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वार्षिक रिपोर्ट
Annual Report
2010-11

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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Indian Agricultural Research Institute

(मानद विश्वविद्यालय)

(Deemed University)

नई दिल्ली-110 012

New Delhi-110 012

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PREFACE

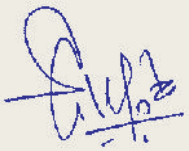
The Indian Agricultural Research Institute is country's pioneer institution in the fields of agricultural research, education and extension. It has been moving with the times to enhance the nation's capability for food grain production commensurate with the increase in the country's population. Its historical contribution to the country's Green Revolution is too well known to bear repetition. The Institute is in the vanguard of the country's efforts to launch an Ever Green Revolution, which will be both productive and sustainable.

New research leads were provided by the Institute in the areas of crop improvement, crop and resource management and environment, crop protection, basic and strategic research and social sciences. During the reported period, two wheat (*Triticum aestivum*) varieties, Pusa Suketi and HI 1553 were released for Northern Hills Zone and North-Eastern Plains Zone, respectively, while a *durum* variety Pusa Gaurav was recommended for release in Madhya Pradesh. A brinjal hybrid DBHL-20 was identified for release in Punjab, Delhi and Uttar Pradesh. Transgenic plants with enhanced tolerance to biotic and abiotic stresses are at different stages of development. Capacity building interventions in enhancing entrepreneurship among rural women led to the initiation of new enterprises. Three patents for different processes and products were granted and eight technologies were commercialized.

The Institute's 49th convocation was held on February 5, 2011 at which 99 M.Sc. and 73 Ph.D. students were awarded degrees. Many scientists, students and faculty received prestigious awards and recognitions for excellence in research and academics.

This report was compiled by a committee comprising Dr. Malavika Dadlani, Joint Director (Research) as the chairperson and Dr. A. R. Sharma, Professor (Agronomy); Dr. Prem Lata Singh, Professor (Agricultural Extension); Dr. Rashmi Aggarwal, National Fellow (Plant Pathology); Dr. C. Vishwanathan, Principal Scientist (Plant Physiology); Dr. Alka Singh, Principal Scientist (Agricultural Economics); Dr. A.K. Singh, Senior Scientist (Genetics); Dr. T.K. Behera, Senior Scientist (Vegetable Science); Dr. K.M. Manjaiah, Officer-in-charge, AIM Cell, PG School; and Mr. Chacko Thomas, former Editor (English)/Dr. Kehar Singh, Technical Officer, Publication Unit as members. The final editing of the manuscript was done by Mr. Chacko Thomas, former Editor (English), IARI.

I am thankful to all who have been associated with the timely publication of this report.



(H.S. Gupta)
Director

July 2, 2011
New Delhi

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IARI : AN INTRODUCTION

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

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

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

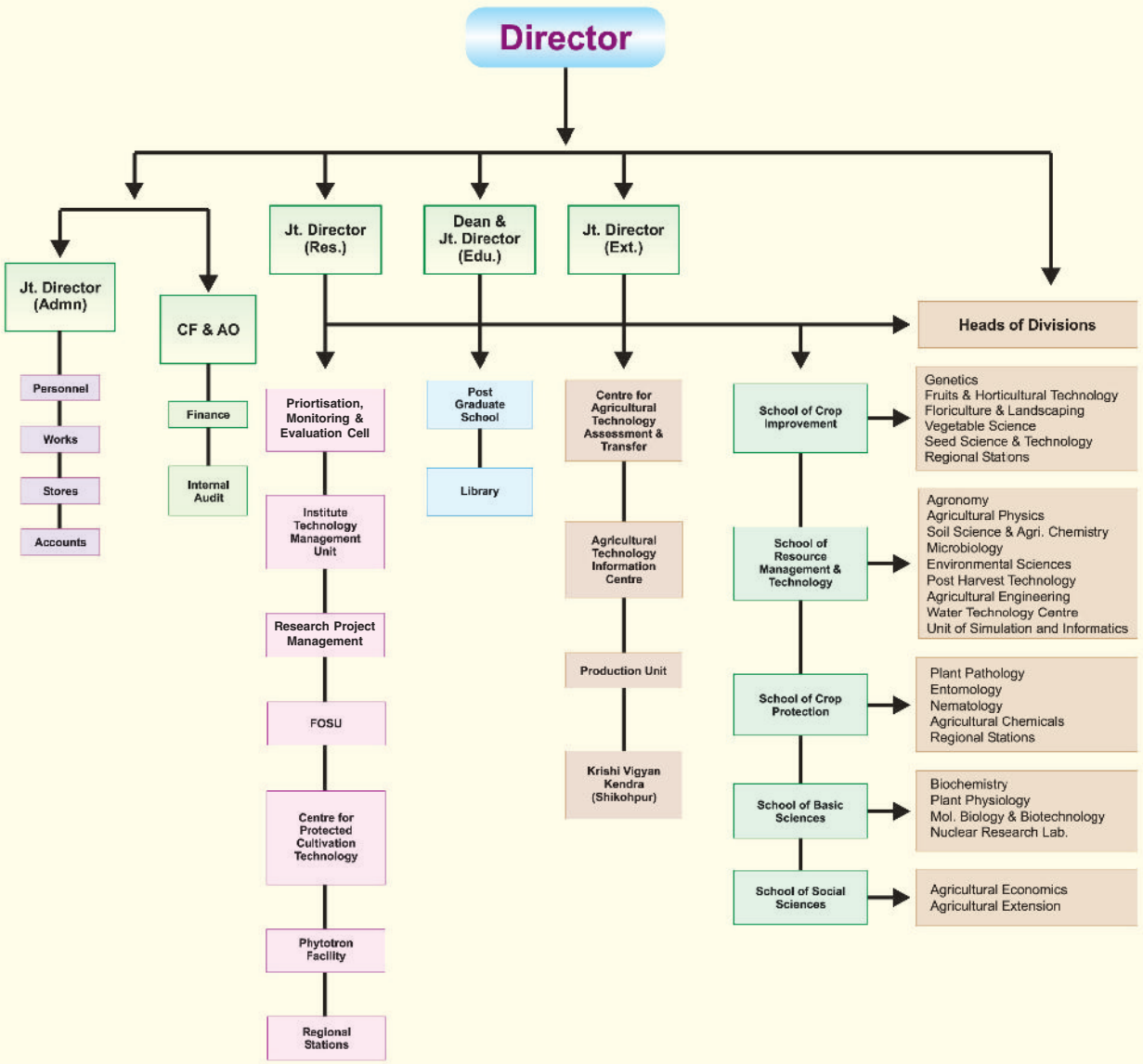
The mandates of the Institute are as follows:

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

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

The Institute has 20 divisions, 5 multi-disciplinary centres situated in Delhi, 8 regional stations, 2 off-season nurseries, one krishi vigyan kendra at Shikohpur, 3 all India coordinated research projects with headquarters at IARI, and 10 national centres functioning under the all India coordinated research projects. It has a sanctioned staff strength of 3105 comprising scientific, technical, administrative and supporting personnel. The revised budget estimates of the Institute constituted a total amount of ₹ 20,901.08 lakh (Plan & Non-plan) for the year 2010-11.

Indian Agricultural Research Institute



Organizational Structure

विशिष्ट सारांश

भारतीय कृषि अनुसंधान संस्थान वैज्ञानिक प्रगति पर आधारित टिकाऊ खेती के लिए प्रौद्योगिकियों का सृजन करने, उच्च गुणवत्तापूर्ण उच्चतर कृषि शिक्षा प्रदान करने, अग्रिम पंक्ति की प्रसार–प्रौद्योगिकियों को विकसित करने, संस्थागत क्षमता निर्माण और अन्य अनुसंधान और विकास संगठनों और पणधारकों के साथ सहभागिताओं को विकसित करने में निरन्तर अपनी नेतृत्वदायी भूमिका निभा रहा है। वर्ष 2010–2011 के दौरान, भा.कृ.अ.सं. ने प्राकृतिक संसाधन प्रबंधन, फसल संरक्षण तथा कटाई उपरांत प्रसंस्करण तथा मूल्य संवर्धन के लिए अनेक फसल किस्मों, फार्म मशीनरी और उपकरण तथा कृषि प्रौद्योगिकियों को विकसित किया है। संस्थान के मूल और कार्य नीतिपरक अनुसंधान कार्यक्रमों ने ज्ञान सृजन की दिशा में महत्वपूर्ण प्रगति की है जो कि वैश्विक जलवायु परिवर्तन का सामना कर रही लचीली कृषि के लिए आवश्यक है। अनुसंधान, प्रसार और शिक्षा के क्षेत्र में भा.कृ.अ.सं. की मुख्य उपलब्धियों को नीचे संक्षेप में दिया जा रहा है :

फसल सुधार से संबंधित संभागों ने धान्य, दलहन, तिलहन, सब्जी, फल और सजावटी फसलों में उच्च उपज, बेहतर गुणवत्ता, विभिन्न कृषि पर्यावरणीय स्थितियों के अनुकूल तथा रोग प्रतिरोधिता के साथ उन्नत किस्मों का विकास किया है। गेहूं की किस्में, नामतः, पूसा बसंत (एचडी 2985) और पूसा बहार (एचडी 2987) को अधिसूचित किया गया। पूसा बसंत में पर्ण रतुए के प्रति वयस्क पादप प्रतिरोधिता है और यह 3.74 टन प्रति हैक्टर की औसत उपज के साथ उत्तर पूर्वी मैदानी क्षेत्र की देर से बोई जाने वाली तथा बहुत अधिक देर से बोई जाने वाली स्थितियों के लिए उपयुक्त है। पूसा बहार में भूरे और काले रतुओं के प्रति दोहरी वयस्क पादप प्रतिरोधिता है। यह 1.8 टन प्रति हैक्टर की औसत उपज के साथ प्रायःद्वीपीय क्षेत्र की बारानी और सीमित सिंचाई वाली परिस्थितियों के लिए उपयुक्त है। उच्च उपजशील गेहूं किस्म पूसा सुकेती (एचएस 507) को समय से बोई जाने वाली सिंचित परिस्थिति में 4.68 टन प्रति हैक्टर की औसत उपज के साथ ही साथ उत्तरी पर्वतीय क्षेत्र की समय से बोई जाने वाली सिंचित एवं बारानी परिस्थितियों के तहत खेती के लिए जारी किया गया। यह किस्म पर्ण और पट्टीदार रतुओं, पर्ण अंगमारी तथा करनाल बंट की प्रतिरोधी हैं। गेहूं की किस्म एचआई 1563 को 3.7 टन प्रति हैक्टर की औसत उपज के साथ उत्तर पूर्वी मैदानी क्षेत्रों की सिंचित–देर से बोई जाने वाली स्थितियों के लिए जारी किया गया। यह किस्म पर्ण पट्टीदार और तने रतुओं के लगभग सभी हानिकारक रोगप्ररूपों की प्रतिरोधी है। राज्य बीज उप–समिति ने मध्य प्रदेश की सिंचित, समय से बोई जाने वाली परिस्थितियों के लिए 5.36 टन प्रति हैक्टर की औसत उपज वाली ड्यूरम गेहूं की किस्म पूसा गौरव (एचआई 8691) की सिफारिश की। इस किस्म में तने और पर्ण रतुओं के सभी मौजूद और हानिकारक रोगप्ररूपों के प्रति प्रतिरोधिता है। किस्म एचडी 3016 को ब्रेड बनाने की विशेषताओं जैसे कि डबलरोटी के आयतन का उच्चतर मान (cc) तथा ब्रेड गुणवत्ता स्कोर के लिए, अन्य नियंत्रित किस्मों से श्रेष्ठ पाया गया। इसकी उपज नियंत्रित किस्मों की अपेक्षा 8.08 से 12.71 प्रतिशत उच्चतर थी।

चावल में, जल्दी पकने वाली, अर्ध–बौनी और न झड़ने वाला विशिष्ट बासमती प्रजनन वंशक्रम IET 21960 (पूसा 1509–03–3–9–5) विकसित किया गया जिसकी उत्कृष्ट दाना किस्म और उच्च उपज थी। इस वंशक्रम को *खरीफ* 2011 के दौरान परीक्षण के लिए उन्नत किस्मीय परीक्षण (AVT) के तहत प्रौन्नत किया गया। बासमती चावल में ब्लास्ट प्रतिरोधिता को सुधारने के लिए मार्कर समर्थित प्रतीप संकर प्रजनन से पूसा बासमती–1 की पृष्ठभूमि में मुख्य ब्लास्ट प्रतिरोधी जीनों (*Pil, Pikh, Pita, Pib, Piz5, Pi5* तथा *Pi9*) का वहन करने वाले समजीनी वंशक्रमों का विकास किया गया। इन वंशक्रमों को सीधी किस्मों के साथ ही साथ बासमती प्रजनन कार्यक्रम में ब्लास्ट प्रतिरोधी जीनों के लिए दाता के रूप में भी जारी किया जा सकता था। मार्कर समर्थित प्रतीप संकर प्रजनन विधि के द्वारा ब्लास्ट प्रतिरोधी जीनों Piz5 तथा Pi54 का पूसा 1609 के एक विशिष्ट बासमती प्रत्यास्थापक वंशक्रम, में अन्तर्गमन किया गया। काला नमक की दाने और पकाने की क्वालिटी विशेषताओं के साथ बौने गठन और उच्च उपज को मिलाकर पूर्वी उत्तर प्रदेश से छोटे दाने वाली सुगंधित चावल की भू–प्रजाति, काला नमक के उन्नत संस्करणों को विकसित किया गया। इन वंशक्रमों में, जो कि अभी परीक्षण के विभिन्न स्तरों पर हैं, उत्तर प्रदेश के काला नमक उगाने वाले क्षेत्रों में छोटे दाने वाले सुगंधित चावल के उत्पादन और उत्पादकता को बढ़ाने की व्यापक संभावना है।

जल्दी पकने वाले मक्का के हाइब्रिड एएच 97002, एएच 97017 और एएच 97018 जिनकी औसत उपज 5.8–6 टन प्रति हैक्टर की है और जो कि आन्ध्र प्रदेश, कर्नाटक और महाराष्ट्र में खेती के लिए उपयुक्त है, पर समन्वित परीक्षण किए गए। जौ में, दो श्रेष्ठ जीनप्ररूपों बीएचएस 393 तथा बीएचएस 344 को अखिल भारतीय समन्वित परीक्षणों के एवीटी बारानी के तहत दूसरे वर्ष के परीक्षण के लिए प्रौन्नत किया गया। बाजरे में, पूसा कम्पोज़िट 621, जिसने पिछले

तीन वर्षों के दौरान नियंत्रित किस्मों की अपेक्षा समन्वित परीक्षणों में निरन्तर बेहतर निष्पादन किया, को पहचान के लिए लिया गया।

चने के चार श्रेष्ठ जीनप्ररूपों जैसे बीजी 3005, बीजी 3012, बीजीएम 571 तथा बीजीएम 572 को एवीटी–1 परीक्षणों के तहत प्रोन्नत किया गया। मसूर में, उच्च उपजशील किस्म एल 4701 को तीन क्षेत्रों, नामतः केन्द्रीय क्षेत्र (CZ), उत्तर पूर्वी मैदानी क्षेत्र (NEPZ) और उत्तर पश्चिमी मैदानी क्षेत्र (NWPZ) के लिए एवीटी–1 की ओर प्रोन्नत किया गया। सरसों की किस्म पूसा मस्टर्ड–26 (NPJ-113) जिसमें शीर्षस्थ उच्च तापमान की सहिष्णुता थी, को हरियाणा, राजस्थान, पंजाब, जम्मू और कश्मीर के मैदानी क्षेत्र, दिल्ली और पश्चिमी उत्तर प्रदेश की देर से बोई जाने वाली स्थितियों (अर्थात् कपास, चावल और ग्वार की कटाई के बाद नवम्बर की बुवाई) के लिए जारी किया गया। 126 दिनों में पकने वाली इस किस्म की औसत उपज 1.6 टन प्रति हैक्टर है और इसमें तेल की मात्रा 37.6 प्रतिशत है। उत्तर प्रदेश, मध्य प्रदेश, उत्तराखंड और राजस्थान के कोटा क्षेत्र की अगेती बुवाई परिस्थितियों के लिए 1.53 टन प्रति हैक्टर की औसत बीज उपज तथा 41.7 प्रतिशत तेल की मात्रा वाली पूसा मस्टर्ड 27 (EJ-17) को जारी किया गया।

शाकीय फसलों में, अखिल भारतीय समन्वित अनुसंधान परियोजना (शाकीय फसलें) द्वारा बैंगन हाइब्रिड डीबीएचएल–20 की जारी किए जाने के लिए पहचान कर इसकी पंजाब, दिल्ली, उत्तर प्रदेश और बिहार में खेती के लिए सिफारिश की गई। इस किस्म के फल लम्बे, गहरे जामुनी और चमकदार होते हैं तथा फल का भार 90 से 100 ग्राम होता है। यह हाइब्रिड, जिसकी कि प्रतिरोपण के लगभग 55 दिन के बाद पहली कटाई की जाती है, की औसत उपज 52.4 टन प्रति हैक्टर है। प्याज चयन (सेल-126) जिसके कि गहरे लाल रंग के कंद (बल्ब) होते हैं और जिसकी औसत उपज 31.6 टन प्रति हैक्टर है, ने अखिल भारतीय समन्वित अनुसंधान परियोजना (शाकीय फसलें) परीक्षणों के तहत निरन्तर अच्छा निष्पादन किया। करेले में 12 नए जायांगीय × और उभयलिंगाश्रयी हाइब्रिडों और तीन प्रमुख जायांगीय वंशक्रमों को विकसित किया गया।

बीज ओज और फसल उपज को सुधारने के लिए स्थिर चुम्बकीय क्षेत्र और y–किरणों के साथ बीज उपचार तकनीकों को विकसित किया गया। भण्डारण में हुई क्षति को सुधारने के लिए और अंकुरण तथा पौदों के ओज को सुधारने के लिए स्थिर चुम्बकीय क्षेत्र उपचार (Ih के लिए 100 mT) विकसित किए गए। कम खुराक की y–विकिरण (0-5 KGy) बीज उपचार ने चने के जीनप्ररूपों के उपज घटकों को बढ़ा दिया। यह सोयाबीन में LOX गतिविधि और अपस्वाद को कम करने में भी प्रभावी था।

आम के चार हाइब्रिड नामतः पूसा प्रतिभा, पूसा श्रेष्ठ, पूसा पीताम्बर और पूसा लालिमा को भा.कृ.अ.सं. के 49वें दीक्षांत समारोह में जारी किया गया। इन हाइब्रिडों में नियंत्रित पूसा अरुणिमा की अपेक्षा बेहतर गुणवत्ता विशेषताएं थीं, अतः इनकी एनसीआर दिल्ली क्षेत्र के लिए सिफारिश की गई। अंगूर में, बीजरहित हाइब्रिड, बैंक्वी एबयाड × पर्लेट–75–32 और (Hur × BE) × BS ने कटाई–छंटाई की हेड प्रणाली के अंतर्गत बेहतर निष्पादन किया और इससे अच्छी गुणवत्ता, जल्दी पकने वाले और बेहतर उपज वाले फल प्राप्त हुए।

सजावटी फसलों में, गुलाब के तीन हाइब्रिड (हाइब्रिड टी ग्रुप), दो पौदों और तीन कलिका स्पोर्ट्स तथा फ्लोरिस्ट क्राईसेन्थम के चार आशाजनक पौदों को विकसित किया गया। ग्लैडियोलस के दो हाइब्रिडों (बरलेव × हैडीवाइन तथा मयूर × हंटिंग सॉन्ग) तथा एक खुली परागन किस्म रिजेन्सी ओपन को फूलों के लक्षणों के लिए आशाजनक पाया गया। गेंदा में, उच्च कैरोटिनॉइड मात्रा के लिए चयन से, चयन Af/WS-2 की पहचान की गई जिसमें कैरोटिनॉइड की मात्रा (58-89 µg/100 g) पूसा नारंगी गेंदा (41-20 µg/100 g) से उच्चतर थी।

फसलों में अनेक आनुवंशिक स्टॉकों, रोगाणुओं और कीटों की पहचान की गई, उनके गुणधर्म लक्षणों का निर्धारण किया गया और उन्हें विकसित किया गया। चावल में चार आनुवंशिक स्टॉक नामतः पूसा 1605–05–38–3–1 (INGR 10121), पूसा 1605–05–38–3–2 (INGR 10122), पूसा 1601–05–46–1–1 (INGR 10123), पूसा 1601–05–46–5–3 (INGR 10124) जिनमें जीवाण्विक अंगमारी प्रतिरोधिता थी, को विकसित और पंजीकृत किया गया। मक्का में MLB और BLSB रोगों के प्रतिराधी क्रमशः 15 और 4 जीनप्ररूपों की पहचान की गई। कपास में P 56-4 (IGNR 10155) को उच्च रेशा मजबूती (27.8 g/tex) के लिए पंजीकृत किया गया और पूसा 1752 की मशीन से पिकिंग के लिए पहचान की गई। करेले में अल्पावधि के जायांगीय जीनप्ररूपों DBGy202 तथा DBGy201 को विकसित किया गया।

कवक की नई प्रजातियों नामतः *कोरीनेस्पोरा बोमबासिना, सी. स्लेरोडेनड्रिग्ना, सी. मोरासिना तथा सी. फिकीजेना* को कवकीय जैव विविधता संकलन में जोड़ा गया। भा.कृ.अ.सं. ने विभिन्न ग्रुपों नामतः जाइगोमाइसिटीज़ (58), हाइफोमाइसिटीज़ (160), एस्कोमाइसिटीज़ (43), पेनीसिली (42), एस्परगिली (63), कोलमाइसिटीज़ (34) तथा फ्यूजारिया (120) से संबंधित 520 प्रामाणिक कवकीय कल्चरों को देशभर के विभिन्न प्रयोक्ताओं को सप्लाई किया। तमिल नाडु और महाराष्ट्र से एकत्रित किए गए *स्टेनीनेर्मा* के दो नए सूत्रकृमि विभेदों को क्रमशः वंशों *स्टेनीनेर्मा* तथा *हेटरोहेबडिटीस* को प्रदान किया गया। दो नई सूत्रकृमि प्रजातियां *टाइलेनक्लोरोनाइकस बेमबूसी* प्रजाति एन. और *हैलीकोटीलेंकिस रायपुरनेसिस* प्रजाति एन. को रायपुर, छत्तीसगढ़ में चावल के राइज़ोस्फ़ेयर से एकत्रित किया गया। कीट जैव वर्गिकीय विश्लेषण अनुसंधान से *हेमीपेटरा* की नई प्रजातियों, केरल में पामपादुमपारा में फिकस एक्सपेरेटा परपोषी पौधों पर *क्रिसना, पामपादुमपारानेसिस* की पहचान की गई।

