype of Rice Knowledge Management Portal (RKMP) was developed with SQL Server as backend and ASP.Net as front end. Five information systems (General, Extension, Farming, Research, Service Information system) were developed. Contents for extension information system (EIS) and farming information system (FIS) were collected and integrated with RKMP portal. Location specific FAQ page was designed. A web application including static and dynamic information was developed.

## 8.3 LIBRARY SERVICES

IARI Library is one of the largest and the finest Agro-biological libraries in South East Asia housing about 6 lakh publications including 1 lakh books/monographs, 3,50,000 journal volumes, 45,000 bulletins, 15,000 post graduate theses, 10,000 pamphlets, 30,000 news clippings, 30,000 reports, and other reference materials. The Library has, on its role 2000 members, which include students, scientists and technical staff. It also serves about 8,000 visitors every year.

Library is a member of DELNET (Developing library Network) and AGLINET (Agricultural Library Network) and serves as the depository of FAO, Rome and CGIAR institute's publications.

### 8.3.1 Acquisition Programme

#### 8.3.1.1 Books

During the period under report, the Library procured 1204 publications, which include 136 in Hindi and 1068 in English costing Rs. 68,18,764/-. The Library also acquired 810 gift publications, 178 IARI theses and five RFT theses.

#### 8.3.1.2 Serials

The Library procured 806 journals/serials through subscription, gifts and publications on exchange. It subscribed to 131 foreign journals (out of which 11 are having online access) and 228 Indian journals and 114 advances/ annual reviews. Exchange relationship was maintained at national and international levels with 185 institutions/parties by sending annual reports/Indian journals and society publications. Two hundred fifty eight (258) annual/scientific/ technical reports of different institutions and 417 bulletins were received in the Library. The expenditure incurred on Serial Acquisition from Plan was Rs. 1,21,00,924 (Rs. One crore twenty one lakh nine hundred twenty four only).

### 8.3.2 Documentation Activities

#### 8.3.2.1 AGRIS project

IARI Library was declared as an input centre for "National Agricultural Research Database" (NARD) under AGRIS Project. The Library was assigned the job of scanning articles from 10 most important Indian journals. The input was done in ISO format using AGRIN methodology. During the period under report, 650 articles were scanned, processed and sent to DIPA, ICAR for inclusion in AGRIS Index.

#### 8.3.2.2 Development news in agriculture

Fourteen thousand two hundred and thirty six issues of 14 news papers were scanned and 59 news items pertaining to IARI as well as ICAR were sent to the Director, IARI and the Principal Scientist (PPI).

#### 8.3.2.3 Document processing

In all, 1757 documents consisting of books, bulletins, IARI post-graduate theses and Hindi books were processed (classified and catalogued).

### 8.3.3 Resource Management

#### 8.3.3.1 Binding of publications

In all, 1500 volumes consisting of 7250 loose issues of journals, reports and bulletins were bound and 397 volumes accessioned.

#### 8.3.3.2 Reference, circulation and stack maintenance

During the period under report, 8550 publications were issued to its members. In all, 31 documents were issued on Inter Library Loan to various institutions including NISCAIR. Three hundred and twenty "No Due Certificates" were issued to staff, including scientists, after checking the relevant record.

### 8.3.4 Services

#### 8.3.4.1 Facility to faculty and students

The scientists of the Institute can use the terminals of training cell for accessing internet and other services of the Library. The Library has student facility unit with 10 pentium IV terminals having internet connectivity to access internet, e-mail and literature search.

#### 8.3.4.2 Wi-fi connectivity in reading halls

Reading halls have wi-fi connectivity with 10 pentium IV terminals. Students can also bring their laptop for research work.

#### 8.3.4.3 CD-ROM workstation

Nearly 1,16,320 references were downloaded by 285 users consisting of Scientists, students of IARI and visitors from all over India. The cost based references downloaded were 54754, which generated a revenue of Rs. 68,196/- during the period under report.

#### 8.3.4.4 Reprography services

During the period, the total number of copies from photocopy machines was 1,47,824 pages which were provided to scientific and technical staff officially from the holding of the Library.

### 8.3.5 e-Granth

Strengthening of digital library and information management under NARS (e-Granth), a subcomponent of ICDS of component-I of NAIP project, was started from May 2009 with twelve libraries of ICAR institutes and SAU's as Consortia partners and IARI as the lead centre.

Under the project, 78,573 records of publications were sent to Online Computer Library Centre (OCLC) to merge with Worldcat (catalogue of 71,000 libraries of the world) through batch processing. Cataloguing of recent books is done directly in worldcat through connexion software of OCLC.

# 9. PUBLICATIONS

One of the important mandates of the Institute is to develop an information system, add value to information and share the information nationally and internationally. The Institute scientists brought out a large number of publications in the form of research papers, books/chapters in book, popular articles, etc. Apart from these publications, the Institute brought out several regular and *ad hoc* publications both in English and Hindi.

## 9.1 RESEARCH/SYMPOSIA PAPERS

| | | |
|---|---|---|
| a) | Research papers published in international journals | 208 |
| b) | Research papers published in national journals | 355 |
| c) | Symposia/conference papers | 669 |

## 9.2 BOOKS/CHAPTERS IN BOOK

| | | |
|---|---|---|
| a) | Books | 24 |
| b) | Chapters in books | 266 |

## 9.3 POPULAR ARTICLES 311

## 9.4 INHOUSE PUBLICATIONS

### 9.4.1 Regular Publications (English)

- IARI Annual Report 2008-2009 (ISSN: 0972-6136)
- IARI News (Quarterly) (ISSN: 0972-6144) - 5 issues
- IARI Current Events (Monthly) - 15 issues

### 9.4.2 *Ad hoc* Publications (English)

- Post-harvest Physiology of Horticultural Produce (ISBN 978-81-88708-35-2)
- Post-Graduate Research and Human Resource Development at IARI: 1996-2007 (ISBN 978-81-88708-36-9)
- Management Development for Extension Professionals (ISBN 978-81-88708-37-6)
- Greenhouse Technology (ISBN 978-81-88708-38-3)
- IARI Technologies for Farmers' Prosperity and Food Security (ISBN 978-81-88708-39-0)
- Floriculture for Prosperity: A Production Manual for Commercial Floriculture (ISBN 978-81-88708-41-3)
- Resources – An Arc-view Customized Regional Resource Characterizing System (ISBN 978-81-88708-43-7)
- *Rhizobium* Biofertilizer Technology for Sustainable Agriculture (ISBN 978-81-88708-44-4)
- User©-An EIA Tool for Managing Salt Affected Agricultural Land & Irrigation Waters (ISBN 978-81-88708-45-1)
- Cases on Management Development and Organisational Behaviour (978-81-88708-46-8)
- Qualitative and Quantitative Improvement in Crop Production Systems and Soil Health (ISBN 978-81-88708-47-5)
- Microirrigation (ISBN 978-81-88708-48-2)
- A Practical Manual for Weed Management (ISBN 978-81-88708-49-9)
- A Practical Manual on Methods of Chemical Analysis of Manures and Fertilizers (ISBN 978-81-88708-50-5)
- Vegetable Variety Development and Evaluation (ISBN 978-81-88708-51-2)
- Bioprospecting Microbes for Agriculture (ISBN 978-81-88708-52-9)
- Epiphytology, Forecasting and Assessment of Losses (ISBN 978-81-88708-53-6)

- Multi-criteria Decision Making and Optimization Methodology for Sustainable Farming Systems (ISBN 978-81-88708-54-3)
- Radiotracer Techniques in Soils and Fertilizers - A Practical Manual (ISBN 978-81-88708-55-0)
- New Dimensions of Agricultural Research and Extension (ISBN 978-81-88708-57-4)
- Practical Manual on Bougainvillea (ISBN 978-81-88708-58-1)
- Manual on Farming Systems (ISBN 978-81-88708-59-8)
- Hybrid Rice Seed Production Technology (PRH-10) (TB-ICN:55/2009)
- Major Diseases of Rice (TB-ICN:56/2009)
- Low Pressure Drip Irrigation Technology for Horticultural Crops (TB-ICN:57/2009)
- Diseases of Vegetable Crops (TB-ICN:58/2009)
- Wheat Diseases and their Management (TB-ICN:59/2009)
- Success Story of Champion Farmers (TB-ICN:60/2009)
- National Extension Programme for Market Led Agriculture (TB-ICN:61/2009)
- Biofertilizer for Better Soil Health and Higher Crop Productivity (TB-ICN:62/2009)
- Improved Technologies for Fruit Cultivation (TB-ICN:63/2009)
- Vegetables Cultivation for Prosperity and Nutritional Security (TB-ICN:64/2009)
- Seed Production Technology of *Rabi* Crops (TB-ICN: 65/2009)
- A Report on Water Resources Augmentation Plan of IARI Farm (TB-ICN:66/2009)
- Souvenir - Consolidating the Productivity Gains in Wheat (TB-ICN:67/2009)
- Conservation Agriculture: For Sustainable Production of Wheat in India (TB-ICN:68/2009)
- Wheat and Barley Varieties Released in India (TB-ICN:69/2009)
- Spot Blotch (*Bipoloris sorokiniana*) - A Threatening Disease of Wheat (TB-ICN:70/2009)
- Seed Production Agronomy of Paddy Pusa Basmati 1121 (TB-ICN:71/2010)
- Laser Land leveling (TB-ICN:72/2010)
- Drip Irrigation (TB-ICN:73/2010)
- Variety Maintenance and Seed Production of Vegetable Crops (TB-ICN:74/2010)
- Hybrid Seed Production in Solanaceous Vegetables (TB-ICN:75/2010)

### 9.4.3 Regular Publications (Hindi)

- *Pusa Surbhi* (yearly) (ICN : H-78/2009) - 1 issue
- *Pusa Samachar* (Quarterly) (ISSN 0972-7280) - 5 issues
- *Prasar Doot* - 3 issues
- *Samyiki* (monthly) - 15 issues

### 9.4.4 *Ad hoc* Publications (Hindi)

- *Khadya Suraksha Evam Kisan Samaradhi Ke Liye Pusa Sansthan Ki Proudyogikian* (ISBN 978-81-88708-40-6)
- *Samaradhi Ke Liye Pushpa Vigyan: Vyavsayik Pushpa Vigyan Ke Liye Utpadan Pustika* (ISBN 978-81-88708-42-0)
- *Uchcha Utpadan Evam Aai Hetu Unnat Krishi Proudyogikian* (ISBN 978-81-88708-56-7)
- *Sabzion Ki Paudh Utpadan Hetu Adhunik Prodyogiki* (ICN : H-66/2009)
- *Bemousmi Sabzi Utpadan Hetu Plastic Low Tunnel Prodyogiki* (ICN : H-67/2009)
- *Shaakeeya Phaslon Ke Pramukh Rog* (ICN : H-68/2009)
- *Dhaan Ke Mukhya Rog* (ICN : H-69/2009)
- *Gehoon Ki Phaslon Ke Rog Evam Unka Prabandhan* (ICN : H-70/2009)

- *Chane Ke Rog Evam Prabandhan* (ICN : H-71/2009)
- *Sankar Dhaan Ki Bijotpaadan Takneeki* (ICN : H-72/2009)
- *Sheetkaleen Sabzion Ka Beej Utpadan* (ICN : H-73/2009)
- *Rabi Phaslon Ki Beej Utpaadan Prodyogiki* (ICN : H-74/2009)
- *Aloo Evam Sabzi Phaslon Ka Beej Utpadan* (ICN : H-75/2009)
- *Kam Laagat Mai Adhik Utpadan Lene Hetu Naveentam Gehoon Utpadan Takneek* (ICN : H-76/2009)
- *Basmati Dhaan Ki Utpadan Prodyogikee Evam Sambadh Krishi Vishaya* (ICN : H-77/2009)
- *Madhya Kshetra Ke Liye Gehoon Ki Naveen Prajatiyaan* (ICN : H-79/2009)
- *Behatar Pryavaran Ke Liye Bhaartiya Krishi – Karyavratta* (ICN : H-80/2009)
- *Tikaoo Kheti Ke Liye Mousam Aadhaarit Kisaan Margdarshika* (ICN : H-81/2010)
- *Gehoon Ki Phasal Ke Rog Evam Unka Prabandhan* (ICN : H-82/2010)
- *Khaadyan Suraksha Hetu Krishi Bhoutiki Prodyogikiyan* (ICN : H-83/2010)
- *Pusa Basmati Dhaan 1121 Ka Beejotpadan Sasya Vigyan* (ICN : H-84/2010)
- *Dhaan Ke Pramukh Rog – Lakshan Evam Prabandhan* (ICN : H-85/2010)
- *Kathaa Rachna Evam Chintan* (ICN : H-86/2010)
- *Rogon Ki Pehchaan, Moolyankan Evam Niyantran* (ICN : H-87/2010)
- *Sankar Dhaan Beej Utpadan Evam Bhandaaran* (ICN : H-88/2010)
- *Kharif Phaslon Ki Beej Utpadan Prodyogiki* (ICN : H-89/2010)
- *Rabi Phaslon Men Beej Utpadan Tathaa Krishak Adhikaar* (ICN : H-90/2010)
- *Dhaanya Evam Baagvani Phaslon Ki Beej Utpadan Prodyogiki* (ICN : H-91/2010)
- *Vyavasayaik Dairy Farming* (ICN : H-92/2010)
- *Maali Prashikshana Karyakram* (ICN : H-93/2010)

# 10. COMMERCIALIZATION AND IPR ACTIVITIES

The mandate of the Institute Technology Management Unit (ITMU) relates to registration of patents, facilitation of contract research projects and consultancies by the Institute scientists, intellectual property rights, and interaction with the agri-business industry.

During the period, the ITMU has organised following activities:

## Patents Filed

1. Invention of Mohan's Infective Juvenile Isolator (MIJI) for isolating infective juveniles of entomopathogenic nematodes from infected *insect cadavers* (Dr. Mohan Sharad, Sr. Scientist, Division of Nematology).
2. Development of Scar Marker for identification of *Chaetomium globosum*-A potential bio-control agent (Dr. Rashmi Aggarwal, National Fellow, Division of Plant Pathology).
3. A novel formulation of the plant growth promoting Rhizobacteria with enhanced shelf life and the method of its preparation (Dr. Anupama, Sr. Scientist, Division of Agricultural Chemicals).

## Patents Granted

1. Improved process for the preparation of Mancozeb (Dr. R.L. Gupta, Principal Scientist, Division of Agricultural Chemicals).
2. Efficient process for the preparation of neem based reduced Azadirachtin (s) pesticides (Dr. Suresh Walia, Principal Scientist, Division of Agricultural Chemicals).
3. Biopesticidal formulation with improved shelf life and the process of preparation (Dr. Prem Dureja, Emeritus Scientist, Division of Agricultural Chemicals).
4. Synthetic gene encoding a chimeric δ-endotoxin of *Bacillus thuringiensis* (Dr. P. Ananda Kumar, Director, NRCPB).
5. Additives for improved photostability of Azadirachtin-A (Dr. Prem Dureja, Emeritus Scientist, Division of Agricultural Chemicals).

## Zonal Meeting-cum-Workshop

A two-day ICAR Zonal Technology Management and Business Planning and Development (ZTM&BPD) Meeting-cum-Workshop (North Zone-1) was organized from March 19 to 20, 2010 to discuss IP assets in the 20 institutes under North Zone-I. One hundred five participants attended the meeting, of which 57 were from ITMUs of different Institutes. Three technical sessions were held under the theme, "ZTM&BPD, IP Asset Management and Planning, and Development of IP Business".

**Technology commercialized**

| Technology | Licensed to |
|---|---|
| Pusa 1121 | Indian Foundation Seed & Services Association (IFSSA), Hyderabad |
| Improved Pusa Basmati 1 (Pusa 1460) | (i) Indian Foundation Seed & Services Association (IFSSA), Hyderabad |
| | (ii) GEO Biotechnologies India Pvt. Ltd., Bangalore |
| Pusa RH 10 | (i) Ganga Kaveri Seeds Pvt. Ltd., Hyderabad |
| | (ii) Indo American Hybrid Seeds (India) Pvt. Ltd., Bangalore |
| Development and Evaluation of Basmati Rice Threshing System | Basmati Export Development Foundation (BEDF), New Delhi |
| Development of Irrigation Scheduler-Programmable Systems | Collaborative Research with Mechanical Engineering Research and Development Organization (MERADO), Ludhiana and Centre for Development of Advanced Computing (C-DAC), Mohali |

# 11. LINKAGES AND COLLABORATION

Indian Agricultural Research Institute continued to maintain linkages with various national and international institutes/organisations. At national level the Institute has close linkages with almost all annual crop research institutes, centres, project directorates, coordinated projects as well as a few selected institutes of the ICAR. Collaboration exists with almost all the state agricultural universities (SAUs), central universities, selected conventional universities, several of the institutes of the CSIR, BARC, and various departments such as the departments of Biotechnology; Space Research, and Meteorology, and several other ministries/departments/organizations of the Government of India.

At the international level, Institute has close linkages with several of the CGIAR's international agricultural research centres (IARCs), more particularly with ICRISAT, CIMMYT, IRRI, and ICARDA. Among other international organizations, ISTA, FAO, IAEA, USAID, UNDP, WMO, UNIDO and UNEP have been the closest allies. Several bilateral research linkages with developed and developing countries also exist. These include linkages with USDA, selected universities in USA and Canada, World Bank, Rockfeller Foundation, Winrock International, European Commission, JAICA, JIRC, JSPS, ACIAR, AVRDC (Taiwan), etc.

The details of externally funded projects in operation during the period from 1.1.2009 to 31.3.2010 are given below:

**Details of externally funded projects in operation**

| Name of funding agency | No. of projects |
|---|---|
| ***Within India*** | |
| DBT, DST, ICAR, CICR, CSIR, NCPA, CPCB, Ministry of Water Resources, Ministry of New and Renewable Energy, Ministry of Environments and Forest, Ministry of Earth Sciences, DAC, SAC, NABARD, National Horticultural Mission, NRDC, BARC, ISRO, IIRS, NFBSRA (ICAR), NAIP (ICAR), etc. | 141 |
| A.P. Cess Fund, National Fellow Scheme of ICAR | 15 |
| ***Outside India*** | |
| IPNI India Programme, Indo US (AKI), USAID, UKIERI, CIMMYT, Indo-Australian Programme | 8 |

# 12. AWARDS AND RECOGNITIONS

The Institute won two awards during the period under report: the Agriculture Leadership Award 2009 by a national agriculture magazine, "Agriculture Today", and the Best Annual Report Award 2008-2009 of ICAR. The Institute's scientists also received several prestigious awards and recognitions during the period under report.