सस्यन प्रणालियों की उत्पादकता और टिकाऊपन को सुधारने के लिए फसल और संसाधन प्रबंधन, संसाधनों के इष्टतम प्रयोग तथा निवेश प्रयोग दक्षता को बढ़ाते हुए अनेक कृषि तकनीकें तैयार की गईं। *सेसबेनिया एक्यूलेट* मिलाने के बाद उसमें *क्रोटालरिया जुन्सिया, विगना उनजूकुलाटा* मिलाकर गर्मियों में खेत को खाली छोड़ने पर चावल की पूसा बासमती–1 किस्म की उपज में उल्लेखनीय वृद्धि पाई गई। सोयाबीन–गेहूं सस्यन प्रणाली में, घूरे की खाद + उर्वरकों की 50 प्रतिशत अभिशंसित खुराक के बराबर 50 प्रतिशत N के अनुप्रयोग से गेहूं की फसल की उपज का उतना ही उत्पादन हुआ जितना कि 100 प्रतिशत उर्वरकों की अभिशंसित खुराक के अनुप्रयोग से होता था। बारानी परीक्षणों में, बाजरा–समतुल्य उपज ग्वार के मामले में उच्चतम थी (4.31–5.72 टन प्रति हैक्टर) और उसके बाद मूंगबीन (2.76–3.12 टन प्रति हैक्टर) और बाजरे (1.44–2.23 टन प्रति हैक्टर) की उपज थी। बाजरा + ग्वार अन्तःसस्यन प्रणाली में मेड़ों और खूंडों पर बुवाई करने से उच्चतम बाजरा–समतुल्य उपज प्राप्त हुई। कपास की मक्का–समतुल्य उपज अरहर की मक्का समतुल्य उपज की तुलना में दोगुना और मक्का से तीन गुना अधिक थी। चौड़ी क्यारियों (140 सें.मी., 2 पंक्तियां) में उगाई गई फसल से संकरी क्यारियों (70 सें.मी., 1 पंक्ति) में उगाई गई फसल से उच्चतर उपज प्राप्त हुई और दोनों ओर उठी हुई क्यारियों पर उगाई गई फसल से पारम्परिक समतल भूमि पर उगाई गई फसल से उच्चतर उपज प्राप्त हुई। जब दोनों फसलों के अवशिष्ट मृदा की सतह पर रहने दिए गए तब कपास के लिए शून्य जुताई उसी प्रकार से उत्तम थीं जैसी कि पारम्परिक जुताई होती है।

उर्वरक प्रयोग दक्षता को बढ़ाने पर किये गए अध्ययनों से यह पता चला कि नैनोक्ले पॉलीमर कम्पोज़िट (NCPC) पारम्परिक यूरिया और मृदाओं से सामूहिक N और P की वसूली में DAP से श्रेष्ठ था। मृदा एन्जाइम गतिविधियों और रोगाणु ग्रुपों पर धातु ऑक्साइड नैनो कणों (ZnO तथा Fe_2O_3) और कार्बन आधारित नैनो कणों (फुलेरेन, C60) के प्रभाव का मूल्यांकन करने से यह पता चला कि यूरिएस गतिविधि Fe_2O_3 में न्यूनतम थी और ZnO नैनो कण उपचार में उच्चतम थी। उर्वरकों के दीर्घावधि परीक्षण से यह पता चला कि NPK की अभिशंसित खुराक की अपेक्षा 150 प्रतिशत NPK के प्रयोग से मक्का और गेहूं में क्रमशः 0.53 टन और 0.83 टन प्रति हैक्टर की उपज का लाभ प्राप्त हुआ। खेत पर मृदा परीक्षण को सुलभ कराने तथा उर्वरक संबंधी सिफारिशों के लिए एक डिजिटल मृदा परीक्षण एवं उर्वरक अनुशंसा मापक विकसित किया गया है। यह एक सरल और त्वरित विधि के माध्यम से मृदा में कार्बनिक C, NO_3, P,K, S, Zn तथा B की मात्रा का निर्धारण करता है। इस उपकरण से किसी विशिष्ट फसल की लक्षित उपज के लिए उर्वरक संबंधी अनुशंसाएं भी ज्ञात की जा सकती हैं।

सिंचाई जल के इष्टतम उपयोग तथा पानी की प्रत्येक बूंद से अधिक फसलोत्पादन के लिए प्रौद्योगिकियां विकसित की गईं। प्राकृतिक रूप से वातायित पालीहाउस में शिमलामिर्च या कैप्सिकम की ड्रिप सिंचाई करते हुए खेती करने से खुले खेत में की जाने वाली खेती की तुलना में फसल की जल संबंधी आवश्यकता में लगभग 20–40 प्रतिशत की बचत होती है। ड्रिप तथा अल्पता सिंचाई विधियों के सम्मिलित उपयोग से प्याज की फसल में 85.50 कि.ग्रा./घन मीटर की सर्वोच्च जल उपयोग दक्षता प्राप्त की गई। ड्रिप सिंचाई के अन्तर्गत उगाई गई गाजर की बीज वाली फसल में सतही सिंचाई की तुलना में उपज में उल्लेखनीय वृद्धि हुई तथा बीज की गुणवत्ता में भी सुधार हुआ और इससे जल और उर्वरक की क्रमशः 30 और 35 प्रतिशत की बचत हुई।

सब्जियों की उपज व गुणवत्ता में सुधार के लिए संरक्षित खेती की विधियां विकसित की गईं। सब्जियों के रोगमुक्त बीज उत्पन्न करने के लिए 40 मेश यूवी–स्टेबलाइज्ड नाइलॉन के जाल का एक कीट–रोधी जालघर तैयार किया गया। इस कीटरोधी जालघर में उगी खीरा–ककड़ी और करेले की फसलें फल मक्खी से क्षतिग्रस्त नहीं हुईं और इस विधि से उत्पन्न बीज विषाणु मुक्त थे। खीरा–ककड़ी वर्गीय सब्जियों जैसे लौकी और चप्पन कद्दू की गैर–मौसमी खेती के लिए मनुष्यों के प्रवेश करने वाली सुरंगें तकनीकी रूप से उपयुक्त पाई गईं।

संस्थान ने विभिन्न कृषि क्रियाओं की दक्षता बढ़ाने के लिए अनेक नए कृषि यंत्रों और औजारों का विकास किया है। गोबर के साथ गैर कटे–छटे अपशिष्टों/जीवद्रव्य को मिलाने और पलटने तथा घूरे की खाद के उत्पादन के लिए सूक्ष्म जैविक मात्रा को बढ़ाने के लिए एक 'खाद पलटने और मिलाने वाले यंत्र' तथा 'घूरे की खाद के लोडर' को डिजाइन किया गया। इसकी सहायता के लिए ट्रैक्टर पर लादे जा सकने वाले लोडर तथा कम्पोस्ट छनाई यंत्र का भी विकास किया गया। चारा काटते समय लगने वाली चोटों से बचने के लिए जो सुरक्षात्मक युक्तियां विकसित की गईं उनमें ब्लेड का गार्ड, फ्लाई व्हील का ताला और चेतावनी रोलर जैसी युक्तियां सम्मिलित हैं। छिलका उतारने से पहले दलहनों के छिलके को ढीला करने का एक यंत्र (दाल पर छोटे गड्ढ़े बनाने का यंत्र) विकसित किया गया जिससे दालों की पॉलिश करने से अरहर के दानों की भौतिक गुणवत्ता में वृद्धि हुई।

विभिन्न फलदार फसलों में कटाई पूर्व व कटाई उपरांत प्रबंधन, प्रसंस्करण और मूल्यवर्धन के क्षेत्र में हुए अनुसंधानों के परिणामस्वरूप नई प्रसंस्करण व पैकिंग तकनीकों तथा उत्पादों का विकास हुआ। तुड़ाई के 85 दिन पूर्व अनार के फल को थैले में बंद करने से फल चटके नहीं, उनमें खरोंच नहीं पड़ी, जीवाण्विक धब्बे नहीं आए और फल धूप से जले नहीं। लाल या पीले रंग के थैलों से सेबों को ढकने पर तुड़ाई के समय उन पर गहन लाल रंग दिखाई दिया। आम की वाणिज्यिक किस्म लंगड़ा की इष्टतम परिपक्वावस्था पर तुड़ाई करने और लहरदार फाइबर बोर्ड के तीन प्लाई वाले बक्सों में प्रति बक्से 4–5 किलो आमों को अखबार में लपेट कर कागज की कतरनों के

साथ पैक करने के परिणामस्वरूप उनकी विकृति में 5 प्रतिशत की कमी आई तथा सुदूर बाजार में भेजने के दौरान भार में कमी अपेक्षाकृत 8 प्रतिशत न्यून हुई।

उच्च गुणवत्ता वाले टमाटर के पाउडर तथा आंवला के फल का पाउडर बनाने की एक प्रक्रिया मानकीकृत की गई। पूसा आंवला के पाउडर का रंग सर्वोच्च सफेदी वाले सूचकांक का था तथा बाजार से लिए गए नमूनों की तुलना में इसकी सफेदी बहुत बेहतर थी। बाजरे के तत्काल खाने के लिए तैयार फूले हुए उत्पाद विभिन्न आयु वर्ग के लोगों द्वारा स्वाद के मूल्यांकन के आधार पर उच्च स्वीकार्यता वाले पाए गए। गेहूं के आटे में सोया का आटा मिलाकर तैयार किए गए प्रोटीन से समृद्ध कुकीज़ या बिस्किट स्वाद की दृष्टि से सर्वश्रेष्ठ थे, इसके बाद बाजरे का आटा मिलाकर तैयार किए गए बिस्किटों का स्थान था।

नवीन अणुओं तथा जीनों के लिए अत्यधिक कठिन पर्यावरणों से सूक्ष्मजीवों की बायोप्रॉसपेक्टिन या जैव संभाव्यता से संबंधित कार्य किया गया। *स्ट्रेप्टोमाइसिस* प्रजाति एमआईसी–98 तथा *स्ट्रेप्टोमाइसिस ग्लोबोसस* एमआईसी–198 को ज़ाइलानेज़ (85.91 आईयू/ग्रा. सबस्ट्रेट) तथा एंडोग्लूकानेज़ (198 आईयू/ग्रा. सबस्ट्रेट) की उच्च मात्रा के उत्पादन के लिए क्रमशः कांग्रेस घास के प्रतिस्थापक के रूप में पहचाना गया। *बी. लाइकेनीफॉरमिस* डब्ल्यू बीएस1 (प्रविष्टि संख्या जीयू 590782) तथा *बैसीलस* प्रजाति डब्ल्यूबीएस 3 (प्रविष्टि संख्या जीयू 590784) नामक दो सशक्त तापरागी और सैल्यूलोलिटिक जीवाणुओं को बकरेश्वर के उष्ण झरनों से पृथक किया गया। इन दोनों ही जीवों ने केवल 65 डिग्री सैल्सियस के तापमान पर क्रमशः 0.42 आईयू/मि.ली. तथा 0.35 आईयू/मि.ली. की FPAse सक्रियताएं उत्पन्न कीं। सैल्यूलोज़ एन्जाइमों में जैव ऊर्जा के उत्पादन तथा कपड़ा उद्योग में उपयोग के साथ–साथ लुगदी और कागज उद्योगों में उपयोग की पर्याप्त संभावनाएं हैं। साइनोबैक्टीरिया में रंजक जैवसंश्लेषण के लिए स्थितियों को इष्टतम बनाया गया। पहली बार एक नवीन कवकनाशी यौगिक मैजूस्कूलेमाइड C को शुद्ध करके उसका गुण निर्धारण किया गया। इसे *एनाबीना लाक्सा* से प्राप्त किया गया था। *ट्राइकोडर्मा विरिडे* तथा *स्यूडोमोनास फ्लोरेसेंस* का उपयोग करके जैव फिल्में विकसित की गईं। इष्टतम स्थितियों के अन्तर्गत कम घनत्व वाली पॉलीथीन के अपघटन के लिए जीवाणुओं तथा कवकों को विलगित किया गया। एक नए सूक्ष्मजीव से रोग का शमन करने वाली सुधरी हुई कम्पोस्ट विकसित की गई और उसका मूल्यांकन टमाटर की फसल में किया गया। परिणामों से यह स्पष्ट हुआ कि इस प्रकार के नए व सूक्ष्मजीवों से समृद्ध कम्पोस्ट टिकाऊ तथा जैविक खेती में प्रभावी जैव नियंत्रक एजेन्ट सिद्ध हो सकते हैं।

जलवायु परिवर्तन संबंधी अनुसंधान के क्षेत्र में अनाज वाली फसलों पर जलवायु परिवर्तन के क्षेत्रीय प्रभावों का मूल्यांकन किया गया। सिंचित स्थितियों के अन्तर्गत ली गई चावल की उपज के विश्लेषण से यह संकेत मिला कि हरियाणा और पंजाब में उपज में 8 प्रतिशत तक की कमी आने की संभावना है जबकि उत्तर प्रदेश और बिहार में लगभग 3–4 प्रतिशत उपज कम होने की संभावना है। यह परिदृश्य वर्ष 2020 के लिए आकलित किया गया। भारतीय कृषि से उत्सर्जित होने वाली ग्रीन हाउस गैस की सूची को अद्यतन किया गया। लगभग 43.9 मिलियन हैक्टर क्षेत्र में फैले भारतीय धान के खेतों से 3.37 मिलियन टन मीथेन (CH_4) उत्सर्जित होती है। भारत की कृषि भूमियों से कुल 0.14 मिलियन टन नाइट्रस ऑक्साइड (N_2O) के उत्सर्जित होने का आकलन किया गया। नाइट्रोजन उर्वरकों का नाइट्रस ऑक्साइड के उत्सर्जन में 70 प्रतिशत योगदान है। फसल अपशिष्टों को खेत में जलाने से 0.23 मिलियन टन मीथेन तथा 0.006 मिलियन टन नाइट्रस ऑक्साइड उत्सर्जित होती है। खेतों पर किए गए प्रयोगों से यह प्रदर्शित हुआ कि चावल गहनीकरण प्रणाली से मीथेन उत्सर्जन में परम्परागत रोपे गए धान की फसल की तुलना में 64 प्रतिशत की कमी आती है जबकि नाइट्रस ऑक्साइड–नाइट्रोजन के उत्सर्जन में 23 प्रतिशत की वृद्धि होती है, अर्थात् कुल मिलाकर वैश्विक उष्मन क्षमता में सकल 28 प्रतिशत की कमी आती है। भारतीय खाद्य पदार्थों में कार्बन फुटप्रिंट से यह पता चला कि दूध की तुलना में मांस से 11.9 गुनी, मछलियों की तुलना में 12.1 गुनी, चावल की तुलना में 12.9 गुनी तथा चपाती की तुलना में 36.5 गुनी ग्रीन हाउस गैसें उत्सर्जित होती हैं। मांस से युक्त मांसाहारी आहार में शाकाहारी आहार की तुलना में 1.8 गुनी अधिक ग्रीन हाउस गैसें उत्सर्जित होती हैं।

फसल उत्पादकता पर वायु प्रदूषकों से संबंधित प्रयोगों से यह प्रदर्शित हुआ कि 12.3 ppmv h से AOT 40 (40 ppb के संचित सकल थ्रेशहोल्ड) से चावल की उपज में 15 प्रतिशत कमी आ सकती है। गेहूं की वाणिज्यिक किस्म पीबीडब्ल्यू 343 पर किए गए मुक्त वायु CO_2 समृद्धीकरण (एफएसीई) संबंधी अध्ययनों से यह स्पष्ट हुआ कि कार्बन डाइऑक्साइड का स्तर बढ़ने पर दानों में प्रोटीन अंश के साथ–साथ सेरीन, ग्लूटामीन, प्रोलीन और सिस्टेईन जैसे एमिनो अम्लों में कमी आती है। Mn तथा Cu जैसे खनिज बढ़ते हैं, जबकि Zn, Fe और Mg जैसे खनिज घटते हैं। इससे यह सुझाव मिलता है कि अनाज गुणवत्ता के वर्तमान मानकों को बनाए रखने के लिए कृषि पोषक तत्व के प्रबंध में समायोजन की आवश्यकता है।

समेकित नाशकजीव तथा रोग प्रबंधन व नैदानिकी से संबंधित नई प्रौद्योगिकियां विकसित की गईं। गेहूं में धब्बा उत्पन्न करने वाले *बाइपोलेरिस सोरोकिनियाना,* चने में झुलसा उत्पन्न करने वाले *एफ. ऑक्सीस्पोरम* विशेष प्रजाति *साइसेरिस* तथा सोलेनेसी कुल की सब्जियों में झुलसा उत्पन्न करने वाले *राल्स्टोनिया सोलेनेसीरम* के लिए आण्विक नैदानिकियां विकसित की गईं और उनका मूल्यांकन किया गया। नाइट्रोसेल्यूलोज़ झिल्ली आधारित एक सरल वास्तविक समय वाला पीसीआर पहचान प्रोटोकॉल विकसित किया गया जो तोरिया को संक्रमित करने वाले 16 SrIX समूह के फाइटोप्लाज्मा के लिए था।

आलू के पछेती झुलसा तथा चना के झुलसा रोग के विरूद्ध *कीटोमीयम* और *ट्राइकोडर्मा* आधारित जैवसंरूपों का सत्यापन किया गया। *टेलीकोरिंकस, हेलिकोटाइलेंकस* और *होप्लोलेमस* जैसे वाह्य परजीवी सूत्रकृमियों को दिल्ली और हापुड़ के आसपास आलू की फसल के खेतों में पाया गया। कीटरोगजनक सूत्रकृमि *हेटरोरेबडिटिस बैक्टीरियोफोरा* के कारण *गैलेरिया मेलोनेला* की मृत्यु हुई तथा निर्जलीकृत विसंक्रामक शिशुओं की उग्रता का स्तर ताजे विसंक्रामक शिशुओं की तुलना में लगभग समतुल्य रहा जिससे चौथे इनस्टार लार्वों की मृत्यु संभव हुई। *पेस्टेयूरिया* तथा *स्ट्रेप्टोमाइसिस लावेनड़यूली* के द्वारा सूत्रकृमियों के प्रबंधन की एक विधि विकसित की गई। एक सूत्रकृमिनाशी, फास्फोथियोनेट जिस पर नीम की पर्त चढ़ाई गई थी, *हेटेरोडेरा ज़ी* के विरूद्ध उच्च प्रभावी पाया गया। कार्बोफ्यूरॉन के नैनो–संरूपों से टमाटर की जड़ों को संक्रमित करने वाले *एम. इन्कोग्नीटा* के दूसरी अवस्था के शिशुओं के जड़ों में प्रवेश करने का नियंत्रित किया गया। फूलगोभी की फसल में खेत की मेड़ों पर सूरजमुखी की फसल उगाने से माहुओं के प्रबंधन में सहायता मिली क्योंकि सूरजमुखी की फसल पर इस माहु के प्राकृतिक शत्रु, विशेषकर *कोकीनेला* भृंग आकर्षित होते हैं।

रोगों तथा नाशकजीवों की बढ़ी हुई प्रतिरोधिता से युक्त पराजीनी फसलें विकास की विभिन्न अवस्थाओं में हैं। टमाटर के पत्ती मोड़क विषाणु को लक्ष्य बनाते हुए amiRAVI कान्स्ट्रक्ट आधारित कृत्रिम सूक्ष्म RNA का उपयोग टमाटर को रूपांतरित करने में किया गया। लगभग 63 प्रतिशत प्यूटेटिव पराजीनी टमाटरों ने टमाटर के पत्ती मोड़क विषाणु के विरूद्ध प्रतिरोधिता प्रदर्शित की। flp14, flp 18 तथा सिस्टेईन प्रोटीऐज़ जीनों से लक्षित RNAi कांस्ट्रक्टों से रूपांतरित बैंगन ने *एम. इनकोग्नीटा* के विरूद्ध प्रतिरोधिता प्रदर्शित की। बैंगन में Bt-जीनों की पिरामिडिंग के लिए पूसा हाइब्रिड 6 के नर एवं मादा पूर्वजों को क्रमशः *Bt*-जीनों cry2Aa तथा cry1F के साथ आनुवंशिक दृष्टि से रूपांतरित किया गया। *एम. ओराइज़ी* के प्रति अति उच्च स्तर के प्रतिरोध से युक्त *Pi-k*^{h} जीन (*Pi-k*^{h} का एक आर्थोलॉग) को अभिव्यक्त करने वाले चावल के पराजीनी पौधे का विकास किया गया।

फसल सुरक्षा की दृष्टि से महत्वपूर्ण नए प्राकृतिक व कृत्रिम अणु विकसित किए गए। कृत्रिम केलकोन, 1–(4–फ्लूरोफिनाइल)–3 –फिनाइल–प्रोपेनॉन तथा 3–(4–फ्लूरो–फिनाइल)–5–(3–नाइट्रो–फिनाइल)–6–कार्बेथॉक्सी – 2 – साइक्लोहैक्सेन –1 –वन को *राइज़ोक्टोनिया सोलेनी* और *स्क्लेरोटियम रॉल्फसी* के सशक्त निरोधकों के रूप में पहचाना गया। प्रति कवकीय तथा प्रति सूत्रकृमि सक्रियता से युक्त *यूपेटोरियम एडेनोफोरम* के 6 सगंधित तेलों की पहचान की गई। *पोंगेमिया ग्लेब्रा* के एक जैव घटक करंजिन की प्रति कवकीय सक्रियता को करंजिक अम्ल ईस्टरों में परिवर्तित करके बढ़ाया गया। करंजिन तथा इसके अर्ध–संश्लेषित अपकर्षों ने भी एफीसाइडल सक्रियता प्रदर्शित की। आइसोब्यूटाइल मिथाइल कीटोन (आईबीएमके) + साइक्लोहैक्सेन + क्रेसलॉक्स 3440 को विलायक–सतही ब्लेंड या मिश्रक के रूप में इस्तेमाल करके करंज आधारित पायसीकृत सांद्र (ईसी) विकसित किए गए। साइपरमेथ्रिन + क्लोरपाइरीफॉस का मिश्रण बंदगोभी की फसल में उपयोग की दृष्टि से सुरक्षित पाया गया क्योंकि इसके अपशिष्ट सर्वोच्च अपशिष्ट की सीमा से कम थे, जबकि फूलगोभी और मिर्च की फसल में इस रसायन के छिड़काव के पश्चात् तीन दिन की प्रतिक्षा अवधि निर्धारित करने का सुझाव दिया गया। कीट के नियंत्रण के लिए β–साइफ्लूथ्रिन के नियंत्रित रूप से विमोचित होने वाले संरूप का विकास किया गया।

खरपतवार प्रबंध संबंधी अध्ययनों में सोयाबीन–गेहूं फसल प्रणाली के अन्तर्गत फसल की बढ़वार के 25 दिनों बाद इम्ज़ेथापायर के उपयोग को सोयाबीन के खरपतवारों के नियंत्रण में प्रभावी पाया गया। इम्ज़ेथापायर के साथ पैन्डीमेथालिन के टैंक मिश्रण के उपयोग से चौड़ी पत्ती वाले खरपतवारों का नियंत्रण हुआ। गेहूं की फसल वाले खेतों में व्यापक श्रेणी के खरपतवार नियंत्रण के लिए 0.06 कि.ग्रा./हैक्टर की दर से अंकुरण के पश्चात् क्लोडिनोफॉस–प्रोपारगाइल के उपयोग से खरपतवारों का नियंत्रण हुआ और गेहूं की उपज में वृद्धि हुई। समय पर बोई गई (5 नवम्बर) आलू की फसल में अंकुरण के पूर्व एट्राज़ीन (0.5 कि.ग्रा./है.) तथा मैट्रीब्यूज़िन (0.5 कि.ग्रा./है.) के उपयोग से खरपतवार नियंत्रित हुए और आलूओं की उपज में भी वृद्धि हुई। चावल की फसल में विभिन्न प्रकार के खरपतवारों को नियंत्रित करने में अंकुरण के पूर्व खरपतवारनाशी के रूप में प्रीटिलाक्लोर (1000 ग्रा./है.) का उपयोग करने के पश्चात् व बुवाई के 30 दिनों बाद 22 पाइरेबिक सोडियम (20 ग्रा./है.) का क्रमिक उपयोग सर्वश्रेष्ठ पाया गया।

मौलिक तथा कार्य नीतिपरक अनुसंधान मुख्यतः नए जीनों और प्रोमोटरों के विलगन, आण्विक मार्करों के विकास, पराजीनी पौधों के विकास तथा उनकी उपज बढ़ाने की विधियों पर केन्द्रित किए गए। *एरेबीडॉप्सिस* से एक सूत्रकृमि के विरूद्ध प्रतिक्रिया दर्शाने वाला जड़–विशिष्ट प्रोमोटर तथा कपास से एक गुला या डोडा–विशिष्ट प्रोमोटर विलगित किया गया जिसे संबद्ध ऊतकों में लक्षित जीनों की अति–अभिव्यक्ति में प्रभावी पाया गया। निम्न फाइटेट युक्त पराजीनी सोया किस्म के विकास के लिए *ग्लाइसीन मैक्स* से पूरी लंबाई वाला एक cDNA इनकोडिंग फाइटेज़ विलगित किया गया तथा *ई. कोलाई* में अभिव्यक्त रिकम्बीनेंट HIS-फाइटेज़ की इन्ज़ाइमी सक्रियता की पुष्टि की गई। चावल में इसकी किस्म एन 22 में सूखा प्रतिबल उत्पन्न करने वाला SHN क्लेड AP2/ERF ट्रांसक्रिप्शन घटक जीन पृथक किया गया। *SHN* जीन अभिव्यक्ति का सूखा प्रतिबल के अन्तर्गत उगाई गई चावल की फसल में पत्ती पर मौजूद मोम अंश के साथ सकारात्मक सहसंबंध दिखाई दिया और इस प्रकार यह स्पष्ट हुआ कि इसमें पराजीनी विकास की पर्याप्त क्षमता है।

अजैविक प्रतिबल सहिष्णुता में सुधार के लिए *एरबीडॉक्सिस AtDREB1A* जीन से अभियंत्रित पराजीनी चावल तथा 4 विभिन्न

जीनों (*Osmotin, DHAL$_2$, CODA* तथा *DHSP*) से अभियंत्रित पराजीनी टमाटर विकसित किए गए। *CaMV35S* की अभिव्यक्ति द्वारा पत्ती की विलंबित जीर्णता और विलंबित परिपक्वन क्षमता से युक्त टमाटर का पराजीनी पौधा विकसित किया गया तथा इथीलीन के असंवेदी ग्लैडियोलस के पुष्प से इथीलीन रिसेप्टर जीन *GgERS1* विलगित किया गया।

अजैविक प्रतिबल संबंधी अनुसंधान से फसलों में लवण तथा जलाक्रांत स्थितियों के प्रति सहिष्णुता की यांत्रिकी स्पष्ट हुई। लवण ओवरले संवेदी (एसओएस) पथ जो *एरेबीडॉप्सिस* में लवण सहिष्णुता के प्रति बहुत महत्व रखता है, गेहूं में संरक्षित पाया गया। एसओएस पथ से गेहूं की लवणता सहिष्णुता की पुष्टि होती है जो गेहूं के लवणता के प्रति संवेदनशील अन्य जीनप्ररूपों की तुलना में लवणता के प्रति सहिष्णु जीनप्ररूप खर्चिया 65 में उच्च लवणता उत्प्रेरित अभिव्यक्त स्तरों SOS_1, SOS_2, SOS_3 तथा NHX_1 के स्तरों से सिद्ध होता है। मूंगबीन में जल ठहराव/ अवऑक्सीयता सहिष्णुता की कार्यप्रणाली पर किए गए अध्ययन से पता चला कि साइटोसॉलिक नाइट्रेट रिडक्टेज (cNR), नाइट्रिक ऑक्साइड (NO) तथा गैर–सहजीवी हीमोग्लोबिन (NS-Hb) ने NADH के उपचयन हेतु किण्वन के विकल्प के रूप में कार्य किया जिससे ग्लाइकोलाइटिक पाथवे को जारी रखने में मदद मिली। सूखा सहिष्णुता के साथ उच्च पैदावार के संयोजन हेतु WL711 (सूखा ग्रहणशीलता) × C 306 (सूखा सहिष्णु) के 209 RILs का मूल्यांकन जल–कमी प्रतिबल की प्रफुल्लन पश्चात स्थिति में किया गया। इससे उच्च उपज (540-673.6 gm^2) एवं स्थिरता का संयोजन दर्शाने वाले 8 REILs की पहचान की जा सकी।

भावी पीढ़ी अनुक्रमण का उपयोग 967 जीनों में 1,237 SNPs एवं 29 InDels की पहचान के लिए किया गया जो कि प्रतिबल के तहत नगीना 22 एवं CSR 30 के बीच अवकल रूप से व्यंजित थे। बासमती 370 तथा IRBB 60 के बीच कुल 4,50,883 सहयुग्मनजी SNPs की पहचान की गई और 81 SNP loci को लागत प्रभावी CAPS मार्करों में परिवर्तित किया गया। गेहूं में, मार्करों का विकास उर्वरता पुर्नस्थापन (Xwmc503), पत्ती रतुआ प्रतिरोधिता Lr 32 जीन (AP-PCR SS9L$_{700}$ तथा UBC801$_{800}$) तथा तना रतुआ प्रतिरोधिता Sr जीन (Xgwm131) के लिए किया गया। निम्न इरूसिक अम्ल मात्रा के साथ सम्बद्ध वसा अम्ल इलोन्गेज *FAE1* जीनों में एकल न्यूक्लिओटाइड बहुरूपता (SNPs) का पूसा करिश्मा, ZEM-1 के एक व्युत्पन्न, में मान्यकरण किया गया। सोयाबीन में एसोसिएशन मैपिंग से बीज भंडारण के लिए SSR मार्कर, Satt 600 तथा Satt 285 की पहचान की जा सकी। प्रगत चना प्रजनन वंशक्रमों में मार्कर सहायतार्थ आवर्ती चयन द्वारा मुरझान जीनों से गहराई से जुड़े आण्विक मार्कर TA96, TA110 एवं TS82 की पहचान की गई। आम में, उच्च कुल केरोटिनॉइड मात्रा, छिलके के हरे रंग तथा निम्न अनुमाप्य अम्लता मात्रा के लिए क्रमशः SSR मार्कर, AKS-65180, LMMA-14170 तथा MiSHRS-32 का विकास किया गया।

IRS LISS-III सेटेलाइट प्रतिबिम्ब तथा ^{18}O आइसोटोप सिग्नेचर पर आधारित दिल्ली के यमुना नदी के बाढ़ग्रस्त मैदानों में भू–जल विकास क्षमता के निर्धारण पर सुदूर संवेदी एवं GIS अध्ययन से पल्ला क्षेत्र बाढ़ मैदान फैलाव में नदी बहाव से लगभग ~ 260 MCM प्रतिवर्ष की गैर–आक्रामक भू–जल रिचार्ज क्षमता का पता चला। LAI, क्लोरोफिल तथा पत्ती जल के सोयाबीन जैव–शारीरिक पैरामीटरों का आकलन करने के लिए सोयाबीन में अति–वर्णक्रमीय सुदूर संवेदी मापन का उपयोग किया गया। इसके फलस्वरूप सुदूर संवेदी आंकड़ों से पत्ती एवं केनोपी पैरामीटरों के सुधार हेतु एक कार्यप्रणाली विकसित करने में मदद मिलेगी जोकि नियमित फसल वृद्धि मॉनीटरिंग एवं पैदावार निर्धारण में अति उपयोगी हैं। इस तकनीक का प्रयोग सरसों में एफिड संक्रमण की पहचान करने में भी सफलतापूर्वक किया गया। वर्णक्रमीय अक्षांक यथा NDVI, RVI, AI तथा SIPI में एफिड संक्रमण के साथ उल्लेखनीय सह–संबंध प्रदर्शित हुआ जिससे एफिड संक्रमण की पहचान के लिए अति–वर्णक्रमीय सुदूर संवेदी का उपयोग किए जाने की संभावना का पता चला।

सामाजिक विज्ञान अनुसंधान से भारतीय कृषि के वृद्धि अनुभव का विश्लेषण किया गया। मोटे अनाज (विशेषकर मक्का), तिलहन तथा कपास में तीव्र वृद्धि दरों का प्रदर्शन हुआ। गुजरात में सिंचाई बढ़ाने और प्रौद्योगिकी के बेहतर हस्तांतरण के लिए किए गए संस्थागत सुधारों के कारण कृषि में आकर्षक वृद्धि पायी गई। फलों, सब्जियों, पशुधन और मत्स्यिकीय जैसी उच्च मूल्य वाली जिंसों की तीव्र वृद्धि, बढ़ती मांग और मजबूत बाजार संपर्क के साथ जुड़ी हुई थी। कृषि में अंतर–क्षेत्रीय व्यापार समझौते में एशिया, मध्यपूर्व तथा अफ्रीका में नए भागीदार देशों की ओर व्यापार के चले जाने से क्षेत्रीयता की ओर बढ़ा हुआ रूझान प्रदर्शित हुआ। वर्तमान दशक के दौरान सार्वजनिक निवेश में वृद्धि में पुनः उछाल (16.80 प्रतिशत) आया जबकि निजी निवेश संतुलित (4.8 प्रतिशत) बना रहा।

सीतापुर में दो साइबर प्रसार केन्द्रों की स्थापना की गई तथा आई सी टी टूल्स का उपयोग करने के लिए 6 ग्रामीण युवाओं को प्रशिक्षित किया गया। किसानों ने डाकघरों के माध्यम से बीजों की आपूर्ति को सकारात्मक रूप में लिया गया। मध्यप्रदेश के हौशंगाबाद जिले में आत्मा (ATMA) के अंतर्गत की गई मध्यस्थताओं के परिणामस्वरूप प्रौद्योगिकी अनुकूलन एवं उद्यमशीलता पहल की ओर झुकाव में सुधार हुआ। हालांकि प्रसार व्यवसायियों ने व्यापक जिला कृषि योजना की तैयारी के लिए सहभागिता ग्रामीण आकलन एवं सूचना संचार प्रौद्योगिकियों के लिए टूल्स के उपयोग में तथा किसानों के खेत स्कूल के आयोजन में कौशल की कमी को अनुभव किया।

मध्यप्रदेश में उत्पादक कंपनियों के संबंध में किए गए विश्लेषण से सामाजिक आर्थिक लाभ का पता चला जिसमें कि गुणवत्ता बीजों की उपलब्धता तथा प्रति 100 कि.ग्रा. उत्पाद पर ₹ 100–200 का अतिरिक्त लाभ और बाजार सुनिश्चितता शामिल थी। राज्य

कृषि विभाग एवं मध्य प्रदेश के हौशंगाबाद जिले के धानुका एग्रीटेक के बीच कृषि प्रसार में सार्वजनिक–निजी सहभागिता (पीपीपी) मॉडल से प्रौद्योगिकी का विशेषकर मृदा परीक्षण एवं परामर्श तथा बीज उपचार में प्रभावी ढंग से प्रसार हो सका। मध्य प्रदेश के हौशंगाबाद जिले में दावत फूड्स एवं आत्मा के बीच हुई सार्वजनिक–निजी सहभागिता से धान की खेती किए जाने वाले क्षेत्र में 5 गुणा वृद्धि हुई जिसमें कि 90 प्रतिशत से अधिक में पूसा बासमती–1121 की खेती की गई।

ग्रामीण युवाओं के बीच उद्यमशीलता बढ़ाने में की गई क्षमता निर्माण मध्यस्थताओं के कारण नए उद्यमों को प्रारंभ करने में मदद मिली। मध्य प्रदेश में केसला पॉल्ट्री कॉआपरेटिव में स्वःसहायतार्थ समूह की महिलाओं के प्रेरणात्मक प्रोफाइल के प्रति–चित्रण से अधिकांश स्वः सहायतार्थ महिलाओं में PA-Inf (व्यक्तिगत उपलब्धि–उन्मुखता प्रभाव) तथा इसके उपरांत PSA (व्यक्तिगत एवं सामाजिक उपलब्धि) एवं H (आशा) की बहुत अधिक आवश्यकता का पता चला। समेकित विकास के लिए राष्ट्रीय राजधानी क्षेत्र के परि–नगरीय क्षेत्रों में मॉडल गांवों के विकास हेतु ''कृषि प्रौद्योगिकियों का मूल्यांकन एवं उन्नयन तथा विकासशील बाजारोन्मुख प्रसार मॉडल'' शीर्षक से एक परियोजना का पुनः अभिविन्यास किया गया। राष्ट्रीय प्रसार कार्यक्रम का 17 भारतीय कृषि अनुसंधान परिषद् के संस्थानों/राज्य कृषि विश्वविद्यालयों के साथ सहयोग में पुनः सुदृढ़ीकरण किया गया। भा.कृ.अ.सं. एवं 17 राज्यों के 27 प्रतिष्ठित गैर सरकारी संगठनों के बीच प्रतिभागिता से प्रौद्योगिकी हस्तांतरण का एक नवोन्मेषी मॉडल विकसित किया गया ताकि उनके प्रचालन क्षेत्रों में भा.कृ.अ.सं. प्रोद्योगिकियों का मूल्यांकन एवं प्रसार किया जा सके।

''अधिक उत्पादकता और आय हेतु प्रक्षेत्र प्रौद्योगिकियां'' विषय पर आयोजित भा.कृ.अ.सं. के वार्षिक कृषि विज्ञान मेले में 22 राज्यों के किसानों सहित लगभग एक लाख आगंतुकों ने भाग लिया। संस्थान के एटिक केन्द्र में खेत परामर्श सेवाएं प्रदान करने के साथ–साथ किसानों को पूसा हैल्पलाइन और पूसा एग्रीकॉम के माध्यम से खेत परामर्श सेवाएं प्रदान की गईं। एटिक में किसान कॉल सेन्टर के द्वितीय स्तर की स्थापना की गई। 24 राज्यों के लगभग 18365 किसानों/उद्यमियों/विकास विभाग एवं गैर सरकारी संगठन के अधिकारियों ने एटिक केन्द्र का दौरा किया। संस्थान का शिकोहपुर गुड़गांव (हरियाणा) में स्थित कृषि विज्ञान केन्द्र ने 315 युवाओं (150 पुरूष एवं 165 महिलाओं) के लिए प्रदर्शनों एवं वोकेशनल प्रशिक्षण का आयोजन सक्रिय रूप से किया। 1020 किसानों को टेलीकॉम परामर्श सेवा प्रदान की गई।

संस्थान के कृषि भौतिकी संभाग में स्थित कृषि परामर्श इकाई द्वारा सप्ताह में दो बार दिल्ली तथा राष्ट्रीय राजधानी क्षेत्र के किसानों के लिए मौसम आधारित कृषि परामर्श सेवाएं भेजीं गई। कृषि मौसम परामर्श बुलेटिन सप्ताह में दो बार दैनिक जागरण एवं हरी भूमि समाचार पत्र में प्रकाशित हुए और इन्हें भा.कृ.अ.सं. की बेवसाइट (http://www.iari.res.in) पर भी अपलोड किया गया तथा साथ ही जिला कृषि परामर्श एवं राष्ट्रीय कृषि परामर्श बुलेटिन के लिए उनकी बेवसाइट के लिए उक्त परामर्श को ई–मेल के माध्यम से भारतीय मौसम विभाग (IMD) को भेजा गया। हिन्दी एवं अंग्रेजी में लगभग 103 कृषि परामर्श बुलेटिन तैयार किए गए और 26 समाचार पत्रों में इन्हें शामिल किया गया।

संस्थान की फार्म प्रचालन सेवा इकाई (फोसू) ने भा.कृ.अ.सं. फार्म के 750 एकड़ क्षेत्र में सभी खेती प्रचालनों का प्रभावी ढंग से प्रबंधन किया। फार्म भूमि के लगभग 300 एकड़ क्षेत्र की खेत लेबलिंग के लिए नवीन लेजर लेबलिंग प्रौद्योगिकी का उपयोग किया गया। भा.कृ.अ.सं. बायोमॉस उपयोगिता इकाई द्वारा भा.कृ.अ.सं. फार्म से निकलने वाले अपशिष्ट बॉयोमास और फसल अवशिष्ट का प्रभावी उपयोग कर संस्थान की समग्र जरूरतों की प्रतिपूर्ति हेतु गुणवत्ता कम्पोस्ट की आपूर्ति की गई। संस्थान द्वारा कड़े गुणवत्ता मानकों के अंतर्गत वर्ष के दौरान खाद्यान्न, दलहन, तिलहन, चारा, सब्जियों, फलों, फूलों की विभिन्न किस्मों के केन्द्रक, प्रजनक तथा भा.कृ.अ.सं. बीजों का कुल 1159.446 टन उत्पादन किया गया।

भा.कृ.अ.सं. के स्नातकोत्तर विद्यालय का 49वां दीक्षांत समारोह 5 फरवरी, 2011 को आयोजित किया गया जिसमें योजना आयोग, भारत सरकार के उपाध्यक्ष डॉ. मोंटेक सिंह आहलूवालिया ने मुख्य अतिथि के रूप में अपना दीक्षांत भाषण दिया। इस दीक्षांत समारोह में कुल 99 एवं 73 छात्रों को क्रमशः एम.एससी. एवं पीएच. डी. की उपाधियां प्रदान की गई। इस अवसर पर डॉ. मोंटेक सिंह आहलूवालिया को विज्ञान निष्णात (*ओनोरिस कोसा*) की उपाधि प्रदान कर सम्मानित किया गया।

संस्थान ने छात्रों को मिलने वाली सुख–सुविधाओं को अद्यतन किया, साथ ही उनके लिए अनेक नियमित एवं अल्पावधि प्रशिक्षण पाठ्यक्रमों का आयोजन किया गया। कृषि सूचना तथा जैव–सूचनागत प्रणाली पर संस्थान का विशेष ध्यान बना रहा। संस्थान का पुस्तकालय भा.कृ.अ.सं. एवं देश के अन्य संस्थानों के छात्रों एवं वैज्ञानिक समुदाय को निरंतर अपनी सेवाएं प्रदान कर रहा है। संस्थान की अधिदेशित गतिविधियों पर सूचना का प्रसार करने के उद्देश्य से हिन्दी तथा अंग्रेजी में अनेक गुणवत्ता प्रकाशनों को जारी किया गया जिसमें शामिल थे: वैज्ञानिक समीक्षा अनुसंधान पेपर, संगोष्ठी पेपर, पुस्तक/पुस्तकों में अध्याय, लोकप्रिय लेख, तकनीकी बुलेटिन तथा नियमित एवं तदर्थ प्रकाशन। संस्थान के बहुत से वैज्ञानिकों, छात्रों एवं संकाय सदस्यों ने अनेक प्रतिष्ठित पुरस्कार एवं सम्मान प्राप्त किये तथा संस्थान का गौरव बढ़ाया।

EXECUTIVE SUMMARY

The Indian Agricultural Research Institute (IARI) continued to maintain its leadership role in generating technologies for sustainable agriculture based on scientific advancements, imparting high quality higher agricultural education, developing frontline extension technologies, institutional capacity building, and fostering partnerships with other research and development organizations and stakeholders. During 2010-2011, IARI has developed several crop varieties, farm machinery and equipment, and agri-technologies for natural resource management, crop protection and post-harvest processing and value addition. The Institute's basic and strategic research programmes have made significant progress towards knowledge generation that is necessary for a resilient agriculture facing global climate change. The salient achievements of IARI in research, extension and education are summarized below:

The school of crop improvement has developed improved varieties with high yield, better quality, adaptability to different agroclimatic conditions and disease resistance in cereals, pulses, oil seeds, vegetables, fruits and ornamental crops. The wheat varieties, namely, Pusa Basant (HD 2985) and Pusa Bahar (HD 2987) were notified. Pusa Basant possesses adult plant resistance to leaf rust and is suitable for late and very late sown conditions of North Eastern Plains with an average yield of 3.74t/ha. Pusa Bahar possesses durable adult plant resistance against brown and black rusts. It is suitable for rainfed and restricted irrigation conditions of Peninsular Zone with an average yield of 1.8 t/ha. A high yielding wheat variety Pusa Suketi (HS 507) was released for cultivation under timely sown irrigated as well as rainfed conditions of Northern Hills Zone with an average grain yield of 4.68 t/ha in timely sown irrigated condition. This variety is resistant to leaf and stripe rusts, leaf blight and Karnal bunt. The wheat variety HI 1563 was released for irrigated-late sown conditions of North Eastern Plains with an average yield of 3.7 t/ha. This variety is resistant to almost all the virulent pathotypes of leaf, stripe and stem rusts. Pusa Gaurav (HI 8691), a *durum* wheat variety with an average yield of 5.36 t/ha was recommended for release by the State Seed Sub-Committee for irrigated, timely sown conditions of Madhya Pradesh. This variety possesses resistance to all the prevalent and virulent pathotypes of stem and leaf rusts. A variety HD 3016 was found to be superior to the checks for bread making qualities such as higher value of bread loaf volume (cc) and bread quality score .It yielded 8.08 to 12.71% higher than the checks.