- The Institute was given the Agriculture Leadership Award 2009 by a national agriculture magazine, "Agriculture Today" for helping the country attain and maintain self-sufficiency in food grains and for improving the economic conditions of Indian farmers.
- The Institute received the Best Annual Report Award 2008-2009 of ICAR in the category of big institutes.
- Dr. H.S. Gupta, Director, IARI received the Dr. Amrik Singh Cheema Award (2009-10) of Young Farmers' Association, Punjab for his outstanding contribution to agricultural research, and service to the farming community of Punjab.
- Dr. P.K. Aggarwal, National Professor, Division of Environmental Sciences received the Ernestolly Trieste Science Prize of the Academy of Sciences for the Developing World (TWAS), Italy for his contributions to enhance the understanding of the vulnerability of agriculture in the developing countries to climate change.
- Prof. Anupam Varma, former Dean and Joint Director (Education) and INSA Senior Scientist was identified as outstanding scientist of the year 2009 for the National PNASF (Dr. Prem Nath Agricultural Science Foundation, Bangalore) Gold Medal Award.
- Dr. Baldeo Singh, Joint Director (Extension) was elected President of the Indian Society of Extension Education.
- Dr. T.B.S. Rajput, Project Director, and Dr. Neelam Patel, Senior Scientist of Water Technology Centre received the Ram Nath Singh Award for writing book in Hindi.
- Dr. Anand Swarup, Head, Division of Soil Science and Agricultural Chemistry received the World Management Congress Lifetime Achievement Award 2009 for his outstanding contribution to agricultural research and education.
- Dr. D.V.K. Samuel, Head, Division of Agricultural Engineering was elected Fellow of the Indian Society of Agricultural Engineers.
- Dr. (Ms.) M. Dadlani, Head, Division of Seed Science and Technology was elected Fellow of the National Academy of Agricultural Sciences (NAAS) and was nominated as a Member of the Working Committee of SAARC Seed Forum (SSF), Dhaka.
- Dr. P. Kalia, Head, Division of Vegetable Science received the Himachal Gaurav Award by the Government of Himachal Pradesh for his contribution to research and teaching.
- Dr. (Ms.) Prem Dureja, former Head, Division of Agricultural Chemicals received the Dr. K.C. Mehta Memorial Award of NAAS in Plant Protection for her contribution to research.
- Dr. R.K. Jain, Head, Division of Plant Pathology was elected President of the Indian Phytopathological Society, and was nominated as a Member of the DBT Task Force on Agricultural Biotechnology.
- Dr. R.K. Sairam, Head, Division of Plant Physiology was elected Hon. Secretary-cum-Executive Editor of the Indian Society for Plant Physiology.
- Dr. Ravender Singh, Head, Division of Agricultural Physics received the Hari Om Ashram Trust Award for the Biennium 2007-2008 for his outstanding contribution to Natural Resource Management. He was also elected Vice-President, Delhi Chapter of the Indian Society of Soil Science.

- Dr. T. Janakiram, Head, Division of Floriculture & Landscaping received the Dr. Prem Nath Agricultural Science Foundation Gold Medal Award 2009 for his outstanding research contribution for the promotion of horticulture and food security in India; and the Horticulture Society of India Gold Medal in Floriculture for the year 2009 for his outstanding contribution to horticulture; was awarded ISOH Fellowship by the Indian Society for Ornamental Horticulture, New Delhi for his outstanding contribution to floriculture; and Fellowship of the Indian Society of Horticultural Research and Development, Uttarakhand, for his contribution to R&D in horticulture; and was elected Vice- President of the Indian Society of Ornamental Horticulture, New Delhi.
- Dr. N.P.S. Sirohi, Professor, Division of Agricultural Engineering received the C.V. Paul Gold Medal of the Indian Society of Agricultural Engineers for excellence in research and teaching.
- Dr. R.K. Rattan, Professor, Division of Soil Science and Agricultural Chemistry was elected Secretary of the Indian Society of Soil Science.
- Dr. R. Kaur, National Fellow, Division of Environmental Sciences was awarded the USIEF Fullbright Fellowship Award for her contribution to hydroinformatics.
- Dr. A.K. Patra, Principal Scientist, Division of Soil Science and Agricultural Chemistry was elected Fellow of the National Academy of Agricultural Sciences.
- Dr. Balraj Singh, Principal Scientist, Centre for Protected Cultivation Technology (CPCT) was awarded the Fellowship of the Academy of Science, Engineering and Technology for his outstanding contribution to the promotion of protected horticulture.
- Dr. J.P. Sharma, Principal Scientist and Incharge, Centre for Agricultural Technology Assessment and Transfer (CATAT) was elected Secretary of the Indian Society of Extension Education. He also received the Dr. G.S. Vidyarthi Award of the Indian Society of Extension Education, New Delhi.
- Dr. M.S. Sachdev, Principal Scientist, Nuclear Research Laboratory was elected Member of the Steering Committee of the Global Partnership on Nutrient Management Programme of the United Nations Environment Programme (GPNM – UNEP).
- Dr. S.S. Sindhu, Principal Scientist, Division of Floriculture & Landscaping received the Anna Saheb P Shinde National Leader Award for his contribution to research and development in floriculture and landscaping. He also received the Dr. H.B. Singh Award for popularizing bougainvillea.
- Dr. V.K. Baranwal, Principal Scientist, Division of Plant Pathology was elected Secretary of the Indian Virology Society.
- Dr. A. Chaudhary, Senior Scientist, Division of Environmental Sciences was awarded the Indo-US Professorship (ASM International Professorship) for his contribution to environmental microbiology.
- Dr. (Ms.) Anju Kamra, Senior Scientist, Division of Nematology received the Guman Devi Verma Memorial Award for Best Scientist by the Indian Society of Mycology and Plant Pathology.
- Dr. (Ms.) Anupama Mann, Senior Scientist, Division of Agricultural Chemicals received the Young scientist award of NAAS for her contribution to research.
- Dr. B. Gangaiah, Senior Scientist, Division of Agronomy was elected Secretary of the Indian Society of Agronomy, New Delhi. He was also elected Fellow of the Indian Society of Pulses Research and Development, Kanpur.
- Dr. Bhupinder Singh, Senior Scientist, Division of Plant Physiology was awarded the AAAS Senior Award for the 2009 of the Indian Society for Plant Physiology for his contribution to plant physiology and cognate sciences.
- Dr. Dinesh Kumar, Senior Scientist, Division of Agronomy was awarded the Commonwealth Academic Staff Fellowship 2008, which was availed during the period February 1, 2009 to July 31, 2009 at New Castle University, U.K. He also received the Dr. D.N. Puri Memorial Award 2007-08 for his significant contribution in the field of agronomy.
- Dr. D.K. Sharma, Senior Scientist, Division of Environmental Sciences was awarded the Commonwealth Fellowship for his contribution to phytoremediation.
- Dr. Gautam Chawla, Senior Scientist, Division of Nematology was elected Fellow of the Society of Plant Protection Sciences, New Delhi.

- Dr. Harender Kumar, Senior Scientist, Division of Nematology received the Outstanding Scientist Award of the Society of Plant Protection Sciences, New Delhi.
- Dr. Indra Mani, Senior Scientist and Dr. D.V.K. Samuel, Head, Division of Agricultural Engineering received the Outstanding Book Award of the Indian Society of Agricultural Engineers for their book on Mechanization of Vegetable Production and Post-Harvest Management.
- Dr. K.K. Biswas, Senior Scientist, Division of Plant Pathology received the Meritorious Scientist Award for 2009-10 of the Society of Plant Protection Sciences, New Delhi.
- Dr. Kanhaiya Singh, Senior Scientist, Regional Station, Pusa, Bihar was awarded the Fellowship of the Indian Society of Horticultural Research and Development.
- Dr. K.V. Prasad, Senior Scientist, Division of Floriculture & Landscaping was awarded the Horticulture Society of India Fellowship for the year 2009 for his contribution to horticulture and ISOH Fellowship of the Indian Society of Ornamental Horticulture, New Delhi.
- Dr. Manoj Khanna, Senior Scientist, Water Technology Centre was nominated as a Member of the Working Group of WMO on development of hydrological drought indices.
- Dr. R.K. Yadav, Senior Scientist, Division of Vegetable Science received the Young Scientist Award of the Council of Science and Technology, U.P. for his contribution to research.
- Dr. R.R. Sharma, Senior Scientist, Division of Post Harvest Technology received the Himachal Shri Award of Himotkarsh Organization of Himachal Pradesh.
- Dr. Vanita Jain, Senior Scientist, Division of Plant Physiology was awarded the JJ Chinoy Gold Medal by the Indian Society for Plant Physiology.
- Dr. Vanita Jain, Dr. Vijay Paul, and Bhupinder Singh, Senior Scientists of the Division of Plant Physiology were awarded the Fellowship of the Indian Society for Plant Physiology.
- Dr. Yashbir Singh Shivay, Senior Scientist, Division of Agronomy received the Distinguished Scientist Award 2009 in the field of Agronomy by the Society for Recent Development in Agriculture.