In rice, an early maturing, semi-dwarf and non-shattering elite *Basmati* breeding line IET 21960 (Pusa 1509-03-3-9-5) with superior grain quality and high yield was developed. This line was promoted to Advanced Varietal Trial (AVT) 1 for testing during *kharif* 2011. Marker assisted backcross breeding for improving blast resistance in *Basmati* rice led to the development of isogenic lines carrying major blast resistance genes (*Pi1, Pikh, Pita, Pib, Piz5, Pi5 and Pi9*) in the background of Pusa Basmati 1. These lines have the potential to be released as direct varieties as well as donors for blast resistance genes in the *Basmati* breeding programme. By marker assisted backcross breeding method, blast resistance genes *Piz5* and *Pi54* were introgressed into Pusa 1609, an elite *Basmati* restorer line. Improved versions of Kalanamak, a short grain aromatic rice land race from eastern Uttar Pradesh, were developed by combining grain and cooking quality attributes of Kalanamak with dwarf stature and high yield. These lines, in various levels of testing, hold a great promise for enhancing the production and productivity of short grain aromatic rice in Kalanamak growing areas of Uttar Pradesh.

Early maturing maize hybrids, AH 97002, AH 97017 and AH 97018 with an average yield of 5.8 – 6 t/ha suitable for cultivation in Andhra Pradesh, Karnataka and Maharashtra were advanced to the coordinated trials. In barley, two superior genotypes BHS 393 and BHS 344 were promoted to the second year of testing under AVT-rainfed of All India Coordinated trials. In pearl millet, Pusa Composite 621, which performed consistently better than the checks during the past three years in the coordinated trials, was taken up for identification.

Four superior genotypes of chickpea, viz., BG 3005, BG 3012, BGM 571 and BGM 572 were promoted to AVT-1 trials. In lentil, a high yielding variety L 4701 was promoted to AVT- 1 for three zones, namely, Central Zone (CZ), North Eastern Plains Zone (NEPZ) and North Western Plains Zone (NWPZ). A mustard variety Pusa Mustard 26 (NPJ-113) with terminal high temperature tolerance was released for late sown conditions (i.e., November sowing after the harvest of cotton, rice and *guar*) of Haryana, Rajasthan, Punjab, plains of Jammu & Kashmir, Delhi and Western UP. This variety maturing in 126 days, has an average yield of 1.6 t/ha and 37.6% oil content. Pusa Mustard 27 (EJ-17) with an average seed yield of 1.53 t/ha and 41.7% oil content was released for early sown conditions of U.P., Madhya Pradesh, Uttarakhand and Kota region of Rajasthan.

In vegetable crops, a brinjal hybrid DBHL-20 was identified for release by the AICRP (VC) and recommended for cultivation in Punjab, Delhi, Uttar Pradesh and Bihar. The fruits of this variety are long, dark purple and glossy with a fruit weight of 90-100 g. This hybrid, which comes to first harvest in about 55 days from transplanting, has an average yield of 52.4 t/ha. An onion selection (Sel-126) with dark red coloured bulb and an average yield of 31.6 t/ha performed consistently well under AICRP (VC) trials. In bitter gourd, 12 new gynoecious × monoecious hybrids, and three predominately gynoecious lines were developed.

Seed treatment techniques with static magnetic field and γ-ray were developed to improve seed vigor and crop yield. Static magnetic field treatment (100 mT for 1h) was developed to ameliorate the deterioration caused in storage and improve the germination and vigour of the seedlings. A low dose γ-radiation (0.5 KGy) seed treatment enhanced the yield components of chickpea genotypes. It was also effective in reducing LOX activity and off-flavour generation in soybean.

Four mango hybrids, namely, Pusa Pratibha, Pusa Shreshth, Pusa Peetamber and Pusa Lalima were released at the 49th convocation of IARI. These hybrids with quality attributes better than those of the check Pusa Arunima, were recommended for NCR Delhi region. In grape, seedless hybrids, Banqui Abyad x Perlette-75-32 and (Hur x BE) x BS performed well on Head system of training with good quality fruits, early ripening and yield.

In ornamental crops, three hybrids (Hybrid Tea group), two seedlings and three bud sports of rose, and four promising seedlings of florist chrysanthemum were developed. Two gladiolus hybrids (Berlew x Headywine and Mayur x Hunting Song) and one open pollinated variety Regency Open were found promising for flower characters. In marigold, selection for high carotenoid content led to the identification of a selection Af/WS-2 with carotenoid content (58.89 µg/100g) higher than that of Pusa Narangi Gainda (41.20µg/100g).

Several genetic stocks in crops, microbes and insects were also identified, characterized and developed. In rice, four genetic stocks, namely, Pusa 1605-05-38-3-1 (INGR 10121), Pusa 1605-05-38-3-2 (INGR10122), Pusa 1601-05-46-1-1 (INGR 10123), Pusa 1601-05-46-5-3 (INGR 10124) with bacterial blight resistance were developed and registered. In maize, 15 and 4 genotypes resistant to MLB and BLSB diseases, respectively, were identified. In cotton, P 56-4 (IGNR No. 10155) was registered for high fiber strength (27.8g/tex), and Pusa 1752 was identified for machine picking. In bitter gourd, short duration gynoecious genotypes, DBGy 202 and DBGy201 were developed.

New species of fungi, namely, *Corynespora bombacina*, *C. clerodendrigena*, *C. moracina* and *C. ficigena* were added in fungal biodiversity collection. IARI has also supplied 520 authentic fungal cultures belonging to different groups, namely, Zygomycetes (58), Hyphomycetes (160), Ascomycetes (43), Penicilli (42), Aspergilli (63), Coelomycetes (34) and Fusaria (120) to various users across the country. Two new nematode strains of *Steinernema* collected from Tamil Nadu and Maharashtra were assigned to the genera *Steinernema* and *Heterorhabditis*, respectively. Two new nematodes species, *Tylenchorhynchus bambusi* sp. n. and *Helicotylenchus raipurensis* sp.n. were collected from the rhizosphere of rice in Raipur, Chhattisgarh. Insect biosystematics research led to the identification of a new species of Hemiptera, *Krisna pampadumparaensis* on *Ficus exasperata* host plants at Pampadumpara in Kerala.

The research on crop and resource management, resource optimization, and enhancement of input use efficiency yielded many agro-techniques for improving the productivity and sustainability of cropping systems. Incorporation of *Sesbania aculeate,* followed by *Crotalaria juncea*, *Vigna unguiculata* and summer fallow was found to give significantly higher yield in rice cv. Pusa *Basmati* 1. In soybean-wheat cropping system, application of 50% N equivalent as FYM + 50% recommended dose of fertilizers

(RDF) was found to produce wheat crop yield on a par with that of 100% RDF. In rainfed experiments, pearlmillet-equivalent yield was the highest in the case of clusterbean (4.31-5.72 t/ha), followed by that in mungbean (2.76-3.12 t/ha) and pearlmillet (1.44-2.23 t/ha). Further, pearlmillet + clusterbean intercropping system gave the highest pearlmillet-equivalent yield under ridge and furrow sowing. The maize-equivalent yield of cotton was found to be two times higher compared to the maize equivalent yield of pigeonpea, and three times more than maize. The crop grown on broad-beds (140 cm, 2 rows) produced higher yield as compared to that on narrow-bed (70 cm, 1 row), and the crop on both the raised beds yielded higher than the conventional flat-sown crop. Zero tillage was as good as the conventional tillage for cotton when the residues of both the crops were retained on the soil surface.

Studies on enhancement of fertilizer use efficiency showed that nanoclay polymer composite (NCPC) fertilizer was superior to conventional urea and DAP in cumulative N and P recovery from the soils. Assessment of the effect of metal oxide nanoparticles (ZnO and Fe_2O_3) and a carbon-based nanoparticle (fullerene, C60) on soil enzyme activities and microbial groups revealed that urease activity was the lowest in Fe_2O_3 and the highest in ZnO nanoparticle treatment. Long-term fertilizer experiments showed that the application of 150% of NPK over the RDF of NPK produced a yield advantage of 0.53 t and 0.83 t/ha in maize and wheat, respectively. For facilitating on-farm soil testing and fertilizer recommendation, a Digital Soil Test and Fertilizer Recommendation Meter (STFR) was developed. It quantifies the soil organic C, NO_3, P, K, S, Zn and B following a simple and rapid procedure. The instrument can also provide fertilizer recommendations for a specific crop and the target yield.

Technologies were developed for optimization of irrigation water and production of more crop per drop. Cultivation of *Capsicum* with drip-irrigation under a naturally-ventilated polyhouse saved about 20-40% total crop water requirement as compared to that of open field cultivation. A maximum water-use efficiency of 85.50 kg/m^3 could be obtained in onion by combining drip and deficit irrigation methods. Seed crop of carrot under drip irrigation produced significantly more high quality seed compared to that of the surface irrigated crop and saved 30% water and 35% fertilizers.

Protected-cultivation methods were developed for improving vegetable yield and quality. An insect-proof net house with a 40 mesh UV-stabilized nylon net was designed to produce disease free seeds of vegetables. Cucumber and bitter gourd grown in this insect-proof net house were free from fruit fly damage and the seeds produced were free from virus disease. Walk-in-tunnels were found to be technically suitable for off-season cultivation of cucurbits, viz., bottle gourd and summer squash.

The Institute developed new agricultural machinery and implements for enhancing the efficiency and output in various agricultural activites. A 'Turning and Mixing Machine' and 'FYM Loader' were designed to mix and turn the unchopped residues/biomass with cow dung and microbial consortium for efficient FYM production. A tractor-mounted loader and a compost sieving machine were also developed to support this. Safety interventions for chaff cutter to prevent injuries were developed which included a blade guard, a flywheel lock and a warning roller. Machines were developed to loosen the husk of pulse grains before dehusking (pitting machine) and to enhance the physical quality of pigeonpea grains by pulse polisher.

The research on pre- and post-harvest management, processing and value addition in different fruit crops resulted in the development of new processing and packing techniques and products. Bagging of pomegranate 85 days prior to harvest considerably reduced the cracking, scratching, bacterial spots and sun burning. Apples covered with red or yellow coloured bags exhibited intense red colour at harvest. Mango fruits of cv. Langra harvested at optimum maturity and packed in 4-5 kg 3-ply CFB boxes with newspaper shred cushion resulted in 5% reduction in spoilage and 8% check in weight loss during distant marketing.

A process for the production of high quality tomato fruit powder and *Aonla* fruit powder was standardized. The colour of Pusa Aonla Powder had the highest whiteness index as compared to that of market samples. A pearlmillet based ready-to-eat puffed product was found to be highly acceptable on organoleptic evaluation by people of different age groups. Protein rich cookies prepared from wheat flour by incorporating soy flour scored the highest organoleptic score, followed by pearlmillet incorporated cookies.

Bioprospecting of microbes from extreme environments was undertaken for novel molecules and genes. The *Streptomyces* sp. Mic98 and *Streptomyces globosus* Mic198 were identified with high amounts of xylanase (85.91 IU/g substrate) and endoglucanase (198 IU/g substrate) production, respectively, with congress grass as substrate. Two potential thermophilic and cellulolytic bacteria designated as *B. licheniformis* WBS1 (Accession number GU590782) and *Bacillus* sp. WBS3 (Accession number GU590784) were isolated from Bakreshwar hot spring. Both the organisms produced FPAse activities of 0.42 IU/ml and 0.35 IU/ml ,respectively at 65^{0}C only. The cellulose enzymes have the potential for the production of bio-energy and use in textile, as well as pulp and paper industries. The conditions for pigment biosynthesis in cyanobacteria were optimized. For the first time, a novel fungicidal compound, majusculamide C, from *Anabaena laxa* was purified and characterized. Biofilms using *Trichoderma viride* and *Pseudomonas fluorescens* were developed. Bacteria and fungi were isolated for degradation of low density polyethene under optimized conditions. A novel microbe amended disease suppressive compost was developed and evaluated in tomato. Results revealed the potential of such novel microbe–fortified composts as effective biocontrol agents for sustainable and organic agriculture.

In climate change research, regional impacts of climate change on cereal crops were assessed. The analysis indicated that the rice yield under irrigated condition is likely to reduce up to 8% in Haryana and Punjab, while the reduction in yield is likely be around 3-4% in Uttar Pradesh and Bihar in a 2020 - scenario. The inventory of GHG emission from Indian agriculture was updated. Indian rice fields covering 43.9 million ha emitted 3.37 million tonnes of CH_4. Total N_2O emission from agricultural soils of India was estimated as 0.14 million tonnes. Nitrogenous fertilizer contributed 70% of N_2O emission. Burning of crop residues in field emitted 0.23 million tonnes of CH_4 and 0.006 million tonnes of N_2O. On-farm experiments showed that the System of Rice Intensification (SRI) reduced the methane emission by 64% and increased the N_2O-N emission by 23% as against the conventional transplanted method, resulting in an overall 28% reduction in global warming potential. Carbon footprint of Indian foods indicated that mutton emitted 11.9 times as much GHG as milk, 12.1 times that of fish, 12.9 times that of rice and 36.5 times that of *chapati*. A non-vegetarian meal with mutton emitted 1.8 times higher GHG than that of a vegetarian meal.

Experiments on air pollutants on crop productivity showed that an AOT 40 (accumulated over threshold of 40 ppb) of 12.3 ppmv h can cause a 15% decline in rice yield. Free-air CO_2 enrichment (FACE) studies on wheat cv. PBW343 revealed that elevated CO_2 decreased the grain protein content as well as amino acids such as serine, glutamine, proline and cysteine. Minerals such as Mn and Cu increased, while Zn, Fe and Mg decreased, suggesting that adjustments of agricultural nutrient management may be required to retain the current grain quality standards.

New technologies for diagnostics and integrated pest and disease management were developed. Molecular diagnostics were developed and validated for *Bipolaris sorokiniana* causing spot blotch of wheat, *F. oxysporum* f.sp. *ciceris* causing chickpea wilt and *Ralstonia solanacearum* causing wilt of solanaceous crops. A simplified nitrocellulose membrane (NCM) based real time PCR detection protocol was developed for 16 SrIX group phytoplasma infecting *toria*.

Chaetomium and *Trichoderma* based bioformulations were validated against late blight of potato and chickpea wilt, respectively. Ectoparasitic nematodes such as *Tylencorhynchus*, *Helicotylenchus* and *Hoplolaimus* were found in potato grown fields around Delhi and Hapur. Entomopathogenic nematode *Heterorhabditis bacteriophora* caused mortality of *Galleria mellonella,* and the rehydrated infective juvenile (IJ) retained their virulence level comparable to that of fresh IJ in causing mortality to IV instar larvae. A method for nematode management with *Pasteuria* and *Streptomyces lavendulae* was developed. The nematicide, phosphothionate, coated with neem, proved to be highly effective against *Heterodera zeae*. Nanoformulations of carbofuran effectively checked the penetration of 2nd stage juveniles of *M. incognita* in tomato roots. Border cropping with sunflower was effective in attracting natural enemies specially *Coccinella* beetles that helped to manage the aphid population in cauliflower field.

Transgenic crops with enhanced resistance to disease and pests are at different stages of development. Artificial microRNA based construct amiRAVI targeting tomato leaf curl virus was used to transform tomato. About 63% of putative transgenic tomatoes showed resistance to tomato leaf curl virus. Brinjal transform with RNAi constructs targeting flp 14, flp 18 and cystein protease genes showed resistance against *M. incognita*. For pyramiding Bt-genes

in brinjal, the male and female parents of Pusa Hybrid 6 were genetically transformed with *Bt*-genes *cry2Aa* and *cry1F*, respectively. Transgenic rice plant expressing the *Pi-r*^{h} gene (an orthologue of *Pi-k*^{h}*)* with very high degree of resistance to *M. oryzae* was developed.

Novel natural and synthetic molecules of importance in crop protection were developed. Synthesized chalcones, 1-(4-fluorophenyl)-3-phenyl-propenone and 3-(4-fluoro-phenyl)-5-(3-nitro-phenyl)-6-carbethoxy-2-cyclohexen-1-one, were identified as potent inhibitors of *Rhizoctonia solani* and *Sclerotium rolfsii*. Six essential oils of *Eupatorium adenophorum* with antifungal and antinemic activities were identified. The antifungal activity of karanjin, a bioactive constituent of *Pongamia glabra*, was enhanced by converting it to karanjic acid esters. Karanjin and its semi-synthetic derivatives also exhibited aphicidal activity. Karanj based EC formulations were developed by using isobutyl methyl ketone (IBMK) + Cyclohexanone + Creslox 3440 as a solvent-surfactant blend. The mix of cypermethrin +chlorpyriphos was found to be safe to use in cabbage as residues were below MRL level, while a waiting period of 3 days was suggested for cauliflower and chilli. A controlled release formulation of β- cyfluthrin was developed for insect control.

In weed management studies, imzethapyr application in soybean-wheat cropping system at 25 days of growth was found to be effective in managing the weeds in soybean. Tank mix application of pendimethalin with imazethapyr controlled broad leaved weeds. Post emergence application of clodinofop-propargyl @ 0.06 kg/ha provided a broad spectrum weed control in wheat fields, thereby enhancing the yield. Pre-emergence application of atrazine (0.5 kg/ha) and metribuzin (0.5 kg/ha) controlled the weeds and increased the tuber yield in timely sown potato (5th November). Sequential application of pretilachlor (1000 g/ha) as pre-emergence weedicide, followed by bispyribac sodium (20 g/ha) at 30 DAS proved best in controlling the complex weed flora in rice.

Basic and strategic research focused on the isolation of novel genes and promoters, development of molecular markers, methods to enhance yield and development of transgenic plants. A nematode responsive root - specific promoter from *Arabidopsis* and a boll-specific promoter from cotton were isolated which have the potential to overexpress the target genes in the respective tissues. Towards the development of low phytate transgenic soybean, a full length cDNA encoding phytase was isolated from *Glycine max* and the enzyme activity of recombinant HIS-phytase expressed in *E. coli* was confirmed. In rice, a drought stress inducible SHN clade AP2/ERF transcription factor gene was isolated from rice cutivar N22. The *SHN* gene expression showed a positive correlation with the leaf wax content in rice under drought stress, and hence has the potential in transgenic development.

Transgenic rice engineered with *Arabidopsis AtDREB1A* gene and transgenic tomato engineered with 4 different genes (*Osmotin*, *DHAL*$_2$, *CODA* and *DHSP*) were developed for improving abiotic stress tolerance. Tomato transgenic plant with delayed leaf senescence and delayed ripening potential was developed by expressing *CaMV35S* promoter driven ethylene receptor gene *GgERS1* from an ethylene insensitive gladiolus flower.

Research in abiotic stress tolerance elucidated the mechanisms of salt and water logging tolerance in crops. The salt overly sensitive (SOS) pathway, which is crucial for salt tolerance in *Arabidopsis*, is found to be conserved in wheat. The SOS pathway confers salinity tolerance of wheat as evident from the higher salinity induced expression levels SOS_1, SOS_2, SOS_3 and NHX_1 genes in the salt tolerant genotype Kharchia 65 compared to those in salinity sensitive genotypes. Studies on the mechanisms of waterlogging/hypoxia tolerance in mungbean revealed that cytosolic nitrate reductase (cNR), nitric oxide (NO) and non-symbiotic haemoglobin (NS-Hb) act as an alternative to fermentation for the oxidation of NADH and thus help in the continuation of glycolytic pathway. To combine high yield with drought tolerance, 209 RILs of WL711 (drought susceptible) x C 306 (drought tolerant) were evaluated under post-anthesis water deficit stress. This led to the identification of 8 RILs showing a combination of high yield (540-673.6 gm^{-2}) and stability.

Next-generation sequencing was used to identify 1,237 SNPs and 29 InDels in 967 genes that were differentially expressed between Nagina22 and CSR30 under stress. A total of 450,883 homozygous SNPs were identified between Basmati 370 and IRBB 60, and 81 SNP loci were converted into cost efficient CAPS markers. In wheat, markers were developed for fertility restoration (Xwmc503), leaf rust resistance Lr32 gene (AP-PCR $SS9L_{700}$ and $UBC801_{800}$) and stem rust resistance *Sr* gene (Xgwm131). Single Nucleotide

Polymorphisms (SNPs) in Fatty acid elongase *FAE1* genes associated with low erusic acid content were validated in Pusa Karishma, a derivative of ZEM-1. Association mapping in soybean led to the identification of SSR markers, Satt600 and Satt285 for seed storability. Marker Assisted Recurrent Selection in advance chickpea breeding lines identified the molecular markers TA 96, TA 110 and TS 82 that are tightly linked to wilt genes. In mango, SSR markers, AKS-65180, LMMA-14170- and MiSHRS-32 were developed for high total carotenoid content, green peel colour and low titrable acidity content, respectively.

Remote sensing and GIS studies on assessment of groundwater development potential in the Yamuna River flood plains of Delhi based on the IRS LISS-III satellite image and the ^{18}O isotope signatures revealed that non-invasive ground water recharge potential from river discharge in the Palla region flood plain stretch was about ~ 260 MCM per year. Hyperspectral remote sensing measurements in soybean were used to estimate soybean biophysical parameters of LAI, chlorophyll and leaf water. This will help develop a methodology for retrieval of leaf and canopy parameters from remote sensing data that are very useful in regular crop growth monitoring and yield assessment. This technique was also used successfully to identify aphid infestation in mustard. The spectral indices, *viz.,* NDVI, RVI, AI and SIPI showed significant correlation with aphid infestation, suggesting the scope of using hyperspectral remote sensing for identification of aphid infestation.