**Dr. H.S. Gupta, Director, IARI (right) receiving the Agriculture Leadership Award 2009 from Dr. Montek Singh Ahluwalia, Deputy Chairman, Planning Commission, Government of India**

# 13. BUDGET ESTIMATES

**Statement showing budget estimates, revised estimates and expenditure under Plan for the year 2009-10 and 2010-11**

**Rs. in lakh**

| Head | 2009-10 | | | 2010-11 |
|---|---|---|---|---|
| | Budget estimates | Revised estimates | Expenditure | Budget estimates |
| **A. Recurring** | | | | |
| Pay & Allowances | | | | |
| TA | 59.00 | 47.00 | 46.70 | 60.00 |
| HRD | 5.00 | 5.00 | 4.88 | 30.00 |
| Contingencies | 750.00 | 750.00 | 749.97 | 775.00 |
| **Total (A)** | **814.00** | **802.00** | **801.55** | **865.00** |
| **B. Non-Recurring** | | | | |
| Equipments | 911.00 | 175.00 | 175.00 | 600.00 |
| Furniture | | 22.00 | 22.00 | 40.00 |
| Works | 50.00 | 1,000.00 | 999.79 | 845.00 |
| Library | 175.00 | 175.00 | 175.00 | 200.00 |
| Land | | | | |
| Provision for OBC | | 99.00 | 98.87 | 100.00 |
| **Total (B)** | **1136.00** | **1,471.00** | **1,470.66** | **1,785.00** |
| **Grand total (A+B)** | **1950.00** | **2273.00** | **2272.21** | **2650.00** |

**Statement showing budget estimates, revised estimates and expenditure under Non-plan for the year 2009-10 and 2010-11**

**Rs. In lakh**

| Sub-head | 2009-10 | | |
|---|---|---|---|
| | Budget estimates | Revised estimates | Expenditure |
| Estt. Charges | 9,500.00 | 13,240.00 | 13,198.70 |
| OTA | 4.00 | 3.87 | 3.80 |
| TA | 20.00 | 22.68 | 22.68 |
| Other charges including equip. | 1,500.00 | 2,213.97 | 2,213.90 |
| Works | | | |
| i) Office building | 325.00 | 436.85 | 436.78 |
| ii) Residential building | 225.00 | 277.35 | 277.30 |
| iii) Minors works | 75.00 | 91.33 | 91.29 |
| Other items | 225.00 | 308.80 | 308.22 |
| **Total** | **11,874.00** | **16,594.85** | **16,552.67** |

**Rs. in lakh**

| Head | 2010-11 |
|---|---|
| | Budget estimates |
| Capital | |
| Establishment | 10,780.00 |
| Wages | |
| OTA | 2.50 |
| TA | 20.00 |
| Research & operational expenditure | 505.00 |
| Administrative expenditure | 1,256.00 |
| Misc. | 443.50 |
| **Total** | **13,007.00** |

# 14. STAFF POSITION

**(As on 31.03.2010)**

| Category | | No. of posts | | | |
|---|---|---|---|---|---|
| | | Sanctioned | Filled | | |
| | | | Direct recruitment | By assessment | Total |
| **A.** | **SCIENTIFIC STAFF** | | | | |
| 1) | Research Management Personnel | 6 | 4 | - | 4 |
| 2) | Principal Scientist | 69 | 38 | 90 | 128 |
| 3) | Senior Scientist/Scientist (S.G.) | 184 | 83 | 122 | 205 |
| 4) | Scientist | 355 | 273* | - | 61 |
| **B.** | **TECHNICAL STAFF** | | | | |
| 1) | Category III | 25 | 20 | | |
| 2) | Category II | 308 | 269 | | |
| 3) | Category I | 395 | 334 | | |
| 4) | Auxiliary | 02 | 02 | | |
| **C.** | **ADMINISTRATIVE STAFF** | | | | |
| 1) | Group A | 19 | 11 | | |
| 2) | Group B | 273 | 218 | | |
| 3) | Group C | 238 | 196 | | |
| **D.** | **SKILLED SUPPORTING STAFF** | 1363 | 1231 | | |

**Note: * Out of 273 positions of Scientist filled through direct recruitment, only 61 are working in the grade of Scientist. The remaining 212 scientists (i.e., 90 Principal Scientists & 122 Senior Scientists) have been promoted as Principal Scientists and Senior Scientists through assessment.**

# 15. MISCELLANY

## I. On-going Projects at IARI as on 31.03.2010

| | | |
|---|---|---|
| a) | School of Crop Improvement | 34 |
| b) | School of Resource Management | 30 |
| c) | School of Crop Protection | 19 |
| d) | School of Basic Sciences | 14 |
| e) | School of Social Sciences | 13 |
| | **Total** | **110** |

## II. Scientific Meetings Organized

| | | |
|---|---|---|
| a) | Workshops | 25 |
| b) | Seminars | 28 |
| c) | Summer institutes/Winter school | 09 |
| d) | Farmers' day (s) | 61 |
| e) | Others | 54 |
| | **Total** | **177** |

## III. Participation of Personnel in Scientific Meetings

### *India*

| | | |
|---|---|---|
| a) | Seminars | 198 |
| b) | Scientific meetings | 195 |
| c) | Workshops | 106 |
| d) | Symposia | 140 |
| e) | Others | 65 |
| | **Total** | **704** |

### *Abroad*

| | | |
|---|---|---|
| a) | Seminars | 10 |
| b) | Scientific meetings | 18 |
| c) | Workshops | 08 |
| d) | Symposia | 05 |
| e) | Others | 20 |
| | **Total** | **61** |

## IV. Significant Suggestions Given/Decisions Taken at the Meetings of Senior Management Personnel and Important Recommendations of QRT

### Board of Management

- Financial powers should be delegated uniformly amongst the Joint Directors of Research, Education and Extension).
- Writing/reviewing of ACRs collectively by the Joint Directors of Research, Education & Extension was not considered feasible, and hence the position be reviewed specifically wherever it is necessary and not in all cases.
- In future, all Joint Directors of Research, Education & Extension will be included appropriately for participation in the Institute's important events, meetings and policy making.

### Academic Council

- The degree nomenclature of M.Sc. (Agricultural Engineering) has been changed as M.Tech. (Agricultural Engineering).
- The format of MoU to be executed between IARI and ICAR institutes/SAUs for collaborative study programmes at PG level has been approved.
- A Scientist with Ph.D., who joins the IARI/NBPGR/IASRI/DMR/NRCPB will automatically be inducted as a Faculty Member on the intimation of his/her joining by the Chairman, BOS of the discipline.

### Extension Council

- The regular updating of IARI website needs to be done.
- Establish vermi-compost demonstration units at all IARI regional stations and study the efficiency of traditional and modern technologies of construction of vermi-

compost units in terms of cost and output jointly by the WTC and the Division of Entomology. A vermi-compost demonstration unit be established at the WTC for the benefit of farmers.

- Greater attention be given for the supervision of seed production programme especially for maintaining the quality standards of seeds supplied under participatory seed production programme.
- Coordination between the Seed Production Unit and ATIC must be maintained to ensure adequate and timely availability of seeds of different crops and vegetables for sale to the farmers through the ATIC.
- Elicit the farmers' feedback about the positive and negative features of IARI technologies.
- There is a need for an MOU between the Institute and the Young Farmers' Association of Punjab to strengthen linkage, and streamline the transfer of technology programme.
- The concept of 'herbal garden', 'crop cafeteria', and 'nutrition garden' at the ATIC be further expanded in terms of plants population and size of the garden.

## Research Advisory Committee

### School of Crop Improvement

***Division of Genetics***

- The number of programmes with respect to various crops be reduced. Minor crops like pea and cowpea may be dropped. Instead, efforts should be made to develop short duration mungbean varieties especially to fit in rice-wheat cropping system, and pigeon pea and chickpea varieties for resistance to various diseases and abiotic stresses.
- Research on synthetic wheat needs to be strengthened in collaboration with the CIMMYT.
- The Division should take lead in developing drought tolerant wheat varieties by incorporating drought tolerant gene (DREB) into normal high yielding wheat varieties through marker assisted breeding. The challenge is to replace old C 306 variety with varieties having higher yielding ability.
- Farmers' participatory research in plant breeding be given due emphasis.

***Division of Seed Science & Technology***

- The division should lay greater emphasis on production of hybrid seeds of vegetable crops through partnership with private sector.
- Focused research on testing hybrid purity of transgenic crops required.
- Germplasm of varieties and inbred parents of hybrids needs to be deposited with the NBPGR genebank for maintenance purpose.

***Division of Fruits and Horticultural Technology***

- Greater importance be given to develop grape varieties (especially for wine purpose) that mature before rainy season in north Indian conditions.
- Focused work on developing seedless citrus varieties for juice making is required.
- New approaches to control mango malformation (specially in popular variety Amrapali) may be explored. Work on regular bearing in mango should get priority.
- Guava rootstocks resistant to wilt/termite need to be developed.

***Division of Vegetable Science***

- Research programme pertaining to the development of hybrid cauliflower, cabbage and improved varieties of garden pea be taken up on priority.
- The division should lay emphasis on development of varieties suited for protected cultivation.
- Public-private partnership be encouraged for hybrid seed production of vegetable crops.

***Division of Floriculture & Landscaping***

- Work on rose breeding should be given major importance. The division should come up with good rose varieties especially suited for export purpose.
- Crops such as *Antirrhinum* & *Lilium* may be dropped from the research agenda.
- New marigold varieties, which are also known to be effective in controlling the root knot nematode problem, need to be developed in collaboration with the scientists from the Division of Nematology.

- Linkages need to be built with industries and private sector for promoting new varieties/hybrids.

***Division of Post Harvest Technology***

- Soybean crop be included in the new research programme along with maize and millets. Efforts need to be made on developing soybean-based snack food and products to popularize its use as a food crop.
- Research linkages with CFTRI need to be established.
- Skilled human resource in the area of Food Science be developed.

***Centre for Protected Cultivation Technology (CPCT)***

- The Centre should develop technology for low cost net houses/green houses/poly houses and popularize the same for resource-poor farmers. Benefit-cost ratios of such technologies need to be worked out in collaboration with the Division of Agricultural Economics.
- Efforts should be made for commercialization of protected cultivation technology for high value crops.
- Advanced techniques for soil-less cultivation need to be developed.

**School of Natural Resource Management**

***Division of Agronomy***

- Studies on diversification of cropping systems, especially to economise water and nutrient use, have to be given major emphasis.
- Packages of practices for high value crops such as Broccoli, *basmati* rice, baby corn, capsicum, cucumber and carrot need to be developed. Collaboration with the Division of Microbiology and Agricultural Engineering be strengthened.
- Focused research programme on agronomy and weed management of *Bt* cotton is required.
- Emphasis be given on long-term research on conservation agriculture in major cropping systems such as rice-wheat, cotton-wheat, etc.

***Water Technology Centre***

- The Centre should develop new technologies for maximizing water use efficiency in important cropping systems of northern India.
- Work on saline water/waste water be strengthened in collaboration with the Divisions of Vegetable Science, Biochemistry, and Soil Science amd Agricultural Chemistry.
- Research programmes on efficient rain water harvesting be taken up in near future.

***Division of Soil Science & Agricultural Chemistry***

- Problems related to soil health need to be addressed. Alternatives to the use of phosphatic fertilizers be looked at as a matter of priority.
- Work on conservation agriculture for enhancing the productivity and resource use efficiency be given due emphasis in collaboration with the Division of Agronomy.
- Research programme pertaining to nano-technology for nutrient use efficiency may be taken up.

***Division of Environmental Sciences***

- The Division should develop newer technologies to reduce greenhouse gas emissions from major cropping systems, especially, rice-based systems.

***Division of Agricultural Physics***

- Remote sensing and GIS technologies need to be promoted for exploring the optimal land use cropping systems with focus on Indo-Gangetic plains.
- Sensors for water and nutrient use may be developed for Decision Support Systems.
- Use of radiation in post harvest management of fruits and vegetables should be an area of priority research in future.

***Division of Agricultural Engineering***

- Studies on the development and structural design of polyhouses, low-cost nethouses and greenhouses be given prime importance in collaboration with the CPCT.

- The Division should lay focus on developing sensors for laser levelling and precision agriculture.
- Research work pertaining to drying of horticultural produce may be pursued in poly houses instead of green houses.
- Research programme on the use of bio-energy in agriculture and improvement of available harvesters for long grained rice be taken up on priority in future.

***Division of Microbiology***

- Research programme with respect to biotransformation of microbes to improve their viability and efficacy at higher temperatures be given high priority.
- Alternatives to wheat straw for biofuel purpose need to be worked out.
- Attempts should be made to develop and standardize methodologies for preparation of enriched compost that can degrade cow dung faster.
- The Division should take lead in the production, efficacy and commercialization of bio- fertilizers.

***Unit of Simulation & Informatics***

- Work on simulation modeling may be strengthened taking the help of other disciplines.
- Focused work on bioinformatics is required in collaboration with the Division of Genetics and the National Research Centre on Plant Biotechnology (NRCPB).

**School of Basic Sciences**

***Division of Plant Physiology***

- The Division should focus research on the physiological, bio-chemical and molecular bases of abiotic stress tolerance in variety C 306 (for drought) and Kharchia (for salinity).
- Efforts should be made to undertake studies on improving the photosynthesis and nitrogen use efficiency of crops in relation to climate change.
- Studies on post-harvest physiology and value addition in flowers may be undertaken. Research work pertaining to nutritional quality of banana may be discontinued.

***Division of Biochemistry***

- The Division should focus on research work on enhancing efficiency in the biochemical and metabolic pathways.
- More in-depth studies with respect to the expression of heat stock proteins in relation to thermo tolerance in wheat are required.

***National Research Centre on Plant Biotechnology (NRCPB)***

- Research programme proposed by the Centre should aim at product development for the benefit of the end-user.
- Public-private partnership needs to be strengthened for the promotion of the products developed by the Centre.

***Nuclear Research Laboratory***

- Work on nitrogen use efficiency in major crops needs to be strengthened.
- Use of radiation for post-harvest management through increased shelf life be taken up in collaboration with DRDO institutions.

**School of Crop Protection**

***Division of Plant Pathology***

- Research work on mining and transfer of novel genes for virus resistance in some important horticultural crops (e.g., papaya) may be given due emphasis.
- Research programme with respect to bacterial and fungal disease management be strengthened.
- Efforts should be made to develop tomato transgenics having in-built resistance to both virus and nematodes. For this, collaboration with the NRCPB be strengthened.
- Work on diagnostics needs to be translated at the field level.

***Division of Nematology***

- Due emphasis be given on research work pertaining to nematodes of national importance.
- Problem of termites in IARI field may be addressed on priority in collaboration with the Division of Entomology.

***Division of Entomology***

- The Division of Entomology should focus on integrated pest management strategy for major crops and popularize the same for the benefit of farmers. For this, there should be greater collaboration with the National Centre on Integrated Pest Management.

***Division of Agricultural Chemicals***

- Efforts should be directed towards commercialization and large scale field testing/ use of the hydrogel formulation developed by the Division of Chemicals.

**School of Social Sciences**

***Agricultural Extension/CATAT/ATIC***

- The Division of Agricultural Extension should explore new innovative approaches (e.g. use of ICTs/portals/ models) for dissemination of technology.
- Training on content development for farmers is required. Vocational training programmes should also be given due emphasis.
- Studies on the improvement of livelihoods of resource poor farmers through IARI technology need to be undertaken by the Division of Agricultural Extension.
- Strong linkages of extension programmes with marketing mechanisms are required.

***Division of Agricultural Economics***

- Focused programmes on technology policy & forecasting will be desirable.
- Impact assessment of IARI technologies needs to be investigated.
- Future research programmes on increasing the competitiveness of Indian agriculture, especially in the context of globalization, have to be given priority.

**PG School**

- Training of young scientists abroad in selected areas of specialization be taken up on priority by convincing the ICAR authorities on its importance in long run.
- PG programmes should be well integrated with the main research programmes of the Divisions.
- Academic collaboration with other universities and international centres needs to be strengthened. In this context, sandwich programme for higher education be developed.
- Provision should be made to provide additional funds for the renovation of hostel buildings, and an international students' hostel be constructed soon.

**General Comments**

- Efforts should be made to strengthen the Divisions with more skilled manpower. Allocation of the competent staff to critical research areas be ensured.
- Young scientists should be deputed abroad for international exposure and for generating novel research ideas, learning new technology and developing new technical skills.
- There is a need to review the challenge programmes of the Institute to address some of the issues of national importance. Post-doctoral fellows should be linked with major challenge programmes.

## QRT (2000-08)

**Research**

- Heterosis breeding in rice, pigeonpea, mustard and wheat should be strengthened and research on pulses should focus more on crops like pigeonpea and chickpea.
- Molecular breeding should be an integral part of the crop improvement programmes.
- Studies on the effect of climate change in relation to adaptation and mitigation should be undertaken in an interdisciplinary manner.
- A well-equipped screening system for abiotic stress tolerance at different stages of crop growth be developed at the Institute.
- Research programmes on farm machinery and power need to be focused on development of precision farm implements and machinery and utilization of renewable energy resources.
- The Institute should focus research on remote sensing and simulation modeling approach for better crop planning.
- Research on resource conservation technologies be strengthened.

- Research linkage and coordination between the regional stations and the relevant main division of IARI should be strengthened.
- Analysis of cost: benefit ratio should be an integral part of technology development, especially, for INM, IPM and conservation agriculture.
- Basic research on soil processes involving nutrient fluxes and flows, organic recycling in relation to organic matter formation and its stability, nutrient availability and soil quality for enhanced productivity and environment safety should be emphasized.
- Considering the importance of new molecules in plant protection, the Institute should concentrate more on synthesis and development of new molecules of pesticides.
- In view of the importance of processing and value addition in food and horticultural crops, a new Centre for Food Science and Post Harvest Technology with full component of human resource and infrastructure be established at IARI.
- Research programmes of the Nuclear Research Laboratory (NRL) are no longer viable and, therefore, the recommendations of RAC 2005 for the reorganization of the Nuclear Research Laboratory were re-endorsed.
- The names of the Division of Genetics and the Division of Fruits and Horticultural Technology be changed as 'Division of Genetics and Plant Breeding' and 'Division of Fruit Science', respectively.

### Human Resource Development

- Shortage of faculty in most disciplines is seriously affecting the research and teaching activities of the Institute. Therefore, the vacant positions of scientific staff in each discipline be filled on priority over the next three years.
- The position of Professor in each discipline may be filled by direct recruitment with the designation of Principal Scientist (Professor).
- IARI may involve scientists working in other ICAR institutes and other reputed institutions in research guidance of the students at the Institute only after due accreditation and commitment to participate in teaching.
- IARI should institute Adjunct Professor Scheme as per guidelines being adopted by ICAR.
- The construction of a new hostel and major renovation of old hostels were recommended. ICAR should help the Institute to get necessary approvals from Urban Arts Commission and other bodies.

### Extension

- IARI Extension Education Programme be implemented on pilot basis in different regions with the involvement of SAUs/ICAR institutes/extension agencies/industry.
- Senior level extension specialists from five disciplines (Agronomy, Soil Science, Genetics, Entomology and Pathology) need to be identified as members of 'Production Unit' to assist the Joint Director (Extension).
- The Institute should develop appropriate concepts and methodologies for better agricultural extension and technology transfer at national level.
- The Institute should make more efforts in expanding and strengthening the existing public-private partnership.

### Administrative

- In order to retain competent scientists and provide leadership at IARI, which has a Deemed University status, the Heads of Divisions at IARI be given the status of RMP.
- The Institute should develop a time-bound programme for training of technical and administrative staff.
- The Institute should also work on paperless system of governance as far as possible.

### Financial

- IARI should develop a financial management package online linking the Divisions to the Directorate.