Social sciences research analyzed the growth experience of Indian agriculture. Coarse cereals (particularly maize), oil seeds and cotton showed rapid growth rates. The impressive agricultural growth in Gujarat was found to be due to institutional reforms to expand irrigation and better transfer of technology. The rapid growth of high value commodities like fruits, vegetables, livestock and fisheries was associated with rising demand and strong market linkages. Inter-regional trade agreements in agriculture showed an increasing trend towards regionalism with shift in trade to new partner countries in Asia, Middle East and Africa. The growth in public investment rebounded again (16.80%) during the current decade and private investment remained modest (4.8%).

Two Cyber Extension Centres were established in Sitapur, and 6 rural youth trained for using ICT tools. The delivery of seeds through the post offices was perceived positively by the farmers. The propensity for technology adoption and entrepreneurial initiatives had improved as a result of interventions under ATMA in Hoshangabad district of M.P. However, extension professionals expressed skill gaps in the use of tools for Participatory Rural Appraisal and Information Communication Technologies preparation of Comprehensive District Agricultural Plan, and organization of Farmers' Field Schools.

Case analysis of producer companies in Madhya Pradesh revealed socio-economic benefits, including the availability of quality seeds, an additional gain of ₹100-₹ 200/100 kg of produce and assured market. Public-private partnership (PPP) models in agricultural extension between the state Department of Agriculture and Dhanuka Agritech, Hoshangabad district of Madhya Pradesh led to effective technology dissemination, particularly in soil testing and advisory and seed treatment. PPP between Dawat Foods and ATMA in Hoshangabad district of Madhya Pradesh led to 5 times increase in the area under paddy, 90% of which was under Pusa Basmati 1121.

Capacity building interventions in enhancing entrepreneurship among rural youth led to the initiation of new enterprises. Mapping of the motivational profile of SHG women in Kesla Poultry Cooperative in Madhya Pradesh indicated high need for PA-Inf (personnal achievement oriented influence) followed by PSA (personal cum social achievement) and H (hope) in majority of the SHG women. The project "Assessment and Promotion of Agricultural Technologies and Developing Market-led Extension Models" was reoriented to develop model villages in peri-urban areas of NCR for integrated development. The National Extension Programme was further strengthened in collaboration with 17 ICAR Institutes/SAUs. An innovative transfer of technology model involving partnership between IARI and 27 reputed non-government organizations from 17 states,carried out the assessment and dissemination of IARI technologies in their operational areas.

The annual Krishi Vigyan Mela of IARI on the theme "Farm Technologies for Enhanced Productivity and Income" was attended nearly by 1, 00,000 visitors including farmers from 22 states. Besides the farm advisory services provided at ATIC, farmers were given farm advice through Pusa helpline and Pusa AgriCom. A second level of Kisan Call Centre was established at ATIC. About 18,365 farmers/ entrepreneurs/development department and NGO officials

from 24 states visited ATIC. The Institute's Krishi Vigyan Kendra at Shikohpur, Gurgaon, (Haryana) was actively involved in demonstrations and vocational trainings for 315 youths (150 men and 165 women).Telecom advisory services were given to 1020 farmers.

Weather-based agro-advisory services for farmers of Delhi and NCR were sent twice a week by the Agro-advisory Unit located in the Division of Agricultural Physics. Bi-weekly agromet advisory bulletins were published in newspapers (*Dainik Jagran* and *Haribhoomi*) and uploaded on IARI website (http://www.iari.res.in) and sent through e-mail to IMD for their website for district agro-advisory and national agro-advisory bulletins. About 103 agro-advisory bulletins were prepared in Hindi and English and 26 newspaper coverages were done.

The Farm Operation Service Unit (FOSU) efficiently managed all field operations in 750 acres of IARI farm. A new laser leveling technology was used for field levelling of about 300 acres of farm land. The IARI Biomass Utilization Unit efficiently used waste biomass and crop residues from IARI farm and supplied quality compost to fulfill the entire need of the Institute. The Institute produced a total of 1159.446 tonnes of nucleus, breeder and IARI seeds of different varieties of cereals, pulses, oilseeds, forage, vegetables, fruits, flowers, etc. during the year under strict quality control.

The 49th convocation of the Post-Graduate School of IARI was held on February 5, 2011. Dr. Montek Singh Ahluwalia, Deputy Chairman, Planning Commission, Government of India, who was the chief guest, delivered the convocation address. At this convocation, a total of 99 M.Sc. and 73 Ph.D. students were awarded degrees, and Dr.Montek Singh Ahluwalia was conferred with the Degree of Doctor of Science (*Honoris Causa*).

The Institute updated student amenities and also conducted several regular and short-term training courses. Agri-information and bioinformatics 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 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. Many scientists, students and faculty of the Institute received several prestigious awards and recognitions and brought laurels to the Institute.

1. CROP IMPROVEMENT

Crop improvement programme of the Institute is focused on genetic enhancement and pre-breeding activities, breeding for productivity enhancement, resistance/tolerance to biotic and abiotic stresses, improvement of nutritional quality and developing crop varieties capable of mitigating the adverse effect of global climate change.

1.1 CEREALS

1.1.1 Wheat

1.1.1.1 Varieties released and notified

Two wheat varieties, HD 2985 (Pusa Basant) and HD 2987 (Pusa Bahar) were notified vide Govt. of India Gazette Notification No. 632 (E) dated 25.03.2011 for general conditions.

Pusa Basant (HD 2985). The wheat variety Pusa Basant (HD 2985) was recommended for commercial cultivation under late and very late sown conditions of North Eastern Plains Zone (NEPZ). It has a genetic potential of 5.14 t/ha with an average yield of 3.74 t/ha.

Pusa Bahar (HD 2987). The wheat genotype Pusa Bahar (HD 2987) was recommended for commercial cultivation under conditions of rainfed and restricted irrigation in Peninsular Zone (PZ). It has a genetic potential of 3.22 t/ha with an average yield of 1.8 t/ha under rainfed conditions; and a genetic potential of 3.86 t/ha and average yield of 3.25 t/ha under restricted irrigation. It possesses durable adult plant resistance against brown and black rusts.

Pusa Suketi (HS 507). A wheat genotype Pusa Suketi (HS 507) developed at Regional Station (Tutikandi), Shimla was released by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops for its commercial cultivation under timely sown irrigated and rainfed conditions of Northern Hills Zone (NHZ).

The variety has an average grain yield of 4.68 t/ha (yield potential: 6.0 t/ha) under irrigated condition, and 2.66 t/ha (yield potential: 5.43 t/ha) under rainfed conditions of NHZ. HS 507 has the distinction of being the only genotype with resistance against all the pathotypes of all the three rusts at seedling stage. It combines high adult plant resistance against leaf and stripe rusts along with good resistance against leaf blight and Karnal bunt. It has semi-spreading growth habit with purple auricle colour. The variety has amber and semi- hard grain with a test weight of 41.0 g.

Pusa Suketi (HS 507), a wheat variety for timely sown, irrigated and rainfed conditions of NHZ

Pusa Gaurav (HI 8691). A *durum* wheat variety Pusa Gaurav (HI 8691) was recommended for release by the State Seed Sub-Committee in December, 2010 for irrigated, timely sown conditions of Madhya Pradesh. It is a high yielding variety giving an average yield of 5.36 t/ha (8.0% higher than that of HI 8498, the most widely cultivated *durum* variety, and 20.0% higher than that of Lok 1, the most popular wheat variety) in the coordinated trials across Madhya Pradesh. It has resistance to all the currently prevalent and virulent pathotypes of stem and leaf rusts. It exhibited a rust resistance spectrum different from that of HI 8498, and hence, will broaden the rust resistance base for wheat cultivation in central India. Its high hectolitre weight, protein content (> 12.0 %), and hardness index (82) will ensure high semolina recovery.

Pusa Gaurav (HI 8691), a *durum* wheat variety recommended for irrigated, timely sown conditions of Madhya Pradesh

Less cooking time it takes and less gruel solid loss it has will provide good quality to pasta products. In addition, its high 1000-grain weight, good grain appearance, and insignificant mottling will fetch premium price for the farmers.

1.1.1.2 Variety identified for release

HI 1563. A wheat variety HI 1563 developed at Regional Station, Indore was identified for release for irrigated, late sown conditions of NEPZ. It has wide adaptability and an average yield of 3.7 t/ha. In addition to its high levels of field resistance to leaf, stripe and stem rusts, it possesses seedling resistance to almost all the pathotypes and adult plant resistance to most virulent pathotypes of the three rusts. It has good levels of resistance to leaf blight, powdery mildew and foot rot diseases. The variety possesses good quality with high hectoliter weight, good grain appearance, high sedimentation value, high extraction rate, and good bread, *chapati* and biscuit making quality. It has good levels of micronutrients like iron, zinc and copper.

HI 1563, a wheat variety suited for the irrigated, late sown conditions of NEPZ

1.1.1.3 Entries in coordinated trials

A large number of wheat genotypes were tested in coordinated trials under various production conditions throughout the country.

Elite genotypes of wheat under evaluation in coordinated trials

Trials	Entry name/ number (Zone)
Advanced Varietal Trials (AVT)	**AVT II:** HD 3043 (NWPZ), HS 514 (NHZ), HI 1571 (PZ), HI 1572 (CZ) ***Durum* wheat -** HI 8704 (CZ) and HI 8703 (NWPZ) **AVT I:** HD 3055 (NWPZ), HD 3070 (NWPZ & NEPZ), HD 3071 (NEPZ & PZ), HD 3052 (SHZ), HD 3072 (SHZ), HW 5216 (SHZ), HW 5224 (SHZ) **AVT:** HD 3058 (NWPZ), HD 3059 (NWPZ), HD 3065 (NWPZ), HD 3066 (NWPZ), HD 3065 (NEPZ), HD 3066 (CZ), HI 1579 (CZ), HI 1580 (CZ), HD 3040 (PZ), HD 3068 (PZ), HS 541 (NHZ), HS 542 (NHZ), HS 543 (NHZ), HS 535 (NHZ), HS 536 (NHZ), HS 537 (NHZ), HS 538 (NHZ), HS 539 (NHZ), HS 544 (NHZ), HS 545 (NHZ), HS 540 (SHZ), HD 3075 (SHZ), ***Durum* wheat**- HI 8713(CZ), HI 8714 (NWPZ), HI 8715 (CZ), HI 8722 (CZ)
Initial Varietal Trials (IVT)	HD 3101 (NHZ), HD 3102 (NHZ), HD 3103 (SHZ), HW 5224 (SHZ) ***Dicoccum* wheat**- HW 1098
National Initial Evaluation Trials (NIVT)	**NIVT 1A:** HD 3076, HD 3077, HD 3078, HD 3079, HD 3080, HD 3081, HD 3082, HD 3083 **NIVT 1B:** HD 3085, HD 3086, HD 3087, HD 3088, HD 3089 **NIVT 3:** HD 3090, HD 3091, HD 3095, HD 3096, HD 3092, HD 3093, HD 3094, HW 1111, HW 2072, HW 2073, HW 2068, HW 4206, HW 5223, HW 5232 and HW 5234 **NIVT 4:** HD 4725, HD 4726 **NIVT 5A:** HD 3098, HD 3097, HD 3099, HI 1582, HI 1583, HI 1584, HI 1585, HI 1586, HI 1587 ***Durum* wheat**- HI 8723, HI 8724, HI 8725, HI 8726, HI 8727, HI 8728, HI 8729, HI 8730, HI 8731, HI 8732 and HI 8733
Common Varietal Trials (CVT)	HW 4215 (SHZ), HW 4015 (SHZ)

1.1.1.4 Promising genotypes

A genotype HD 3016 gave higher yields ranging from 8.08 to 12.71% in all the three years of testing against the checks, C 306, K 8027 and HD 2888. It out yielded all the checks in all the three years of testing. It has shown consistent performance over the years and locations with a high level of resistance against stripe rust and leaf rust. The adult plant resistance of HD 3016 against brown and black rusts is mainly due to minor genes and, therefore, likely to be durable. It has the highest number of grains/head and second highest ear head/m^2 among the checks. It has the best HMW sub-units combination for bread making with *Glu-1* score a perfect 10/10. HD 3016 has the highest value of bread loaf volume (cc), bread loaf volume (ml/dough weight) and bread quality score.

The variety, therefore, may find favour with bread making industries. The variety with dwarf plant type (77 cm) has the least heading days (76) and maturity duration (122) and is, therefore, better equipped to tolerate the climatic vagaries in comparison to all the checks.

HD 3016, a high yielding wheat variety resistant to stripe and leaf rusts, and adult plant resistance to brown and black rusts

1.1.1.5 Selection of breeding material for suitability to cropping system and conservation agriculture

With the objective of breeding genotypes suited for conservation agriculture, three crop systems based on rotating wheat with maize, pearl millet and rice were compared with conventional wheat cropping with fallows. The evaluation of the breeding lines, germplasm and released varieties under different production systems such as zero tillage, raised bed and zero conventional tillage, flat bed and conventional tillage, zero till and raised bed was carried out.

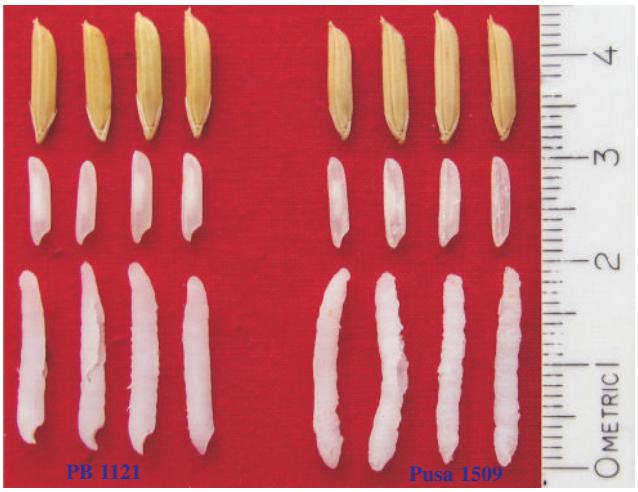
In maize-wheat rotation, a total of 390 maize hybrids consisting of 38 early maturing experimental hybrids, 105 medium maturity hybrids and 247 released and experimental hybrids were evaluated for identifying the maize hybrids suited for zero tillage conditions. In the early maturing group, Vivek and Hybrid 9, and in full duration group, the hybrids HTMH, JKMH 102, GK 3090, CMH 08, KNMH 4010131, Bio 562, Bio 9681, Pro 379, B55, Titan and HQPM 1 were found promising, in pearl millet-wheat cropping system. A total of 89 experimental hybrids were evaluated, of which 17 hybrids, viz., IHT 203, IHT 209, IHT 213, IHT 214, IHT 215, IHT 217, IHT 218, AHT 401, AHT 203, AHT 204, AHT 212, AHT 213, AHT 214, AHT 215, AHT 218, AHT 220 and AHT 505 were found promising under zero till condition. From 720 genotypes of wheat tested in maize-wheat cropping system under conservation agriculture practices, the entries CSW1, CSW2, CSW13 and CSW16 out yielded the highest yielding check significantly and are under further testing at multiple locations. Similarly, among the wheat genotypes tested under conservation agriculture practices in rice-wheat cropping system, the entries CSW 18, CSW4, CSW19 and CSW 21 specifically were found performing better than the check entries. In pearl millet-wheat cropping system, the entries found yielding significantly higher than the best yielding checks were: CSW15, CSW5 and CSW20. Strong indication for specific adaptation of the genotypes to cropping system and conservation practices was found from this experiment.

1.1.2 Rice

1.1.2.1 Elite *basmati* breeding line in coordinated trial

Pusa 1509 (IET 21960). An elite *basmati* breeding line, IET 21960 (Pusa 1509-03-3-9-5) developed from the cross Pusa 1301/ Pusa Basmati 1121, was tested in Initial Varietal

Trial-Basmati, during *kharif* 2010 and promoted to Advanced Varietal Trial 1-Basmati. It is a semi-dwarf variety with a seed- to- seed maturity of 120 days and average yield of 4.8 t/ ha. It showed significant superiority over both the checks, Pusa Basmati 1 and Taraori Basmati in Punjab (17.20%, and 41.4%) as well as in Uttar Pradesh (9.28% and 29.52%). This genotype possesses strong aroma, extra long slender grains (8.35 mm) with moderate HRR (53.5%) and very less chalkiness. It has very good KLAC (17.2 mm), high ASV (7.0) and intermediate amylose content (21.96%). In the panel test under coordinated programme, it was rated the best owing to its excellent elongation, taste and aroma.

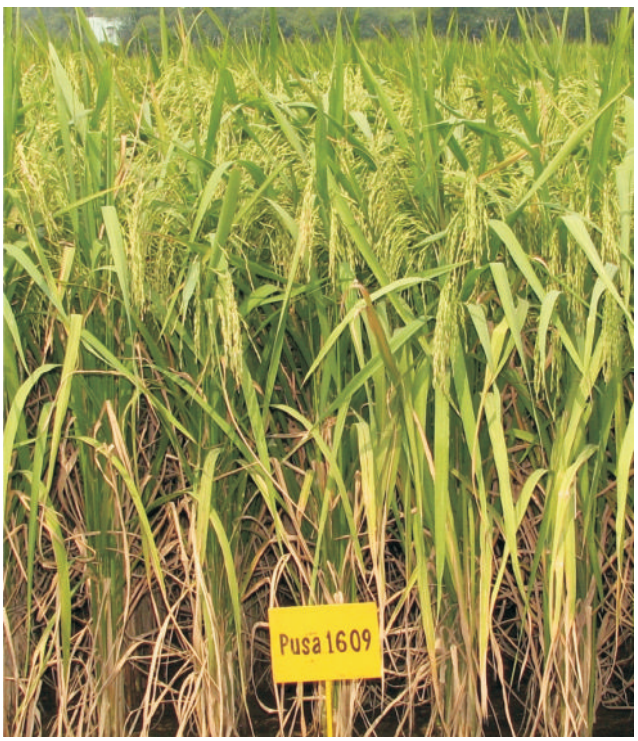


Pusa 1509, an elite semi-dwarf early maturing *Basmati* rice line (above). A comparison of the characteristics of PB 1121 and Pusa 1509 (below)

Compared to Pusa Basmati 1121, this genotype is 20 days earlier, non-shattering and non-lodging with superior cooked kernel shape.

1.1.2.2 Promising elite lines

Pusa 1609, a blast resistant Basmati restorer line. The line Pusa 1609 was developed by pyramiding of genes *Piz5* and *Pi54* in PRR 78, the pollen parent of Pusa RH 10. Based on background analysis, the BC_2F_6 lines, namely, Pusa 1602-06-30-1-51 carrying *Piz5* and Pusa 1603-06-10-2-12 carrying *Pi54* having recurrent parent genome recovery (RPG) of 87.88% and 89.01%, respectively, were identified, intercrossed and advanced through pedigree selection. It resulted in the development of elite breeding lines, namely, Pusa 1609-09-3-60, Pusa 1609-09-3-4, and Pusa 1609-09-11-30 having RPG of 91.62%, 90.21%, and 88.80%, respectively, and carrying both the genes in homozygous condition. These lines showed blast resistance. The hybrids produced by crossing Pusa 6A with blast resistant version of PRR 78, were found to be on a par with original Pusa RH10 in yield, grain and cooking qualities with an added advantage of blast resistance.



Pusa 1609, a blast resistant elite restorer line

Pusa 1638-07-48, a semi dwarf high yielding short grain aromatic rice line. Kalanamak is a popular short grain aromatic rice variety from eastern UP, which is characterized by black husk, strong aroma and excellent grain and cooking quality attributes. However, like traditional *Basmati* varieties, Kalanamak is very late (160 days seed-to-seed maturity), photoperiod sensitive, tall, prone to lodging and low yielding.

Pusa 1638-07-48, a semi dwarf high yielding short grain aromatic rice with quality attributes of Kalanamak

With a view to developing high yielding, dwarf, short grain aromatic rice varieties, which are on a par with Kalanamak in grain and cooking quality, Kalanamak was crossed with a semi-dwarf short grain aromatic rice breeding line, Pusa 1176. As a result of rigorous selection for earliness and dwarf plant type, several high yielding fixed lines with grain and cooking quality similar to Kalanamak were developed. These are at various stages of evaluation. One of the lines, Pusa 1638-07-48, which has grain dimensions, husk colour and cooking quality typical of Kalanamak, yielded 3.8 t/ha compared to 2.0 t/ ha in Kalanamak. These lines hold great promise for enhancing the production and productivity of short grain aromatic rices in Kalanamak growing areas of Uttar Pradesh.

1.1.3 Barley

1.1.3.1 Entries in coordinated trials

Two genotypes viz., BHS 393 and BHS 344, were promoted to the second year of testing under AVT-rainfed of All India Coordinated Trials. Five genotypes, viz., BHS 397, BHS 398, BHS 399, BHS 400 and BHS 401, were included in All India Coordinated Barley Trials for further evaluation under both grain as well as dual purpose (grain & fodder) categories.

1.1.4 Maize

1.1.4.1 Entries in coordinated trials

The performance (grain yields) of promising early maturing hybrids (AH 97002, AH 97017 and AH 97018) in the coordinated trials was in the range of 5.8 t to 6 t/ha in Zone IV comprising the states of Andhra Pradesh, Karnataka and Maharashtra.

1.1.4.2 Development and evaluation of new maize hybrids and inbred lines

Crosses of late x early genotypes and their generation advancement were undertaken in *rabi* 2010 for facilitating new segregants, specifically for the distinct maturity groups. A set of 50 late and 62 early maize inbred lines were evaluated for different traits, including their prospective use as seed or pollen parents in generating new cross combinations. Twenty-five new maize inbred lines were developed for assessing their combining ability, and elite maize inbred lines comprising late maturity group (25) and early maturity group (150) were maintained.

1.1.4.3 Screening for biotic and abiotic stresses

Thirty elite hybrids and 114 inbreds were screened against maize leaf blight (MLB) and banded leaf and sheath blight (BLSB) through artificial epiphytotics. Five experimental hybrids (HD 26338 x HD P1, HD 26340 x HD P1, 26341 x HD P2, 26342 x HD P1 and 26347 x HD P2) and 10 inbreds with MLB tolerance and one inbred (DL200408-2) with both MLB and BLSB tolerance were identified. Eight F_1s were generated for introgression of MLB resistance using registered resistance sources. Screening of more than 1000 maize lines for MLB tolerance was carried out under natural epiphytotic condition during *kharif* 2 010 as the disease incidence was very high due to favourable environmental conditions on account of high moisture and humidity condition all through the growing season.

Preliminary screening of 400 maize inbred lines for water logging tolerance indicated that 6 inbreds were highly tolerant to waterlogging as indicated by various growth parameters and corroborated by profuse aerial roots. In addition, 50 inbreds including their sister lines were moderately tolerant.