## V. Resource Generation

### 1) Consultancy & other services

| | |
|---|---|
| Consultancy services | Rs. 9,73,600 |
| Contract research | Rs.4,23,522 |
| Contract service | Rs. 1,34,832 |
| Training | Rs.2,31,670 |
| **Total (A)** | **Rs.17,63,624** |

| | | |
|---|---|---|
| **2)** | **Revolving fund** | **Sale Proceeds Revenue Generated** |
| (a) | Seed | Rs. 2,27,33911 |
| (b) | Commercialization | Rs.16,89,988 |
| (c) | Prototype manufacturing | Rs.53,07083 |
| | **Total (B)** | **Rs.297,30,982** |
| **3)** | **Post Graduate School receipt** | |
| | **Training Programme** | |
| (a) | Foreigners & Indians | Rs. 1,12,810.00 |
| | **M.Sc./Ph.D Programme** | |
| (b) | Institutional economic fee from foreign scholars under Work Plan | Rs. 78,13,226.00 + US$ 21600.00 |
| (c) | Receipt from Registrar (A) Account No. 5432(9029.201.4314): all fees except institutional economic fee, including sale of information bulletin through D.D. | Rs. 19,03,482.00 |
| (d) | Cash transferred from Syndicate Bank to Director's Account No. C-49(9029.305.17) from sale of information bulletin | Rs. 3,76,325.00 |
| (e) | Receipt deposited in Director's Account No. C-49(9029.305.17) for theses evaluation, PDC & Misc.( does not include refund of IARI scholarship by students) | Rs. 2,83,637.00 |
| | **Total (C)** | **Rs. 1,04,89,480.00 + US$ 21600.00** |
| | **Grand Total (A+B+C)** | **Rs. 41,984,086.00 + US$ 21600.00** |

## VI. Infrastructural Development

- Dr B.P. Pal Laboratory and Study Centre, establishment at IARI Regional Station, Amartara Cottage, Shimla, Himachal Pradesh.
- A one-room structure was constructed for storage of onion bulb and machines used for on-farm seed extraction of tomato, carrot, and onion at the farm of Seed Production Unit.

## VII. All India Coordinated Research Projects in Operation during the year January 1, 2009 to March 31, 2010

### Project Headquarters

1. All India Coordinated Project on Plant Parasitic Nematodes with integrated Approach for their control.
2. All India Coordinated Research Project on Floriculture (Upgraded as Directorate of Floricultural Research)
3. All India Network Project on Pesticide Residues

### National Centres Functioning at IARI under All India Coordinated Research Projects

1. All India Network project on Biofertilizers (Erstwhile All India Coordinated Research Project on Biological Nitrogen Fixation)
2. All India Coordinated Project on Long Term Fertilizer Experiments
3. All India Coordinated Research Project on Soil Test Crop Response Correlations
4. All India Coordinated Research Project on Floriculture
5. All India Network Project on Pesticide Residues
6. All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries
7. All India Coordinated Research Project on Soybean
8. All India Coordinated Research Project on Sub-Tropical Fruits
9. All India Coordinated Research Project on N.S.P. (Crops)

## VIII. Foreign Visitors during January 1, 2009 to March 31, 2010

| Sl. No. | Visitor (s) | Month |
|---|---|---|
| 1. | A 10-member delegation led by Mr. K. B. Wahundeniya, Dy. Director (Research), Council of Agricultural Research Policy, Sri Lanka | January, 2009 |
| 2. | A group of participants attending the 4th World Congress on Conservation Agriculture at NASC Complex | January, 2009 |
| 3. | H. E. Mr. Gerrey Ritz, Minister of Agriculture, Canada | January, 2009 |
| 4. | A 10-member delegation of Seed Alliance Without Boundaries (SAWIB) from Iraq, Afganistan, and Uzbekistan | February, 2009 |
| 5. | A 2-member delegation from USAID- DAI, Kabul, Afganistan | March, 2009 |
| 6. | Mr. John Schwarzmayas, M/s Winterseiger, Austria | March,2009 |
| 7. | A delegation led by Mrs. Renee Bergkamp, Director- General (Enterprise and Innovation), Govt. of the Netherlands | April, 2009 |
| 8. | Prof. Jimmy Botela, Scientist, University of Queensland, Australia | April, 2009 |
| 9. | Dr. John Burns, Dean, College of Agriculture Resources, Texas Tech. University, USA | April, 2009 |
| 10. | Dr. Ed. Runge, Programme Director, Monsanto's Beachell-Borlaug International Scholar, IARI, A&M University, USA | May, 2009 |
| 11. | A 2-member delegation from Nepal Agricultural Research Council, Nepal | May, 2009 |
| 12. | A 6-member delegation led by Dr. Cyprian Ebong, Director-Quality Assurance, National Agricultural Research Organization (NARCO), Uganda | June, 2009 |
| 13. | Dr. G. Mimia Talab, Project Manager of GM Vilmorin & Company (Limarian Group), Research South - 3021, Ldenon, France | June, 2009 |
| 14. | Dr. Frank Fear, Senior Associate Dean, College of Agricultural and National Research, Michigan State University, USA | June, 2009 |
| 15 | A 6- member delegation led by Mr. Liu Jinzhou, Member of Development and Agrarian Services, Sri Lanka | July, 2009 |
| 16. | Her Excellency Hillary Clinton, US Secretary of State, USA | July, 2009 |
| 17. | A 15-member delegation from National Institute of Policy and Strategic Studies (NIPPS) led by Prof. Danfulani Ahmed, Director-General, NIPPS, NIGERIA | August, 2009 |
| 18. | A 12-member delegation of Nepal Civil Service Officers led by Mr. Bishnu Nath Sharma, Joint Secretary, Ministry of Local Government, Govt. of Nepal, Nepal | August, 2009 |
| 19. | Dr. Gordon Gee, President, Ohio State University, USA | August, 2009 |
| 20. | A 4-member delegation from Alabama Cooperative Extension System, Alburn University, Alabama, USA | August, 2009 |
| 21. | A 3-member delegation led by His Excellency Dr. Marc G. Fortin, Asstt. Deputy Minister of Research, Canada | August, 2009 |
| 22. | Prof. Itamar Glazer, Head, Institute of Plant Science, Agricultural Research Organization (ARO), Bet Dagan, Isreal | August, 2009 |
| 23. | A high-level delegation led by His Excellency Mizengo Kayanza Pinda, MP, Prime Minister of the United Republic of Tanzania | September, 2009 |
| 24. | A 5-member delegation headed by Dr. Stephen Wambulwa Muliokela, Executive Director, Golden Valley Agricultural Research Trust (GART), Zambia | October, 2009 |
| 25. | A 5-member delegation from Makerere University, Uganda | October, 2009 |
| 26. | A 6-member delegation headed by Mr. Liu Jinzhou, Member of Standing Committee, Director- General of the Committee on Agriculture and Rural Affairs of Guangdong Provincial People's Congress, China | October, 2009 |

| Sl. No. | Visitor (s) | Month |
|---|---|---|
| 27. | Dr. Auguste Kouassi, Special Advisor to the President of Republic of Ivory Coast, Ivory Coast | November, 2009 |
| 28. | A 3-member delegation from Nageria | November, 2009 |
| 29. | His Excellency Salvadar Marin, Minister of University, Industry and Science, Spain | December, 2009 |
| 30. | His Execellency Jose Napoles, Hon'ble Deputy Minister of Agriculture, Ministry of Agriculture, Cuba | December, 2009 |
| 31. | A-10 member delegation from South Korea | January, 2010 |
| 32. | A 2-member delegation of Prof. Timothy Dlton, Professor in Agricultural Economics and Prof. Ted Cable, Professor, Horticulture and Forestry, Kankas State University, USA | January, 2010 |
| 33. | A 25-member delegation from France | January, 2010 |
| 34. | A 31-member delegation from France | January, 2010 |
| 35. | A delegation led by Dr. Robert J. Hauser, Dean, College of Agricultural Consumer and Environmental Science, University of Illinois, USA | January, 2010 |
| 36. | A 4-member delegation from Botswana | February, 2010 |
| 37. | Dr. Rebbie Harawa, Soil Health and Extension Officer, Alliance for Green Revolution in Africa | February, 2010 |
| 38. | Mr. Lars Peder Brekk, Minister of Agriculture and Food, Norway | February, 2010 |
| 39. | A 37-member delegation from Germany | February, 2010 |
| 40. | A 19-member delegation from AACREA, Argentina | March, 2010 |
| 41. | A delegation led by Mr. Jose Manuel Silva Rodriguez, Director- General for Research at the European Commission, Brussels, Belgium | March, 2010 |
| 42. | Her Royal Highness Princess Mathilde of Belgium | March, 2010 |
| 43. | His Excellency Hui Liangyu, Member of Politburo of the Central Committee of Communist Party of China and Vice-Premier of the State Council of the People's Republic of China | March, 2010 |
| 44. | A 13-member delegation led by Dr. N. B. Tamang, Principal Research Officer and Programme Director, PNR Research and Development Centre, Bumthang, Bhutan | March, 2010 |

**Dr. H.S. Gupta, Director, IARI (extreme right) briefing Her Excellency Hillary Clinton, US Secretary of State about the research priorities of IARI. Also seen in the picture (from left) are: Shri Sharad Pawar, Hon'ble Union Minister of Agriculture, Consumer Affairs, Food & Public Distribution; Dr. Mangala Rai, Secretary, DARE & Director-General, ICAR; Ms. Meera Shankar, Ambassador of India to the US and His Excellency Timothy J. Roemer, US Ambassador to India**

**His Excellency Dr. Marc G. Fortin, Assistant Deputy Minister of Research, Canada (right) being welcomed at IARI by Dr. H.S. Gupta, Director, IARI**