1.1.4.4 Advancement and characterization of elite maize inbred lines

Characterization of elite maize inbred lines of different types, namely, field corn (200 including late maturity group

- 62 and early maturity group - 48), baby corn (5), sweet corn (12) and pop corn (10) was undertaken. A collection of 500 genotypes were evaluated in *kharif* 2010 to study the variation in flowering time. A panel of 272 inbred lines were assembled based on the variation of their flowering time. They are being evaluated to find marker-trait association for drought tolerance at three locations, viz., IARI, New Delhi, ANGRAU, Hyderabad, and Maize Research Station, Karimnagar. About 120 drought RILs developed ($F_{7:8}$ stage) using CA00106 (drought susceptible) and CM140 (drought tolerant) parents, are under evaluation at the above three locations during *rabi* 2010-11. A survey of parental polymorphism with SSRs yielded 80 polymorphic markers, which are being further used for genotyping of RILs.

Putative downy mildew resistance genes were identified from bin 6.05, and the upregulated genes were validated through RT PCR. Well known haploid inducer lines RWS, RWK-76 and RWS × RWK-76 were obtained from the University of Hohenheim, Germany, and are being maintained at the National Phytotron Facility.

A set of 77 cross combinations involving parents suitable for baby corn traits were evaluated during *rabi* 2009-10 at IARI Experimental Farm, New Delhi. A hybrid trial involving promising baby corn inbreds developed at IARI was also conducted to evaluate them during *kharif* 2010. Promising combinations with baby corn trait were identified. Selected entries will be used for multi-location trial and development of new inbred lines for baby corn purpose.

Twenty nine sweet corn hybrids generated among the inbreds developed at IARI were evaluated in a replicated trial at IARI Experimental Farm during *kharif* 2010. Cross combinations were in the genetic background of *sh2* and *su1* genes. The experiment led to the identification of three promising sweet corn hybrid combinations.

To enhance the genetic bases of sweet corn germplasm, a diverse set of 100 normal inbreds were crossed with six sweet corn donors having *sh2* and *su1* genes. A set of 469 S1lines of sweet corn type were generated during the reported period. They differed in terms of kernel colour, texture and ear shape. F_2 populations among *Sh2Sh2 x sh2sh2* and *Su1Su1 x su1su1*, were generated for tagging *sh2* and *su1* using bulk segregant analysis (BSA). The harvest of F_1 plants from each of the two populations clearly showed segregation of mutant (*shrunken-2* or *sugary-1*) and normal alleles in the expected ratio of 3:1. In the case of *sh2sh2* × V364 population, three SSR markers differentiated

A promising hybrid for baby corn traits

Segregation of *sh2* and *su1* alleles among F_2 seeds of normal x sweet corn genotypes

Segregation pattern of SSR markers linked to *sh2* and *su1* genes

the bulks and parents while for *su1su1* × V390, six SSR markers could be selected for further analyses in the F_2 population. One SSR marker for *sh2* gene and two SSR markers for *su1* gene were found to be tightly linked. These SSR markers belong to the same linkage group where the respective genes are reported to be located.

1.2 MILLET

1.2.1 Pearl Millet

1.2.1.1 Varieties identified

Pusa composite 621. A composite Pusa Composite 621 performed consistently well for three years in the coordinated trials, and has been taken up for identification.

1.2.1.2 Entries in coordinated trials

One promising hybrid MS 411A x TPR14 was identified for testing in the coordinated trials.

1.2.1.3 Promising elite lines

A total of 237 new hybrids were developed using different male sterile lines and restorers. In the Initial Station Trial comprising 35 test hybrids, two test hybrids, namely, MS 576A x PPMI 190 and MS 576A x PPMI 295 were found promising.

1.2.1.4 Biofortification of pearl millet

Pearl millet is one of the most nutritious food crops. In order to systematically breed new varieties and hybrids enriched with micronutrients, Fe and Zn, a set of 300 germplasm lines including elite breeding lines, released varieties, and inbred parents of the hybrids (CMS lines and restorer lines), were screened for variations in Fe and Zn contents with a view to identifying the potential donors and parents for generating mapping populations to identify QTLs for Fe and Zn. The iron values ranged from 20 to 123ppm in grain with the highest content being in PPMI 2001(123ppm). The zinc values ranged from 20 to 98 ppm with the highest content being in PPM I683. Among the hybrids, Pusa 415 had the highest Fe (48 ppm) and Zn (41 ppm) contents, while Pusa Composite 443 recorded 60 ppm Fe and 44 ppm Zn. Crosses were attempted among the selected parents to study the genetics of Fe and Zn contents and to develop mapping populations.

1.3 GRAIN LEGUMES

1.3.1 Chickpea

1.3.1.1 Entries in coordinated trials

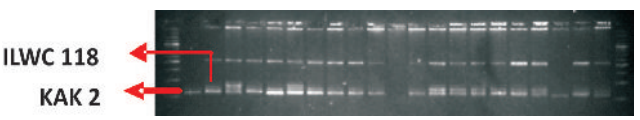
Eighteen (18) new entries were contributed to coordinated trials. Four entries, viz., BG 3005, BG 3012, BGM 571 and BGM 572, were promoted to AVT-1 trials.

1.3.1.2 Pre-breeding for introgression of alleles from wild sources (*C. reticulatum*)

A total of 28 confirmed F_1's from the wide crosses between the wild species *C. reticulatum* (ILWC 118) and the varieties Pusa 1053, and KAK 2 to introgress desirable traits from the wild species were grown. The hybridity of the F_1's was confirmed using STMS markers.

1.3.1.3 Hybridization for enriching drought tolerant alleles

Crosses with ICC 4958 as donor were made with Pusa 372 and Pusa 362 for MABC and JG 130 was crossed with Pusa 372 for MARS to enrich drought tolerant alleles.



Confirmation of the hybridity of F_1 by the use of STMS markers

1.3.2 Mungbean

1.3.2.1 Entries in coordinated trials

The entries Pusa 1031 and Pusa 1032 of mungbean were promoted to AVT of NEPZ, and Pusa 1131 and Pusa 1132 were entered in IVT.

1.3.2.2 Pre-breeding for generation of variability

Forty intervarietal/interspecific crosses were effected to combine MYMV resistance with earliness and bold seed size.

1.3.2.3 Promising elite lines

An extra early maturing elite line which matured in 47 days was identified. It is being improved further.

An extra early maturing elite mungbean line

1.3.3 Lentil

1.3.3.1 Varieties in pipeline

A high yielding variety L 4701 was promoted to AVT 1 for three zones, namely, CZ, NEPZ and NWPZ.

1.3.3.2 Pre-breeding

Thirty-five crosses were made to combine wilt and rust resistance, earliness, bold seed size, and iron and zinc contents in good agronomic bases.

1.3.4 Pigeonpea

1.3.4.1 Entries in coordinated trials

Two early maturing varieties, Pusa 2010/5-1 and Pusa 2010/5-2 with yield potential of 2.0 t to 2.2 t/ha were entered in IVT (E) for NWPZ.

1.3.4.2 Promising elite lines

For the first time, a compact and short statured early selection (maturing in 130 days) was identified. Several nearly homogenous, lines which were identified with the early maturing (<125 days), compact plant type and effective secondary branches bearing bold seeds are in F_4 and F_5 generations.

1.3.4.3 Conversion of CMS and restorers for hybrid development

Backcrossing was carried out to transfer A_2 cytoplasm into 16 genotypes, and A_4 cytoplasm into 25 genotypes in various backcross generations. Three hundred and forty-six advanced progenies and 21 F_4 families of interspecific cross *C. scarabaeoides* x Pusa 33 were evaluated for identification of new A, B and R lines. Further, twenty superior bold seeded (100 seed weight > 9 g) progenies are being evaluated for fertility restoration.

1.4 OILSEED CROPS

1.4.1 *Brassicas*

1.4.1.1 Varieties released

Pusa Mustard 26 (NPJ 113). A mustard variety Pusa Mustard 26 (NPJ 113) suitable for late sown conditions (in November) after harvest of cotton, rice and *guar* in the states of Haryana, Rajasthan, Punjab, plains of Jammu & Kashmir, Delhi and western UP was released. It matures in 126 days with an average yield of 1.6 t/ha. This variety contains 37.6% oil, and is tolerant to high temperatures, and salinity to some extent.

Pusa Mustard 26 (NPJ 113), a mustard variety suitable for late sown conditions

Pusa Mustard 27 (EJ 17). A mustard variety Pusa Mustard 27 (EJ 17) was released for early sown (September sowing) conditions in zone-III comprising the states of U.P., M.P., Uttrakhand, and Kota region of Rajasthan. Average seed yield of this variety is 1.53 t/ha with 41.7% oil content in seeds. It matures in 118 days and is moderately tolerant to high temperatures at seedling as well as maturity stage. It is suitable for multiple cropping system, and can successfully fit in between the harvest of *kharif* crops (September) and sowing of wheat, vegetables and sugarcane (December-January) when fields are generally fallow. This

Pusa Mustard 27 (EJ 17), a mustard variety released for early sown (September sowing) conditions in U.P., M.P., Uttrakhand, and Kota region of Rajasthan

is a good substitute for *toria* (in *toria* growing traditional belt) in this zone.

1.4.1.2 Entries in coordinated and common trials

The following entries are in coordinated & common trials:

Entries in trials

Name of trial	Production condition	Entries name
IVT	Toria/ early mustard (Irrigated/ Rainfed)	NPJ 147, NPJ 148
	Timely sown mustard (Irrigated/ Rainfed)	NPJ 141, NPJ 146
	Late sown mustard	NPJ 149
	Mustard quality	LES 42, LES 43
	Saline/alkaline conditions	NPJ 150
AVT - 1	*Toria* / early mustard (Irrigated)	EJ 22, NPJ 135
	Timely sown irrigated	JS 29
AVT - 2	*Toria* / early mustard	NPJ 124, EJ 20
	Timely sown irrigated	HYT 33
	Quality mustard	LET 36

1.4.1.3 Hybridization and pre-breeding

A total of 199 new crosses and 83 backcrosses in different backcross generations were made to test combining ability, introgress low glucosinolate and incorporate white rust resistance in addition to improving productivity.

1.4.1.4 Conversion of CMS and restorers for hybrid development

A total of 270 new crosses and 314 backcrosses were made for transferring nuclear genes from 19 backgrounds to 4 sterile cytoplasms, viz., *Moricandia arvensis, Erucastrum canariense, D. erucoides* and *D. berthautii.* Based on pollen studies, 112 new crosses and 92 backcrosses were attempted for transferring the fertility restorer genes to the improved backgrounds.

1.4.1.5. Promising elite lines

Seventy hybrids were evaluated, of which 8 hybrids exhibited yield superiority over the best check. The lines NPJ 112 and NRCDR 2 were identified to be good general combiners, and their conversion to CMS lines has been initiated.

From the fixed advanced high yielding populations, 22 white rust resistant lines suitable for late-sown conditions, and 37 short duration lines have been identified for further testing.

1.4.2 Soybean

1.4.2.1 Entries in coordinated trials

In soybean, two entries (DS 2614 and DS 12-13) were entered in AVT-II for Northern Plains Zone, and another two entries (DS 12-5 for Northern Plains Zone and DS 2711 for North Eastern Zone) were entered in AVT-I.

1.4.2.2 Breeding for iron deficiency chlorosis (IDC) tolerance

One hundred and four soybean genotypes were screened in hydroponics for identification of IDC tolerant genotypes. Fourteen genotypes were identified as IDC tolerant.

Screening soybean genotypes for IDC tolerance in hydroponic

Linked SSR markers were validated and gene/STS-based markers designed and tested for marker assisted selection.

1.4.2.3 Breeding for charcoal rot resistance

Two mapping populations (F_2) for charcoal rot resistance were advanced to F_3. Artificial screening through first node inoculation was performed to estimate the genetics of charcoal rot resistance.

Screening of segregating population in soybean for charcoal rot resistance

1.4.2.4 Pre-breeding for creation of genetic diversity

Sixty-eight F_2 plants from the cross with *G. soja* were grown, and lines differing in seed color, plant type, seed size, maturity duration, etc., were identified. Ten new interspecific crosses were made for incorporating biotic and abiotic stress tolerance, shorter duration, yield and quality.

1.5 FIBRE CROP

1.5.1 Cotton

1.5.1.1 Evaluation of *Bt* cotton hybrids for mechanical picking

Ten commercially released *Bt* cotton hybrids, namely, Ankur 2226, MRC 7017 (BG II), MRC 7031 (BG II), MRC 6304, MRC 6025, Masscot, Bioseed 6488, Mist, Tulsai 4 (BG II), and Om 333, and two non Bt genotypes, viz., F 2383 and Pusa 1752, were evaluated for machine picking

Genetic variability for seed colour created through inter-specific (*G max* x *G soja*) hybridization

and yields under different spacing. The highest seed cotton yield recorded was 2076 kg/ha in MRC 6304 in 75cm x 60cm spacing.

1.5.1.2 Evaluation of advanced material

Twenty-one RILs selected for high fibre strength and high yield were also evaluated in F_6 generation. The highest yield of 1327 kg/ha was recorded against 966 kg/ha in local check Pusa 8-6. Seventy-one advanced generation fixed lines were evaluated and the lines yielding higher than the local check Pusa 8-6 for seed cotton were identified.

1.6 VEGETABLE CROPS

1.6.1 Cole Crops

1.6.1.1 Cauliflower

Sixteen self-incompatibility (SI) based hybrids from early maturity group were found promising with the highest average curd weight (875 g) in 327-14-4-17 × Sel.18 followed by 327-14-4-17 × Pusa Deepali (750 g). In mid-early maturity group, out of 28 cytoplasmic male sterile (CMS) and 5 SI based F_1 hybrid combinations evaluated, 14 were found promising. The hybrid DB-15 × 311 gave the maximum average curd weight of 1012 g during November-end to early December. Hybrid 8409 × Sel.7, with a curd weight of 875 g was found promising for mid-December maturity. In mid-late maturity group, hybrid 8409 × 306 gave the highest curd weight (1215 g) followed by 8409 × 313 (1064 g). The hybrid 8409 × BR 202-2, however, recorded the highest curd weight (1500 g) followed by 8409 × AL-15 (1480 g) during the first fortnight of January. These hybrids showed tolerance to black rot and downy mildew diseases. Attempts were made to develop eighty early and

A cauliflower hybrid 8409 x BR 202-2

40 mid group SI based hybrids and 20 early and 60 mid group CMS hybrids.

In resistance breeding programme, 9 inbred populations, 25 F_2s, 14 F_5s and 18 backcross populations were evaluated with respect to curd quality, maturity and resistance/tolerance to downy mildew and black rot diseases. The promising selections were advanced for further evaluation. Inheritance of black rot resistance was studied and found to be governed by single dominant gene in the genotype BR 161. Twenty-seven RILs and 26 NILs against black rot disease were advanced for further phenotyping and genotyping.

Ogura CMS system was established and maintained in 3 early and 9 mid group genetic backgrounds and exploited in hybrid combinations. *Tournefortii* sterile cytoplasm was established in cauliflower background and maintained. Three CMS lines were developed after 10 generations of backcrossing by using heat tolerant Ogura system from cauliflower and were evaluated for their suitability in heterosis breeding programme. The parent Ogu2A exhibited the highest GCA effect for curd length, yield and harvest index, while Ogu1A exhibited the highest GCA effect for earliness. Heterosis for curd yield was the highest in the hybrid Ogu2A × Kt-22.

At IARI Regional Station, Katrain, 50 CMS based snowball group hybrids were evaluated for various horticultural traits. Hybrids KTH-51 (42.5 t/ha), KTH-52 (45.3 t/ha), KTH-44 (39.0 t/ha) KATH-28 (37. 7 t/ha) were found to be promising.

For diversification of CMS system BC_1 generation were developed involving crossing between *Brassica juncea* carrying *Trachystoma balli* and *Diplotaxis catholica* sterile cytoplasms and cauliflower cultivar Pusa Snowball K-1 through embryo rescue. Attempts were also made to develop BC_2 generation to transfer the sterile cytoplasm in cauliflower background. Three promising CMS lines of the station, namely, Ogura IA, Ogura 2A and Ogura 3A were compared for their *in vitro* regeneration ability on different media by using seed as explant. The best response was observed in Ogura 1A followed by Ogura 3A. Ogura 2A responded poorly to *in vitro* culture.

1.6.1.2 Cabbage

At IARI Regional Station, Katrain, one CMS and six self-incompatible (SI) lines of cabbage were used to produce 42 F_1 hybrids. The two F_1 hybrids of cabbage, KTCBH-81 and KTCBH-51 were evaluated and advanced to AVT under the AICRP (VC) trials and produced yields of 61.8 t/ha and 59.5 t/ha, respectively.

In vitro embryo rescue was attempted for diversification of CMS system in cabbage and snowball cauliflower through introgression of sterile *Trachystoma balli* and *Diplotaxis catholica* cytoplasms. The rescued F_1 and BC_1 plants are being maintained through *in vitro* techniques standardized for effective rooting of rescued plants. The most effective rooting was observed in liquid medium by using filter paper bridge technique.

1.6.1.3 Broccoli and Kale

At IARI Regional Station, Katrain, CMS system was transferred to 5 varieties/lines of broccoli, which are in BC_4 generation. Their maintainer lines are being kept. In kale, KTK-64 was evaluated in IET under the AICRP (VC) trials at the station. It gave the highest leaf yield of 40.8 t/ha with a 21% increase over that of the check.

1.6.2 Cucurbitaceous Crops

1.6.2.1 Bitter gourd

Twelve new gynoecious × monoecious hybrids were developed. For transferring the gynoecious trait in Pusa Do Mausami background, BC_2S_2 population was generated and advanced. Three predominantly gynoecious lines were also developed. The earlier developed small fruited salinity tolerant genotypes WBBG 15 and WBBG 18 were utilised for breeding programme.

DBGS- 32

DBGS- 54

Two exotic selections, DBGS-32 and DBGS-54 were found to be potential genotypes for greenhouse cultivation, as they produced optimum fruit size without pollination. For attaining maximum fruit size, however, pollination was found necessary. The parthenocarpic nature of fruit development hastened senescence affecting keeping quality.

Twelve promising lines derived from the exotic lines were evaluated for yield traits, of which 2 selections DBGS-37 and DBGS-57 produced 17.0 t and 19.0 t/ha of fruit

DBGS-57

yields, respectively, as against 15.0 t/ha by Pusa Do Mausami (check). The fruits of DBGS-57 are dark green in colour and are of medium size (16 cm × 5 cm). Two earlier selections (Sel. 1 and Sel. 5) produced 16.7 t and 16.0 t/ha fruit yields, respectively.

1.6.2.2 Cucumber

Two selections, DC-54 and DC-78 yielded 20.2 t and 19.3 t/ha showing yield advantages of 22.4 % and 17.0%, respectively, over that of the check. Another selection DC-82 that produced 18.6 t/ha of fruits was found to be field tolerant to downy mildew and viruses. Monoecious F_1 hybrids, DCH-6 and DCH-13, and gynoecious F_1 hybrid DCHG-10 gave yield advantages of 24.2, 18.5 and 21.4%, respectively, over that of the check Pant Sankar Khira-1.

1.6.2.3 Luffa

Sponge gourd selections, DSG-43 (16.4 t/ha) and DSG-48 (15.8 t/ha) were found promising. Other two selections DSG-6 (14.8 t/ha) and DSG-7 (14.3 t/ha) showed tolerance to tomato leaf curl New Delhi virus. A spontaneous dwarf gynoecious mutant was found.

In ridge gourd, DRG-74 and DRG-98 were found promising with yield advantages of 14.4% and 9.8%, respectively, over that of the check Pusa Nutan. A gynoecious plant with absolute expression of gynoecism was found as a chance seedling.

1.6.2.4 Muskmelon and watermelon

Sixty-eight genotypes of muskmelon, snapmelon, watermelon and *C. callosus* were screened during the rainy season (Aug.-Nov.) for field tolerance to high moisture, downy mildew and viruses.Two lines, Ganganagar Local and IC-274026 were found resistant to wilt and other diseases with good horticultural traits and moderate TSS. Two male sterile lines Ms-1 and Ms-5 in muskmelon are being utilized for heterosis breeding.

1.6.3 Solanaceous Crops

1.6.3.1 Brinjal

One long fruited brinjal hybrid DBHL-20 was identified and recommended for cultivation in Punjab, Delhi, Uttar Pradesh and Bihar by the XXIX Group Meeting of AICRP (Vegetable Crops). Its plants are non-spiny, and semi-erect having light purple and pigmentation partially on younger leaves and new branches. The fruits are long, dark purple, and glossy weighing 90-100 g. It takes about 55 days from transplanting to the first harvest. The average yield is 52.4 t/ha. In round fruited hybrid trial, DBHR-49 yielded 54.6 t/ha showing an increase of 14.1% over that of the check. In small round fruited hybrid trial, DBHSR-58 (37.2 t/ha) was found to be the best. Forty-five genotypes and F_1 combinations were screened against *Phomopsis* blight. Two lines, Bl-1-4 and DB-11a-2, and two hybrids, DBHL-135 and DBHL-33 were found tolerant.

A brinjal hybrid, DBHL-20 recommended for cultivation in Punjab, Delhi, Uttar Pradesh and Bihar

A CMS based carrot hybrid IPC-98xIPC-13 Red

1.6.3.2 Tomato

Three hybrid combinations, H-86 x CR, H-86 x H-88 and H-86 x H-24 were found resistant against *Tomato leaf curl virus* (ToLCV). Pusa 120 was found resistant against root knot nematode. Genetic studies on resistance against *Meloidogyne incognita* Race 1 revealed that resistance was controlled by a single dominant gene in Pusa 120. One genotype, namely, FEB-2 was found to be resistant against early blight (*Alternaria solani*) under natural field conditions. New hybrid combinations, PS x FEB-2, N-5 x PS, P. Sh. x Lab., P. Sh. x PS and P. Sh. x CH were found promising for fruit setting at high temperature during May-June when night temperature reached up to 28 ^{0}C. Two cherry tomato lines, namely, DCT-1 and DCT-2 were found promising.

1.6.3.3 Chilli

Cluster and pendant fruited lines were isolated from F_3 generation of Pusa Sadabahar x Pusa Jwala. Ten lines including different species of capsicum and paprika were raised in phytotron for evaluation. Three genotypes were found to have field tolerance against leaf curl virus complex.

1.6.4 Root and Bulbous Crops

1.6.4.1 Carrot

Six genotypes for July sowing, and 7 genotypes for August sowing were found promising under high temperature and humidity conditions. Under September sowing condition, IPC-13 red recorded the highest root weight (162.5 g), while IPC-53 recorded the maximum root length (24.55 cm) and the maximum root diameter (5.39 cm). A CMS based hybrid IPC-98 x IPC-13 Red recorded the highest root weight (236.67 g).

IPC-126 (78.5 mg/100 g) recorded the highest anthocyanin content, while IPC-56 recorded the highest values for total carotenoids, b carotene and lycopene, the estimated values being 13.46 mg, 8.51 µg and 11.71 mg per 100 g, respectively. IPC-105 (10.45 ^{0}B) recorded the highest TSS followed by IPC-16 (9.70 ^{0}B). Hybrid IPC-126 x IPC-104 (11.81 mg/100 g) recorded the highest anthocyanin content and Hybrid IPC-124 x IPC-122 recorded the highest total carotenoids (17.66 mg/100 g), and b carotene (10.86 µg/100 g) and lycopene (13.61mg/100 g) contents. TSS was the highest in IPC-126 x IPC-13 Red (9.13 ^{0}B).

At IARI Regional Station, Katrain, 70 experimental hybrids developed by using 14 CMS (A) lines and four pollinator (C) lines were evaluated for yield and desirable horticultural traits. The hybrids, namely, KTCH-1020 (40.1t/ha) and KTCH-122 (36.5 t/ha) yielded higher than the hybrid, Pusa Nayanjyoti (35.4 t/ha).

1.6.4.2 Radish

DC (G-S) recorded the highest root weight (400 g) followed by DC (W-W) (366.67 g), DC (P_i-P_i) (300 g), DC (W-P) (300 g) and DC (P_u-P_u) (266.67 g).

1.6.4.3 Onion

An onion selection (Sel-383) with dark red coloured bulbs gave good performance yielding 33.3 t/ha followed

by Sel-153 and Sel-126 with yields of 32.6 t and 31.6 t/ha, respectively. Among CMS based hybrids, H-13 and H-38 were found promising, yielding 42.2 t and 40.6 t/ha, respectively. Bulbs of 4 promising lines and CMS 'A' line were planted with long day variety Brown Spanish at IARI Regional Station, Katrain for attempting crosses between short and long day types.

1.6.5 Leguminous Crop

1.6.5.1 Garden Pea

A garden pea promising selection GP-901 was found to be early, long poded, and powdery mildew resistant. Genotypes, GP-17, GP-6, GP-55, VL-3 and GP-473 showed resistance to *Fusarium* wilt. The genotype GP-17 (extra early) and GP-473 (medium duration) possessed all good horticultural traits and were found promising. A total of 183 crosses were evaluated and 130 were selected for advancement of generation. A total of 240 crosses were made to select high yielding disease resistant varieties. Eight new bulks from advance generations were made for further evaluation.

1.6.6 Malvaceous Crop

1.6.6.1 Okra

Out of twenty-five advance segregating breeding lines, 4 superior lines, namely, Sel-64, Sel-65, Sel-66 and Sel-1 in terms of pod characters, yield and *Yellow vein mosaic virus* (YVMV) resistance were selected and selfed for further utilization. Fourteen cultivated and two YVMV resistant wild genotypes were crossed for transfer of YVMV resistance. Seeds of Pusa A-4 and Sel-1 were irradiated with *gamma* rays for mutation breeding. In M_1 generation, minor variations were recorded for fruit and leaf shape.

1.7 FRUIT CROPS

1.7.1 Mango

1.7.1.1 Release of hybrids

Four mango hybrids, namely, Pusa Pratibha (H-1-1), Pusa Shreshth (H-1-6), Pusa Lalima (H-4-12) and Pusa Peetamber (H-2-6) found to perform consistently well were released at the 49th convocation of IARI.

Pusa Pratibha | **Pusa Shreshth** | **Pusa Lalima** | **Pusa Peetamber**

1.7.1.2 Evaluation of new hybrids

Fifteen mango hybrids were evaluated for different physico-chemical attributes. Among other hybrids, maximum fruit weight (371.09 g) was recorded in H-1-5 followed by H-11-2 (272.60 g) and H-1-11 (262.55 g). The hybrid H-11-2 had intense red colouration on peel. The peel weight varied from 13.94 g in H-1-13 to 59.31 g in H-1-5. Pulp: stone ratio was found to be the highest in H-1-5 (9.75).

1.7.1.3 Hybridization in mango

Seven cross combinations were attempted in mango using Amrapali as female parent and Sensation, Pusa Arunima, Pusa Pratibha, Pusa Shreshth, H-1-11, Janardan Pasand and Irwin mango varieties as male parents. A total

Physico-chemical characteristics of IARI released mango hybrids

Hybrid	Fruit wt. (m)	Fruit length (cm)	Fruit width (cm)	Peel wt. (m)	Pulp wt. (g)	Stone wt. (g)	TSS (%)	Ascorbic acid (mg/100 g pulp)
Pusa Pratibha	192.45	9.98	6.23	26.52	92.45	16.45	21.00	41.90
Pusa Shreshth	217.58	11.37	6.20	45.76	131.88	35.22	21.82	46.23
Pusa Peetamber	159.65	8.68	5.66	26.40	109.50	21.95	21.45	30.0
Pusa Lalima	195.23	9.3	5.30	27.45	118.40	25.30	21.25	37.65
Pusa Arunima	177.25	9.47	6.12	35.58	109.93	36.05	23.65	50.0

Physico-chemical characteristics of mango hybrids

Hybrid	Fruit wt. (m)	Fruit length (cm)	Fruit width (cm)	Peel wt. (m)	Pulp wt. (g)	Stone wt. (g)	TSS (%)	Ascorbic acid (mg/100 g pulp)
H-1-5	371.09	12.73	7.40	59.31	300.57	30.84	19.95	25.00
H-1-9	146.02	9.72	5.89	27.50	94.43	21.67	22.60	34.00
H-1-11	262.55	11.91	6.33	43.15	176.80	37.35	19.50	45.00
H-1-13	125.46	7.78	5.11	13.94	56.32	13.74	16.80	46.23
H-2-14	184.23	10.55	6.10	39.90	113.87	26.90	21.97	25.00
H-3-2	193.10	9.47	6.08	48.25	109.75	30.60	24.45	35.56
H-3-4	168.35	12.44	5.04	30.72	110.06	25.17	15.53	35.00
H-3-14	164.70	9.45	5.48	33.53	95.97	35.57	23.50	25.00
H-11-2	272.60	11.02	6.69	46.70	188.55	34.90	21.10	60.00
H-11-3	207.38	11.01	6.00	43.48	118.45	41.23	22.43	58.23
H-11-4	194.77	10.27	6.01	27.83	77.80	21.33	14.07	45.62

of 1,264 flowers were crossed in 256 panicles. The fruit setting was found maximum in Amrapali × Irwin cross. However, more than 50% fruit setting was noticed in all crosses, except Amrapali × Pusa Shreshth cross.

1.7.2 Citrus

1.7.2.1 Evaluation of citrus collections and cultivars

In sweet orange, the maximum fruit weight (305.45 g) was recorded in MOS-7 and the highest juice content (56.54%) was recorded in MS-4. The number of seeds varied from 10.20 (MOS-3) to 18.23 (MS-17) and TSS was found to be the highest in MOS-3 (10.42%) with the lowest acidity (0.65%). MOS-5 had higher ascorbic acid content (46.91%). The sweet orange cultivar Malta Blood Red had the highest fruit weight (237.80 g) and ascorbic acid content (46.20%). However, juice content (67.25%) and TSS (9.83%) with the lowest acidity (0.29%) were recorded in mosambi. In grapefruit, the fruit weight varied from 282.68 g in Foster to 457.26 g in Marsh Seedless. Marsh Seedless had the highest juice recovery (48.07%) followed by Red Blush (45.56%) and Imperial (43.20%). The number of seeds varied from 2.00 in Marsh Seedless to 53.67 in Imperial. Marsh Seedless also had the highest TSS (10.12%) and ascorbic acid (72.64 mg/100 g). Acid lime collection ALC-2 had the heaviest fruit (90.62 g) with the highest TSS (8.52%). However, juice content was recorded the maximum in ALC-7 (57.65%). Acid lime ALC-1 had the highest acidity (6.35%).

1.7.2.2 Hybridization in citrus

Six hundred fifty-seven flowers of Rangpur lime, Cleopatra mandarin, Attani and RLC-6 were crossed with Troyer, Sacaton, Rubidaux, trifoliate orange and Morton. The maximum fruit setting was noticed in the cross combination of Rangpur lime × Rubidaux (100%) followed by Rangpur lime × Trifoliate orange (75%), RLC-6 × Sacaton (60%) and Cleopatra mandarin × Rubidaux (55.56%). The lowest fruit set was recorded in Rangpur lime × Troyer citrange (6.00%).

1.7.2.3 Induced mutagenesis in Kinnow

Chemical mutagens EMS (0.05, 0.1, 0.2, and 0.5%) and colchicine (0.02, 0.05, 0.10, and 0.20%) were tried by treating Kinnow scion buds. Data on bud sprout revealed more than 50% survival at lower doses of EMS, while at higher dose (0.5%), only 30% bud sprout was recorded. Colchicine treatment although promoted bud take, the per cent sprout was only 10% at different concentrations.

1.7.2.4 Identification of functional flowers in citrus

Based on five morphological traits, the proportions of functional, semi-functional and non-functional flowers were found to be 29.5 and 22.38%; 8.19 and 14.92%; and 62.3 and 59.7%, respectively, in Rangpur lime and Attani. Functional flower shape (dome) generally had less difference in diameter at pedicle- end and distal with 28.51% for Rangpur lime and 18.15% for Attani compared to that of their non-functional flowers, i.e., 48.79 and 26.07%, respectively.

1.7.3 Grapes

1.7.3.1 Evaluation of promising lines and hybrids

F_1 grape hybrid (1,600) and selfled (11,000) seeds produced by using 15 different cross combinations, were sown. Nineteen cultivars were evaluated, of which Tas-e-Ganesh and Centennial Seedless performed consistently well. Both these genotypes that ripened by the second week of June were of acceptable quality as table grape. Five hybrids were assessed for fruit and quality characters. Of these, Banqui Abyad x Perlette-75-32, Hur x Cardinal-76-1 and hybrid (Hur x BE) x BS performed well on Head system of training with good quality fruits, early ripening and yield. Hybrid Hur x Cardinal-76-1 had the biggest berry (5.7 g) with seeds. Hybrid Hur x Cardinal-76-1 and (Hur x BE) x BS, which ripened by the first week of June were found promising.

Grape hybrid (Hur x BE) x BS

1.7.3.2 Evaluation of genotypes for juice and wine making

The existing germplasm were evaluated for ripening and physico-chemical parameters. Cultivar Tempranillo was found to be the earliest to ripen under Delhi conditions and can be utilized for juice and wine making.

Tempranillo

1.7.4 Papaya

At IARI Regional Station, Pusa (Bihar), sixteen papaya germplsam lines were evaluated for different horticulture traits. The minimum height (42 cm) and nodes (27) at first flowering were observed in Pusa Nanha and the minimum fruit weight (450 g) in Surya, whereas the maximum height (105 cm), stem girth (21 cm), number of fruits (42), weight of fruit (2.20 kg) and TSS (14 %) were observed in Red Lady.

1.7.5 Temperate Fruits

1.7.5.1 Apple

A semi-dwarfing apple rootstock PSM-I is being recommended for commercial utilization. Pollination studies were conducted for identifying the *Malus* species that could be used as pollinizers in apple orchards. Pollens of *Malus pumila*, *Malus baccata*, *Malus baccata* var. *mandschurica* and *Malus micromalus* were used to pollinate flowers of Starking Delicious, Golden Delicious, Pusa Amartara Pride, Pusa Gold and spur types of Red Delicious. A few pollen parents helped in fruit set.

Performance of three promising grape hybrids

Hybrid	Ripening	Av. Number of bunches/vine		Av. bunch wt. (g)	Av. berry wt.(g)	TSS (%)	Remarks
		Head	Kniffin				
BA x Per-75-32	2nd wk of June	19.0	46.0	565.0	2.7	18.6	Yellowish seedless berry, suitable as table grape
Hur x Card-76-1	1st wk of June	22.0	34.0	425.0	5.7	22.0	Yellowish bold berry, seeded; can be used as table grape and for *munnakka* making
(Hur x BE) x BS	1st wk of June	32.0	-	455.0	2.3	18.2	Yellowish-green round seedless berry, suitable as table grape

1.7.5.2 Apricot

Evaluation of *Prunus japonica* as a dwarfing rootstock for stone fruits was made. Field performance of the apricot grafts produced during the previous year was evaluated and grafts of other apricot varieties were produced. Propagation of the difficult to root species of apple and *Prunus* species was attempted through hardwood cuttings by initiation of rooting in the hot-bed (21 °C). Very good callusing and root initiation were obtained in the hot-bed designed at IARI Regional Station, Amartara (Cottage).

***Prunus japonica* root stock**

1.8 ORNAMENTAL CROPS

1.8.1 Rose

Three hybrids belong to Hybrid tea group, 2 seedlings and 3 bud sports are under multiplication stage.

The hybrid HT-B14-R10 was developed by crossing Chandrama and First Prize. It produces pinkish white buds, which turn milky white later, and has long lasting flowers. Hybrid HT-B5-R2 was evolved by crossing Mrinalini and Sugandha. The plants have medium growth and produce large, pinkish fragrant blooms. Hybrid, HT-B10-R1 was developed by crossing Eiffel Tower and Queen Elizabeth. The plants have sturdy growth and produce pink coloured blooms.

A thorn less seedling (SD-3) of the variety Preyasi, producing pink coloured compact blooms, was found to be ideal for pot purpose in initial evaluation. A seedling (SD-4) of the variety Century Two was found to produce dark pink blooms with very high fragrance.

Among the bud sports, BS-1 is a new variant bud sport of the variety Arjun that produces white coloured flowers. BS-2 is a bud sport of the variety Folklore that has white stripes on pink background in flowers, and BS-4 is a bud sport of the miniature variety Cricri that produces milky white small blooms in abundance.

SD-3: A thornless seedling of cv. Preyasi

SD-4: A fragrant seedling of cv. Century Two

BS-1: A bud sport of cv. Arjun

1.8.2 Chrysanthemum

1.8.2.1 Isolation of new hybrids

Four promising seedlings each from florist chrysanthemum cultivars, Jaya, Lalpari, Pink Cloud, and Sadhbhawana, and 2 seedlings from cv. Texas Gold were isolated after screening a number of seedlings. Out of the screened seedlings, 4 seedlings, namely, Chacko, Gazania Type, Magenta Magic and Orange Spoon were unique.

1.8.2.2 Evaluation of promising seedlings

Nine promising seedlings from florist chrysanthemum cv. Lalpari were isolated and evaluated. Five seedlings were found to be extremely promising. The seedling S6 is the tallest (61.9cm) with 47.5 branches. It produced 421.5 flowers per plant.

Chacko: A seedling from cv. Jaya

Orange Spoon: A seedling from cv. Jaya

Gazania Type: A seedling from cv. Lalpari

Magenta Magic: A seedling from cv. Lalpari

1.8.3 Gladiolus

Two hundred fifty hybrids were evaluated and two hybrids and one selection, namely, Berlew × Headywine, Mayur × Hunting Song and Regency Open were found promising in respect of vegetative and flowering characters.

Berlew × Headywine: The hybrid produces purple coloured florets (17-18) on long and sturdy spikes. It is a very good multiplier producing more than 2 corms from each mother corm.

The hybrid Mayur × Hunting Song produces red coloured florets (19-20) in a compact arrangement with good

spike length (83 cm) and rachis length (45 cm). It is a medium duration hybrid and takes 90-100 days to flowering. It is a good multiplier producing 2 corms for each mother corm.

Regency Open is a selection from open pollinated population of the variety Regency. The selection produces dark red coloured florets (17-19) on very long and sturdy spikes. It takes 95-100 days to flowering. It is a good multiplier and produces more than 2 corms and 28 cormels from each mother corm.

Berlew x Headywine

Mayur x Hunting Song

Regency Open

1.8.4 Marigold

1.8.4.1 Evaluation of promising selections/hybrids

Seven selections were found promising for rainy season cultivation and one selection and 3 hybrids were found promising for winter season with respect to flower yield and quality. The selection Fr/R-5 has medium plant height, and produces medium size compact flowers of orange colour suitable for garland making. The plants are very floriferous with longer flowering duration. The selection Fr/R-2 has tall plants with dark green foliage. The plants are vigorous and flower abundantly during October-November (festive season). Its medium size flowers of maroon colour are very good for garland making and other social/religious purposes. The selection Fr/R-12 has dwarf and compact growth habit, and is very floriferous having longer flowering duration and suitablility for landscape/bedding purposes.

1.8.4.2 Evaluation of genotypes for carotenoids

Total carotenoids of 26 genotypes including two varieties, Pusa Narangi Gainda and Pusa Basanti Gainda, were estimated, which ranged from 2.05 to 58.89 µg/100 g. The maximum carotenoid content was found in selection Af/WS-2 (58.89 µg/100 g) followed by selection Af/WS-14 (47.82 µg/100 g), which was significantly higher than that of the existing popular variety Pusa Narangi Gainda (41.20 µg/100 g).

1.8.5 Bougainvillea

Three bougainvillea cultivars, such as Mahara, Lady Mary Baring (LMB) and Dr. H.B. Singh were irradiated with 0.0 kr, 0.5 kr, 1.0 kr, 1.5 kr and 2.0 kr *gamma* rays. The cultivars, Mahara and Lady Mary Baring responded to 0.5 and 1.0 kr and produced promising mutants. It was observed that the cultivar Mahara at 0.5 kr and LMB at 1.0 kr changed their morphological characters like colour of bracts/leaves, etc., as compared to those of control.

1.8.6 *Lillium*

At IARI Regional Station, Katrain, eight *Lilium* hybrids and selections were evaluated under open conditions. Sel-2 performed better with respect to days to flowering (206.7 days), plant height (52.3 cm) and number of leaves (57.7). The cultivar Fangio took 223.2 days to flowering.

1.9 SEED SCIENCE AND TECHNOLOGY

1.9.1 Hybrid Seed Production Technology in Bitter Gourd (*Momordica charantia* L.)

Hybrid seed production technology of bittergourd hybrids, Pusa Hybrid 1 and Pusa Hybrid 2, was compared under open field and net house conditions in *kharif* and spring-summer season. Hybrid seed production under net house conditions showed vigorous, healthy and insect free crop with more crossed fruits, higher fruit weight, higher seed yield/fruit and better seed quality. In order to increase the proportion of female flowers for hybrid seed production, foliar application of growth regulators, viz., GA_3 @ 40/50 ppm, Etherel @100 ppm and NAA @ 200 ppm at three stages, i.e., 3-leaf + tendril initiation + bud initiation, was found effective in increasing vine length, number of branches and female flowers per vine, fruits per plant, fruit length, fruit weight, seeds per fruit and 100-seed weight. Maximum fruits and seed setting (seed yield 2kg/100m^2) were achieved when pollination was done between August 15-30 and September 10-20 in *kharif* and between April 10-30 and April 25- May 10 in spring-summer season under net house and open field conditions, respectively.

1.9.2 Characterization and Maintenance of Self–Incompatible and Protogynous Line in Indian Mustard

Studies on protogynous lines in Indian mustard indicated that the duration of protogyny was up to 11 days in timely sown plants while it was reduced to 5 days in late sown plants. A distinct difference in the opening of protogynous flowers in lines/plants in different genetic backgrounds was observed. Evaluation of plants in F_2 generation derived from 5 crosses made on protogyny and normal flower type revealed that two recessive genes controlled protogyny. In order to break self-incompatibility treatments of the stigma before pollination, six amino acids, three growth hormones, sucrose and two salts were tried, and the treatments with kinetin, histidine, sucrose, IAA and GA_3 were found promising. The experimental hybrids based on self-incompatible and protogyny system in Indian mustard showed a yield advantage up to 33% over the check varieties.

1.9.3 Pollination Ecology and Formulation of Seed Testing Protocols and Seed Standards in *Nigella sativa* (black cumin)

Black cumin exhibits the characteristics of both anemophilous and entomophilous flower, and is also a hermaphrodite species with determinate flowering pattern. On examination of seed quality in 8 seed lots, non-deep physiological dormancy (type-1) was observed, and seeds could be tested either by BP or TP method at 20/30°C with the first and the final count on the 7th day and the 10th day, respectively. Fresh seeds required co-application of GA_3 or pre-chilling to reduce non-deep physiological dormancy. Germination varied from less than 80 per cent in 3-carpelled capsules and more than 95 per cent in 8-carpelled capsules. *N. sativa* seeds exhibited orthodox storage behaviour as longevity of seeds increased in a quantifiable and predictable manner with the decrease in moisture content. No significant reduction in seed viability was observed up to one year in seeds having moisture content of 4-6%, while significant decline in seed viability was recorded in seeds having higher moisture content.

1.9.4 Molecular Techniques for Testing Purity of Non-transgenic and Transgenic Hybrids

Studies were undertaken to identify molecular markers for ensuring the purity of hybrids of *Bt*-cotton, brinjal and maize, and their respective male and female parents. Among four SCAR markers, MD1, MD2 and MD4 were found to be useful in ensuring the hybrid purity of seeds of cotton hybrids, whereas six markers could detect hybrid purity as well as extent of selfed seeds in brinjal hybrids. A new protocol was developed for rapid DNA extraction and PCR amplification in brinjal and its applicability for testing genetic purity was validated. A total of 50 SSR markers were tested for its applicability in genetic purity testing of maize hybrids and SSR markers were identified for testing the hybridity as well as extent of selfed seeds.

1.9.5 Pre-sowing Seed Treatments for Enhancing Crop Productivity

Studies on seed enhancement treatments on specialty maize (HQPM 1, VL Amber pop corn) win orange sweet corn (HM 4) and common maize (Prakash) genotypes revealed that seed enhancement treatments significantly improved field emergence, its uniformity, speed of emergence, early seedling/vegetative growth, number of cobs and seed yield/plot over those of control under field conditions. These treatments modified the seed water-binding properties resulting in better availability of water for metabolism, improved seed membrane integrity (reduced leakage of electrolytes and water soluble sugars), increased protein and DNA content and enzyme activity of α-amylase, dehydrogenase and super oxide dismutase. Storage studies on primed seed showed no significant decline in seed quality up to six months at 25°C. Among the treatments, hydropriming (17h/ 20°C) with or without Thiram (3g/ kg of seed), priming with KNO_3 (0.3 %) and Fulvic acid (0.1 %), biopriming with coelomic fluid derived from indigenous earth worm (*Perionyx celanenesis*), seed treatment with Cruiser (4 ml/ kg of seed), Thiram (3g/kg of seed), polymer coating (Seed Coat Red) and magnetic stimulation (1000G/ 2h) could be adopted for on-farm seed enhancement in maize both under *kharif* and spring-summer season.