## Appendix 1
# Members of Board of Management of IARI
### (As on 31.03.2010)

**Chairman**

1. Dr. H.S. Gupta
   Director, IARI

**Members**

2. Dr. K. R. Koundal
   Joint Director (Research), IARI
3. Dr. H.S. Gaur
   Dean & Joint Director
   (Education), IARI
4. Dr. Baldeo Singh
   Joint Director (Extension), IARI
5. DDG (Education)
   KAB-I, ICAR,
   New Delhi
6. Dr. A. K. Srivastava
   Director, NDRI, Karnal
   (Haryana)
7. Dr. Gurbachan Singh
   Agril. Commissioner,
   Deptt. of Agriculture &
   Cooperation, Ministry of
   Agriculture, Krishi Bhawan,
   New Delhi
8. Shri Subhash Baparao Patil
   M.Sc., At Post PALASA,
   Taluk Hadgon, Distt. Nanded
   (Maharashtra)
9. Shri Bipin Shankarrao Kolhe
   At Post : Yesgaon-423601
   Tal. Kopargaon,
   Distt. Ahmednagar
   (Maharashtra)
10. Financial Advisor
    ICAR, Krishi Bhawan,
    New Delhi
11. Shri D. M. Spolia
    Development Commissioner
    Delhi Administration
    Govt. of NCT of Delhi,
    5/9 Under Hill Road
    Delhi-110054

**Member-Secretary**

12. Shri G. R. Desh Bandhu
    Joint Director (Admn.),
    IARI

## Appendix 2
# Members of Research Advisory Committee of IARI
### (As on 31.03.2010)

**Chairman**

1. Dr. R.S. Paroda
   Chairman
   Trust for Advancement of Agricultural Sciences
   Library Avenue, IARI Campus
   Pusa, New Delhi

**Members**

2. Dr. H.S. Dhaliwal
   Professor
   Department of Biotechnology
   IIT Roorakee (Uttarakhand)

3. Prof. S.L. Mehta
   Former Vice-Chancellor
   MPUA&T
   H. No. 71, Gokul Nagar,
   Near Bohra Ganeshji Temple,
   Udaipur, Rajasthan

4. Prof. A. N. Mukhopadhyay
   Sangini, 151 Akanksha
   Udhyan II, Raibareilly Road
   Lucknow -226025 (U.P.)

5. Dr. R.K. Pathak
   11, Ram Kunj,
   Faridi Nagar
   P.O. CIMAP
   Lucknow (U.P.)

6. Dr. S. N. Shukla
   Asstt. Director General (FFC)
   Indian Council of Agricultural Research
   Krishi Bhawan,
   New Delhi

**Two Non-official Members from Board of Management**

7. Shri Subhash Bapurao Patil
   M. Sc., At Post PALASA
   Taluk Hadgon, Distt. Nanded
   (Maharashtra)

8. Shri Bipin Shankar Rao Kohle
   At Post Yesgaon-423601
   Tal. Kopargaon
   Distt. Ahmednagar,
   (Maharashtra)

**Member-Secretary**

9. Dr. K.R. Koundal
   Joint Director (Research)
   IARI, New Delhi

## Appendix 3
# Members of Academic Council of IARI
### (As on 31.03.2010)

**Chairman**

1. Dr. H.S. Gupta
   Director, IARI

**Vice-Chairman**

2. Dr. H.S. Gaur
   Dean & Joint Director
   (Education), IARI

**Members**

3. Dr. Arvind Kumar
   Deputy Director General
   (Education), ICAR
4. Dr. S.K. Sharma
   Director, NBPGR, Pusa Campus,
   New Delhi
5. Dr. V.K. Bhatia
   Director, IASRI, Pusa Campus,
   New Delhi
6. Dr. P.A. Kumar
   Director, NRC on Plant
   Biotechnology
   Pusa Campus, New Delhi
7. Dr. K.R. Koundal
   Joint Director (Research), IARI
8. Dr. Baldeo Singh
   Joint Director (Extension), IARI
9. Dr. M. Mahadevappa
   Director
   JSS Rural Development
   Foundation
   Ramanuja Road
   Mysore-570004
10. Dr. N.N. Goswami
    Former Dean & Joint Director
    (Education)
    JD, 20D, Pitam Pura,
    Delhi-110088
11. Dr. S.L. Mehta
    Former Vice Chancellor,
    MPUA&T,
    H.No. 71, Gokul Nagar,
    Near Bohra
    Ganeshji Temple, Udaipur,
    Rajasthan
12. Dr. S. Nagarajan
    Chairperson,PPV& FRA,
    Govt. of India,
    NASC Complex, New Delhi
13. Dr. T.B.S. Rajput,
    Project Director
    WTC, IARI
14. Dr. Sain Dass,
    Project Director
    Directorate of Maize Research
    Pusa Campus, New Delhi
15. Project Director,
    NRL, IARI
16. Dr. A.K. Dikshit
    Professor of Agricultural
    Chemicals
17. Dr. V. C. Mathur
    Professor of Agricultural
    Economics
18. Dr. D.V.K. Samuel
    Professor of Agricultural
    Engineering
19. Dr. Ram Bahal
    Professor of Agricultural
    Extension
20. Dr. (Mrs.) Archna Sachdev
    Professor of Biochemistry
21. Dr. V.K. Bhatia
    Professor of Agricultural
    Statistics
22. Dr. A.R. Sharma
    Professor of Agronomy
23. Dr. (Mrs.) Usha K. Chopra
    Professor of Agricultural
    Physics
24. Dr. P. K. Malhotra
    Professor of Computer
    Application
25. Dr. R. D. Gautam
    Professor of Entomology
26. Dr. S. D. Singh
    Professor of Environmental
    Sciences
27. Dr.(Ms.) Shanti
    Chandrasekharan
    Professor of Genetics
28. Dr. P. Kalia
    Head
    Division of Vegetable Science
29. Dr. P. Kalia
    Professor of Horticulture
30. Dr. V.R. Sagar
    Professor of Post Harvest
    Technology

31. Dr. A.K. Singh
Head
Division of Fruits & Hort. Technology

32. Dr. T. Jankiram
Head, Floriculture & Landscaping

33. Dr. Dolly Wattal Dhar
Professor of Microbiology

34. Dr. K.C. Bansal
Professor of Molecular Biology & Biotechnology

35. Dr. R.V. Singh
Professor of Nematology

36. Dr. (Mrs.) Janki Kandhari
Professor of Plant Pathology

37. Dr. V.P. Singh
Professor of Plant Physiology

38. Dr. S.S. Parihar
Professor of Seed Science & Technology

39. Dr. R.K. Rattan
Professor of Soil Science & Agricultural Chemistry

40. Dr. R.K. Sharma
Professor of Water Science & Technology

41. Dr. I.S. Bisht
Professor of Plant Genetic Resources

42. Dr. R.S. Chillar
Master of Halls of Residences

43. Mrs. Usha Khemchandani
In-charge, IARI Library

44. Dr. Jitendra Kumar
Faculty Representative

45. Dr. K. Annapurna
Faculty Representative

46. Shri Sandeep Kumar
President, PGSSU

47. Shri Sarvendra Kumar
Students' Representative

48. Shri G.R. Deshbandhu
Joint Director (Admn.)

**Member-Secretary**

49. Dr. K.M. Manjaiah
Registrar (Academic)

## Appendix 4
# Members of Extension Council of IARI
### (As on 31.03.2010)

**Chairman**

1. Dr. H.S. Gupta
   Director, IARI

**Members**

2. Mr. G. R. Deshbandhu
   Joint Director (Admn.), IARI
3. Dr. K.V. Prabhu
   Head, Division of Genetics, IARI
4. Dr. A.K. Vyas
   Head, Division of Agronomy, IARI
5. Dr. R.K. Jain
   Head, Division of Plant Pathology, IARI
6. Dr. Ram Bahal
   Professor of Agricultural Extension, IARI
7. Dr. (Mrs.) Malvika Dadlani
   Head, Division of Seed Science &Technology, IARI
8. Dr. D.V.K. Samuel
   Head
   Division of Agricultural Engineering, IARI
9. Dr. Anand Swarup
   Head, Division of Soil Science & Agricultural Chemistry, IARI
10. Dr. G.T. Gujar
    Head
    Division of Entomology, IARI
11. Dr. V.C. Mathur
    Professor of Division of Agricultural Economics, IARI
12. Dr. T.B.S. Rajput
    Project Director, WTC, IARI
13. Dr. S.N. Sinha
    Head, IARI Regional Station
    Karnal (Haryana)
14. Shri N.B. Singh
    Agricultural Commissioner (Crops), Deptt. of Agriculture & Cooperation, Ministry of Agriculture, Krishi Bhavan
    New Delhi
15. Shri D.K. Thakur
    Joint Director (Agriculture)
    Govt. of NCT of Delhi,
    MSO Building, 11th floor,
    IP Estate, New Delhi
16. Shri K. Mahto
    Director, Agricultural Marketing
    Govt. of NCT Delhi
    49, Sham Nath Marg, Old Sectt.
    Delhi
17. Dr. D.S. Brar
    Principal Scientist
    (Agricultural Extension)
    NDRI, Karnal
18. Shri M. Kazmi
    Director (Farm Information),
    Directorate of Extension,
    Krishi Vistar Sadan
    Pusa Campus, IARI
    New Delhi
19. Dr. K.D. Kokate
    DDG (Extension)
    ICAR, KAB,
    Pusa Campus, New Delhi
20. Dr. K.R. Koundal
    Joint Director (Research)
    IARI
21. Dr. Baldeo Singh
    Joint Director (Extension)
    IARI

**Member-Secretary**

22. Dr. K. Vijayaragavan
    Head
    Division of Agricultural Extension, IARI

## Appendix 5
## Members of Staff Research Council of IARI
**(As on 31.03.2010)**

**Chairman**

1. Director, IARI

**Members**

2. Deputy Director-General (Crop Sciences), ICAR
3. Joint Director (Research), IARI
4. All Project Directors/ Project Coordinators of IARI
5. All Heads of Divisions/ Regional Stations of IARI
6. All Principal Investigators of IARI

**Member-Secretary**

7. Principal Scientist (PPI) IARI

## Appendix 6
## Members of Executive Council of IARI
**(As on 31.03.2010)**

**Chairman**

1. Dr. H.S. Gupta
   Director, IARI

**Members**

2. Dr. K. R. Koundal
   Joint Director (Research), IARI
3. Dr. H.S. Gaur
   Dean & Joint Director (Education), IARI
4. Dr. Baldeo Singh
   Joint Director (Extension), IARI
5. Dr. D.V.K. Samuel
   Head, Division of Agricultural Engineering, IARI
6. Dr. A.K. Singh,
   Head
   Division of Fruits & Horticultural Technology, IARI
7. Dr. G.T. Gujar,
   Head
   Division of Entomology, IARI
8. Dr. Anand Swarup,
   Head
   Division of Soil Science & Agricultural Chemistry, IARI
9. Dr. (Mrs.) Dolly Wattal Dhar
   Professor
   Division of Microbiology, IARI
10. Dr. R.K. Jain
    Head
    Division of Plant Pathology
    IARI
11. Dr. R.K. Sairam
    Head
    Division of Plant Physiology
    IARI
12. Dr. V.C. Mathur
    Professor
    Division of Agricultural Economics, IARI
13. Dr. R. K. Jain
    Project Coordinator
    Division of Nematology, IARI
14. Dr. D.K. Kishore
    Head
    IARI Regional Station
    Amartara Cottage, Shimla
15. DDG (CS), ICAR,
    Krishi Bhawan, New Delhi

**Member-Secretary**

16. Shri G. R. Desh Bandhu,
    Joint Director (Admn.), IARI

## Appendix 7
## Members of Institute Joint Staff Council (IJSC)
### (As on 31.03.2010)

**Chairman**

Dr. H.S. Gupta,
Director, IARI

**Members (Official Side)**

1. Dr. H. S. Gaur
   Dean & Joint Director
   (Education)
2. Dr. P. Natu
   Senior Scientist, RPC
   Directorate
3. Dr. Jagdish Kumar
   Head, IARI R.S. Wellington
4. Shri Sanjay Kant
   Chief Admn. Officer
5. Chief Finance &
   Accounts Officer

**Secretary (Official Side)**

6. Joint Director (Administration)

**Members of the Staff Side (Elected)**

1. Shri S.C. Dixit
   T-4, Division of Genetics
2. Shri Birhm Singh Kataria
   Technical Officer (T-5)
   IARI Library (Expired)
3. Shri Mithlesh Narayan
   T-4, Division of Genetics
4. Shri Chetan Swaroop Issar
   AAO, Directorate
5. Shri Radhey Krishan Thakur
   UDC, Directorate
6. Shri Yogesh Kumar
   UDC, Division of Agricultural
   Extension
7. Shri Ajit Singh Rainu
   UDC, Division of Entomology
8. Shri Umesh Thakur
   SSS, Directorate
9. Shri Bijender Singh
   SSS, CATAT
10. Shri Dharm Singh
    SSS, Division Soil Science &
    Agricultural Chemistry
11. Shri Shashi Kant Kamath
    SSS, Seed Production Unit

**Secretary (Staff Side)**

12. Shri Ganesh Rai
    T-2, Division of Entomology

## Appendix 8
## Members of Grievance Committee of IARI
### (As on 31.03.2010)

**Chairman**

1. Dr. H. S. Gaur
   Dean & Joint Director
   (Education)

**Members (Official Side)**

2. Dr. Suresh Pal
   Head, Division of Agricultural
   Economics
3. Shri M. K. Pachauri
   SAO, Directorate
4. Ms. Piyush Malyan
   AO, Directorate

**Member-Secretary**

5. Shri Chetan S. Issar
   AAO, Directorate

**Members (Staff Side, Elected)**

1. Dr. Vijendendra Singh
   Senior Scientist
   Division of Genetics
2. Shri Birhm Singh Kataria
   Technical Officer (T-5)
   IARI Library (expired)
3. Shri Rohtash Sharma
   Admn. Officer
   Division of Nematology
4. Mohd. Azam
   SSS, Unit for Simulation &
   Informatics

## Appendix 9
# Personnel
### (As on 31.03.2010)

**Directorate**

**Director**

Dr. H.S. Gupta

**Joint Director (Research)**

Dr. K.R. Koundal

**Dean & Joint Director (Education)**

Dr. H.S. Gaur

**Joint Director (Extension)**

Dr. Baldeo Singh

**Principal Scientist (PPI Unit)**

Dr. B.R. Atteri

**Principal Scientist (ITMU)**

Dr. (Ms.) Archna Suman

**Registrar (Academic)**

Dr. K.M. Manjaiah

**Chief Administrative Officers**

Mr. G.R. Deshbandhu

Mr. Sanjay Kant

**Chief Finance and Accounts Officer**

Mr. Radhey Sham

**Agricultural Chemicals**

**Head**

Dr. V.T. Gajbhiye

**Professor**

Dr. A.K. Dikshit

**Network Project Coordinator**

Dr. K.K. Sharma

**National Fellow**

Dr. Madhuban Gopal

**Agricultural Economics**

**Head**

Dr. Suresh Pal

**Professor**

Dr. V.C. Mathur

**Agricultural Engineering**

**Head & Professor**

Dr. D.V.K. Samuel

**Agricultural Extension**

**Head**

Dr. K. Vijayraghavan

**Professor**

Dr. Ram Bahal

**Agricultural Physics**

**Head**

Dr. Ravender Singh

**Professor**

Dr. (Ms.) Usha Kiran Chopra

**Agronomy**

**Head**

Dr. A.K. Vyas

**Professor**

Dr. A.R. Sharma

**Biochemistry**

**Head**

Dr. R.D. Rai

**Professor**

Dr. (Ms.) I.M. Santha

**Entomology**

**Head**

Dr. G.T. Gujar

**Professor**

Dr. R.D. Gautam

**Environmental Sciences**

**National Professor**

Dr. P.K. Aggrawal

**Head**

Dr. H.C. Joshi

**Professor**

Dr. Shiv Dhar Singh

**National Fellow**

Dr. (Ms.) R. Kaur

**Floriculture and Land-scaping**

**Head**

Dr. T. Janakiram

**Project Coordinator**

Dr. K.P. Singh

**Fruits and Horticultural Technology**

**Head**

Dr. A.K. Singh

**Genetics**

**Head**

Dr. K.V. Prabhu

**Professor**

Dr. (Ms.) S. Chandrashekaran

**Microbiology & CCUBGA**

**Head**

Dr. A.K. Saxena

**Professor**

Dr. (Ms.) D.W. Dhar

**Nematology**

**Head**

Dr. A.K. Ganguly

**Professor**

Dr. Rambir Singh

**Project Coordinator**

Dr. R.K. Jain

**Plant Pathology**

**Head**

Dr. R.K. Jain

**Professor**

Dr. (Ms.) Janki Kandhari

**National Fellow**

Dr. (Ms.) Rashmi P. Aggarwal

**Plant Physiology**

**Head**

Dr. R.K. Sairam

**Professor**

Dr. V.P. Singh

**Post Harvest Technology**

**Head**

Dr. R.K. Pal

**Professor**

Dr. Vidya Ram Sagar

**Seed Science and Technology**

**Head**

Dr. (Ms.) M. Dadlani

**Professor**

Dr. S.S. Parihar

**Soil Science and Agricultural Chemistry**

**Head**

Dr. Anand Swarup

**Professor**

Dr. R.K. Rattan

**Vegetable Science**

**Head**

Dr. Pritam Kalia

**Professor (Hort.)**

Dr. Pritam Kalia

**NRC on Plant Biotechnology**

**Director**

Dr. P. Ananda Kumar

**National Professor**

Dr. N.K. Singh

**Professor**

Dr. K.C. Bansal

**Nuclear Research Laboratory**

**Project Director**

Dr. K.R. Koundal

**Water Technology Centre**

**Project Director**

Dr. T.B.S. Rajput

**Professor**

Dr. R.K. Sharma

**National Fellow**

Dr. (Ms.) Renu Khanna Chopra

**Agriculture Technology Information Centre**

**Scientist-in-charge**

Dr. (Ms.) Monika Wasan

**Centre for Agricultural Technology Assessment and Transfer**

**Scientist-in-charge**

Dr. J.P. Sharma

**Centre for Protected Cultivation Technology**

**Scientist-in-charge**

Dr. Balraj Singh

**Farm Operation Service Unit**

**Scientist-in-charge**

Dr. P.K. Sharma

**National Phytotron Facility**

**Scientist-in-charge**

Dr. K.V. Prabhu

**Seed Production Unit**

**Scientist-in-charge**

Mr. Amar Singh

**Unit for Simulation and Informatics (USI)**

**Scientist-in-charge**

Dr. H. Chandrasekharan

**IARI Library**

**In-charge (Library Services)**

Ms. Usha Khemchandani

**IARI Regional Station, Amartara Cottage**

**Head**

Dr. D.K. Kishore

**IARI Regional Station, Indore**

**Head**

Dr. A.N. Mishra

**IARI Regional Station, Kalimpong**

**Scientist-in-charge**

Dr. K.B. Pun

**IARI Regional Station, Karnal**

**Head**

Dr. S.N. Sinha

**IARI Regional Station, Katrain**

**Head**

Dr. R.N. Barwal

**IARI Regional Station, Pune**

**Head**

Dr. K.K. Zote

**IARI Regional Station, Pusa**

**Head**

Dr. I.S. Solanki

**IARI Regional Station, Wellington (The Nilgiris)**

**Head**

Dr. Jagdish Kumar

**IARI Rice Breeding & Genetics Research Centre, Aduthurai**

**Scientist-in-charge**

Dr. M. Nagarajan

**IARI Centre for Improvement of Pulses in South, Dharwad**

**Scientist-in-charge**

Dr. V. Hegde

**IARI Krishi Vigyan Kendra, Shikohpur, Gurgaon**

**Scientist-in-charge**

Dr. Anjani Kumar