Pre-sowing seed treatment combinations were also studied in cotton, soybean, chickpea and wheat. *Trichoderma* spp. and bacterial isolates were purified from different locations in addition to existing isolates. A set of bioagents were screened and *Trichoderma* strains were identified for seed quality enhancement. Compatibility of *Trichoderma* strains with priming and coating materials showed variation in growth and sporulation of bioagent.

1.9.6 Effect of Sowing Dates and Closure Date on Forage and Seed Yield of Berseem

The influence of sowing dates and date of cessation of defoliation on forage and seed yield of berseem (*Trifolium alexendrinum*) was investigated at the Institute's Regional Station, Karnal during *rabi* season of 2009-10. There was a reduction in the yield of green foliage by 19.1% when sowing was delayed up to 15th November, and a reduction of 27% when sowing was delayed up to 25th November as against the yield obtained with 25th October sowing. Delaying the closure date for seed production from 15th April to 5th May increased green forage yield irrespective of sowing dates. Maximum seed yield was obtained under 5th November sowing and 15th April closure for seed production.

Effect of sowing dates and closure dates for seed production in berseem cv. BL 42

Treatment	Green forage yield(t/ha)	Seed yield(t/ha)
Sowing date		
25th October	112.5	0.39
5th November	108.7	0.41
15th November	91.0	0.32
25th November	82.0	0.26
CD at 5%	7.8	0.02
Closure date for seed production		
15th April	92.5	0.37
25th April	98.7	0.35
5th May	104.5	0.31
CD at 5%	1.5	0.02

1.9.7 Seed Production

The Seed Production Unit of the Institute (Delhi) and the Institute's regional stations/centre at Karnal, Indore,

Seed production (tonnes)

Crop	Nucleus Seed	Breeder Seed	IARI Seed	Total Seed
Seed Production Unit, Delhi				
Cereals	-	30.59	171.49	202.08
Millet (Pearl Millet)	-	-	0.76	0.76
Pulses	-	3.26	5.32	8.58
Oilseeds (Mustard)	-	0.14	4.72	4.86
Vegetables & Flowers	0.007	0.45	2.00	2.457
Regional Station, Karnal				
Cereals	2.91	111.55	316.02	430.48
Pulses	-	3.19	3.79	6.98
Oilseeds	0.023	1.83	2.45	4.303
Forage	0.098	1.38	1.36	2.838
Vegetables	0.20	5.62	3.92	9.74
Regional Station, Indore				
Cereals	-	245.30	-	245.30
Fruit (Papaya)	-	0.009	-	0.009
Regional Station, Pusa				
Cereals	3.297	96.892	117.578	217.767
Pulses	0.084	1.984	0.955	3.023
Oilseed (*Toria*)	-	-	1.632	1.632
Vegetables	-	-	0.033	0.033
Fruit (Papaya)	-	-	0.021	0.021
Other (Tobacco)	-	-	0.264	0.264
Regional Station, Wellington				
Cereal (Wheat)	-	15.00	-	15.00
Regional Station, Katrain				
Vegetables	0.042	0.532	2.675	3.627
IARI Centre for Pulses Improvement, Dharwad				
Pulses (Chickpea)	0.070	-	-	0.070

Pusa, Wellington, Katrain and Dharwad produced 1159.446 tonnes, nucleus, breeder and IARI seeds of different varieties of cereals, pulses, oilseeds, forage, vegetables, fruit, flowers and other crop during the year under strict quality control. Apart from the seed production, 2571 fruit plants were produced at the Seed Production Unit (Delhi).

Total seed production (tonnes)

Crop	Nucleus Seed	Breeder Seed	IARI Seed	Total Seed
Cereals	6.207	499.332	605.088	1110.627
Millet	-	-	0.76	0.76
Pulses	0.154	8.434	10.065	18.653
Oilseeds	0.023	1.97	8.802	10.795
Fruit, Vegetables & Flowers	0.249	6.611	8.649	15.509
Forage	0.098	1.38	1.36	2.838
Other (Tobacco)	-	-	0.264	0.264
Total	**6.731**	**517.727**	**634.988**	**1159.446**

2. GENETIC RESOURCES

Plant genetic resources are the most valuable and essential basic raw material to meet the current and future needs of crop improvement programmes. A wider genetic base is thus, of utmost importane in plant breeding research aimed at developing new varieties for increased crop production. The collection and conservation of this diversity in a systematic manner is one of the main priorities of this Institute. Several new germplasm lines, including wild and related species of various crops, were collected from different sources and maintained as active germplasm at the Institute.

2.1 CROP GENETIC RESOURCES

2.1.1 Wheat

2.1.1.1 Maintenance and utilization of wild relatives

About 250 accessions of wild relatives of wheat were grown and screened for rust resistance. For transfer of rust resistance from wild species, BC_1 generation from crosses *T.aestivum*(CS) × *T.militinae*, *T.aestivum* × *Ae.geniculata* and *T.aestivum* x *T.turgidum* were grown and selected plants backcrossed with *T. aestivum*. Cytological analysis of BC_1 was undertaken to understand the extent of chromosome pairing.

The leaf rust resistant lines derived from *Ae.markgrafii* were analysed cytologically. An introgressed line ER9-5 showed better cytological stability with complete bivalent formation. More than 300 genetic stocks were rejuvenated and maintained and 300 new accessions/lines of diverse germplasm were obtained from NBPGR, New Delhi and DWR, Karnal.

2.1.1.2 Genetic stocks and germplasm

More than 1200 genetic stocks identified for different traits, including disease resistance and grain quality, were maintained. Six hundred new accessions/lines were obtained from CIMMYT, Mexico; NBPGR, New Delhi; and DWR, Karnal.

2.1.1.3 Generation advancement and selection in off-season nurseries at Lahaul Spiti and Wellington

Number of entries grown at Lahual Spiti: 949

Number of entries grown at Wellington: 1320

Characters observed: Yellow and brown rusts at Lahual Spiti, brown and black rusts at Wellington

2.1.1.4 Multiplication of inoculums of brown, yellow and black rust races

Races of brown rust multiplied in glass house: 77-5, 77-6, 77-7, 77-8 and 104-2

Races of yellow rust multiplied in glass house: 78 S 84 and 46 S 119

2.1.1.5 New genetic stocks created for rust resistance

At IARI Regional Station, Wellington, the work on transferring race non-specific APR linked genes *Lr*34, *Lr*46, *Sr*22 and *Sr*2 into selected Indian popular wheat cultivars was initiated and F_1 hybrids were planted for top-cross. The effective stem rust genes *Sr*25, *Sr*26, *Sr*27, *Sr*36+*pm*6, *Sr*39, *Sr*40, *Sr*41, and *Sr*44 either singly or in combination with *Sr*24 or *Sr*2 were incorporated to combat the threat from the new stem rust pathotype *Ug*99 virulent on *Sr*31 and stripe rust genes (*Yr*10, *Yr*15, *Yr*16) in the background of elite Indian bread wheat cultivars, and simultaneous molecular confirmation was undertaken.

Newly acquired resistance sources carrying *Lr*52, *Lr*53, *Lr*57 and *Lr*67 (APR), which confer resistance against all three rusts were used for introgression into several adapted Indian cultivars. F_1 crosses for *Lr*53 and *Lr*57 were planted for further backcrossing. More than 135 lines carrying *Lr*9, *Lr*19+*Sr*25, *Lr*24+*Sr*24, *Lr*28, *Lr*32, *Lr*37+*Sr*38+*Yr*17, *Sr*26+*Sr*24, *Sr*27+*Sr*24, *Sr*24+*Sr*36, etc., at F_8 were shared with 22 lead centres including DWR, Karnal, involved in wheat breeding in India.

At IARI Regional Station, Tutikandi, Shimla, 39 advanced bulks of wheat were screened against the most virulent pathotype 121R63-1, out of which 14 were observed as resistant at seedling stage under glass house condition.

At IARI Regional Station, Indore, 600 bread wheat genetic stocks were rejuvenated and about 650 *durum* wheat genetic stocks planted for rejuvenation. These genotypes are being used in crossing programme for the incorporation of various yield component characters in enriching the genetic variability in bread wheat and *durum* wheat.

2.1.2 Rice

2.1.2.1 Registration of bacterial leaf blight resistant genetic stocks

Using marker assisted foreground and background selections, two bacterial blight resistance genes, namely, *xa13* and *Xa21* were transferred in the parental lines of Pusa RH 10, *ie.,* the maintainer parent Pusa 6B and restorer parent PRR 78. Two improved versions each of Pusa 6B, namely, Pusa1605-05-38-3-1 (INGR 10121) and Pusa1605-05-38-3-2 (INGR10122) and PPR78, namely, Pusa1601-05-46-1-1 (INGR 10123) and Pusa1601-05-46-5-3 (INGR 10124), having resistance to bacterial blight, were registered as genetic stocks with NBPGR, New Delhi. These lines are useful genetic resources for developing bacterial blight resistant rice hybrids.

2.1.3 Maize

2.1.3.1 Specialty corns

Crossing programme of specialty corn genotypes with male sterile lines, with special emphasis on baby corn, to assess the utility of male sterility was initiated. Multi-cob genotypes selected in *kharif* 2010 were included in selection, advancement and stabilization scheme. Twenty-five elite germplasm lines of specialty corns were identified for generating new hybrids.

2.1.3.2 Genetic stock evaluation

In addition to 52 genetic stocks for yield component traits, maturity and drought adaptation, 42 maize genotypes were screened against MLB and BLSB, of which 15 and 4, respectively, were found to be resistant to MLB and BLSB. Advancement of crosses for introgression of MLB resistance, by using registered stocks, was undertaken under a maize breeding project, in collaboration with the Division of Plant Pathology, IARI.

2.1.4 Chickpea

2.1.4.1 Screening of chickpea germplasm under soil salinity

One hundred chickpea genotypes were evaluated under saline soil condition with a salt concentration of 1.5 to 2.0 dS/m. The genotypes, Vijay, BG390, Pusa1088, LBeG 7 and Pusa 2024 yielded higher than the salt tolerant variety CSG 8962.

2.1.5 Mungbean

2.1.5.1 Evaluation and maintenance of germplasm

Two hundred eighty-five germplasm lines of mungbean were maintained. In addition to these, 10 accessions of *V. radiata* var. *sublobata,* viz., IC 202538, IC 202580, IC 247405, IC 248344-A, IC 251412, IC 251413, IC 253920, IC 253930, IC 322306 and IC 351404 were multiplied. Mungbean germplasm was screened against *Mungbean yellow mosaic virus* (MYMV).

2.1.6 Lentil

2.1.6.1 Evaluation and maintenance of germplasm

Four hundred fifty germplasm lines of lentil were evaluated and maintained. Evaluation of 238 accessions of core collection provided by IIPR, Kanpur for heat tolerance was carried out to characterize the materials for days to first flowering, days to 50% flowering, days to first pod, plant stand at harvest, 100-seed weight, seed yield/plot, plant height, width, number of filled pods, number of unfilled pods, single plant yield and biomass.

2.1.7 Pigeonpea

2.1.7.1 Germplasm

Single rows of 181 germplasm lines of late maturity group received from NBPGR and a set of 159 germplasm lines including 7A lines (A_2 cytoplasm), 2A lines (A_4 cytoplasm) and 6 R lines were grown for maintenance.

2.1.7.2 Evaluation of wild species

Sixty wild species accessions were evaluated along with *Cajanus cajan* lines for water logging and frost tolerance. Four water logging tolerant wild species were identified as donors for water logging tolerance and also 5 frost tolerant accessions identified.

2.1.7.3 Evaluation in off-season nursery at Navasari Agricultural University, Navasari(Gujarat)

One thousand thirty-four families (F_4, F_5, and F_6) of the cross Pusa Dwarf × H 2001- 4 were grown in off-season nursery for generation advancement to develop RILs.

Evaluation of pigeonpea in off-season nursery at Navasari

2.1.8 *Brassicas*

2.1.8.1 Maintenance of germplasm

Total germplasm = 657: *B. juncea*: 370, *B. carinata*: 170, *B. napus*: 38, *B. rapa*: 39, *B. oleracea*: 6, *B.* nigra:14, *B. tournifortii:* 3, *B. caudatus*: 3, *R. caudatus*: 1, *R. sativa:* 1, *S. alba*: 2, *Eruca sativa*: 6, *Crambe* spp.: 2, *Lapidium* spp: 1, and *Camellina* spp.: 1

Maintenance and evaluation of wild species of *Brassica*

2.1.8.2 Phenotypic and genotypic characterization of *Brassica juncea* germplasm

Three hundred seventy germplasm lines of *Brassica juncea* were phenotyped for eleven morphological traits. Genotyping of these lines is in progress for studying the genetic diversity for development of heterotic pools.

2.1.9 Soybean

2.1.9.1 Germplasm maintained

More than 1200 germplasm accessions were raised for maintenance and evaluation. Two hundred germplasm lines were evaluated for eight morphological traits, namely, plant height, primary branches, days to 50% flowering, days to maturity, pods/plant, seeds/pod, hundred seed weight and seed yield/plant. Based on neighbor and median clustering methods, a set of 29 diverse accessions were finally selected and their variability was measured.

2.1.10 Cotton

2.1.10.1 Registration of germplasm

Strain P56-4 was registered as a germplasm line for high fibre strength with IGNR No. 10155 and IC No. 0584055. It has 27.8 g/tex fibre strength, 28.4 mm span length, 3.9 micronaire value, 53.5% uniformity, 6.2% elongation, 3.8 g boll weight, 32.5% ginning percentage and 175 to 180 days maturity. Pusa 2150 and Pusa 2151 were sponsored in national trials, Br 02 (a) and Br 02 (b), respectively. Strain Pusa 1752 was identified for its suitability for machine picking.

2.1.10.2 Evaluation of germplasm

A total of 200 germplasm lines of *G. hirsutum* were evaluated in single row plots for important traits. Several lines yielded significantly higher than the check Pusa 8-6. In the screening done for *Cotton leaf curl virus* and jassid, 35 and 23 lines, respectively, were found found susceptible while 15 lines were found susceptible to both.

2.1.11 Vegetables

2.1.11.1 Cole crops

Cauliflower. Nine early and 4 mid group SI lines were tested for their level of self-incompatibility and maintained. Selected 30 early and 50 mid-group inbred lines were

maintained and advanced for utilization in breeding programme.

At IARI Regional Station, Katrain, 70 segregating lines/ selections including CMS lines along with their respective maintainers, 4 new lines and 2 DBM tolerant lines were maintained after positive selection.

Cabbage. At IARI Regional Station, Katrain, 60 germplasm lines of cabbage including 6 self-incompatible lines, 4 DBM tolerant lines and 10 CMS lines and their maintainer lines were purified and maintained.

Broccoli. Eight selections of green sprouting broccoli from previous years were evaluated for early season production and the selected plants were advanced for further evaluation. Two purple heading broccoli populations for December and January maturity each were developed and the selected plants were sib-pollinated for further evaluation.

2.1.11.2 Solanaceous crops

Tomato. Forty-five new germplasm lines including 6 leaf curl resistant type, 27 cherry type and 4 husk tomato (*Physalis peruviana*) were collected, evaluated and maintained. Sixteen lines of wild tomato germplasm consisting of *S. pimpinellifolium* and *S. hirsutum* were collected and are being evaluated for special traits, viz., fruit setting ability at high/low temperature, resistance to ToLCV, TSS, and lycopene content.

Brinjal. One hundred twenty-five germplasm lines were evaluated and maintained. Different lines of *Solanum aethiopicum, S. incanum*, *S. gilo, S. insanum, S. indicum, S. torvum* and *S. integrifolium* were collected, evaluated and maintained.

Chilli. Thirty-one exotic lines were collected, evaluated and maintained. One hundred thirty-three new germplasm lines comprising high capsanthin and high capsaicin genotypes were collected from Kashmir and north-east region.

2.1.11.3 Root crops

Carrot and radish. Forty different coloured genotypes were evaluated, and the selected roots were planted for maintenance and seed multiplication for further research programme lines. In radish, 6 new improved genotypes comprising pink, purple and white colour were developed, evaluated and maintained for further use.

2.1.11.4 Cucurbits

Bitter gourd. Fifty genotypes, including 14 exotic lines, were evaluated. Genotype DBGy202 bore the first female flower at the lowest node (9.20) followed by DBGy201 (9.49). Sel-2 had the longest ovary (2.93 cm) with the highest fruit L:D ratio (5.50) depicting longer fruits. The highest individual fruit weight was recorded in EC620332 (129.85 g), and DBG-48 had the maximum number of fruits per plant (48.24). Sel-2 had the highest yield per plant (1222.51 g), and DBG-36 recorded the longest vine length (262.79 cm), while EC620355 had the shortest vine length (112.47 cm).

Variability in bitter gourd

Twenty bitter gourd genotypes were analysed for nutrient contents with and without seeds. The sample analyzed with seeds had the maximum nitrogen content in genotype PBIGH-5 (3.52%). Phosphorus content was highest in PH-2 (0.49%) and potassium content was the highest in DBG-36 (1.84%). Genotype DBG-36 had the highest calcium content (430.33 ppm). Among micro nutrients, the highest manganese content was observed in DBG-43 (31.47 ppm), the highest zinc content in Arka Harit (47.07 ppm), and the highest copper content in PH-2 (12.53 ppm). Iron content was the highest in PBIGH-5 (306.87 ppm) followed by DBG-51 (298.33 ppm).

In the fruits without seeds, DBG-41 had the maximum nitrogen content (3.64%), and PH-2 and Arka Harit had the highest phosphorus content (0.43%). Potassium content was the highest in DBG-43 (2.00%) and calcium content (451.33 ppm) was the highest in DBG-36. The highest manganese and zinc contents were in MC-84 (26.97 ppm) and PBIG-

56 (36.80 ppm), respectively. Copper content was the highest in NDBGH-671(10.51ppm), while iron content was the highest (317.03 ppm) in DBG-38.

Cucumber. Two hundred forty-eight germplasm lines including 16 new collections were evaluated during spring-summer and *kharif* seasons and promising lines were maintained. Eighteen novel genotypes of cucumber including gynoecious lines, carotene rich cucumber, *Cucumis hystivus* disease resistant lines and gherkin types introduced from USA were maintained and utilized in the crossing programme for broadening the genetic base of Indian cucumber. During winter season, fifty-one promising lines of cucumber including six gynoecious and five lines of gherkin, four parthenocarpic types and their segregating progenies were assessed and advanced in polyhouse.

Luffa. One hundred twenty-five germplasm lines of sponge gourd and 119 of ridge gourd including some Satputia types (hermaphrodite) were evaluated during spring-summer and *kharif* season, and promising lines were maintained.

Pumpkin. Thirty-two accessions of *Cucurbita moschata* and four of *Cucurbita argyrosperma* were obtained from NBPGR and fourteen germplasm of pumpkin were collected from north-east India. These are being evaluated.

Muskmelon and watermelon. Twenty-three genotypes of muskmelon, 8 of snapmelon and 19 of watermelon were evaluated. Seventy-six new germplasm lines of muskmelon, 46 of watermelon and wild relatives (12) were collected, and are being evaluated.

Minor cucurbits. Sixteen germplasm lines each of longmelon and roundmelon were evaluated and single plant selections were maintained. Fifty-seven breeding lines of summer squash were maintained. Summer squash Selection DS-8 was found most promising and the yield advantage was 36.4% higher than that of the local check.

Summer squash Selection DS-8

2.1.11.5 Legumes

Garden pea. One hundred sixty genotypes and 90 new germplasm lines of garden pea, and 4 new lines of snappea were collected and multiplied.

Minor legumes. Twenty-six Faba bean germplasm lines are under field evaluation and multiplication. In dolichos bean, 10 new collections are under evaluation and multiplication. In cowpea, 48 new collections were multiplied and assessed for pod quality and disease resistance. Promising lines in these crops were identified for different traits.

2.1.11.6 Bulb crops

Onion and garlic. Eleven new germplasm lines comprising onion, multiplier onion, leek, and chives were evaluated and maintained. Thirty-five genotypes of garlic were evaluated and maintained.

2.1.11.7 Okra

One hundred fifty lines were evaluated for yield and YVMV resistance. Two hundred new germplasm lines received from NBPGR, New Delhi were evaluated for jassids, borer and YVMV resistance. Fifty-seven wild accessions of okra were assessed for biotic and YVMV stress resistance.

2.1.11.8 Lettuce

Seventy-five germplasm lines were collected from HRI, Wellesbourne, U.K.; CITH, Srinagar; IARI Regional Station, Katrain and other sources. These were evaluated during *rabi* season (2010-11), and promising selections are being advanced.

2.1.11.9 Minor leafy vegetables

Five germplasm lines of beet leaf and spinach, 2 of Swiss chard, 7 of *Chenopodium*, 3 lines of *Amaranthus* and 14 of *methi* were collected and evaluated.

2.1.12 Fruits

Fifty-one genotypes of grape, 28 of lime, 2 of lemon, one of sweet lime and 3 accessions of guava were collected and maintained.

Guava. The genotypes with red flesh, and red peel, white flesh with less seed/soft-seeds and dwarf statured types were collected from Uttar Pradesh and Punjab. In guava orchard at Todapur six trees were identified with red peel coloured fruits and their physico-chemical characters were analysed. These selections varied considerably for fruit size, weight and other characters like total soluble solids, titrable acidity and vitamin C content.

New guava genotypes

2.1.13 Ornamanetal crops

2.1.13.1 Rose

A total of 49 new varieties were collected, from NBPGR Regional Station, Shimla, out of which 15 different species were *Rosa tomentosa, Rosa dumalis, Rosa rubiginosa, Rosa lutea, Rosa banksiae, Rosa brunonii, Rosa indica major, Rosa bourboniana, Rosa rubrifolia, Rosa multiflora, Rosa agastria, Rosa wichuriana, Rosa moshchata, Rosa macrophylla* and *Rosa nitida.*

2.1.13.2 Gladiolus

Ten new cultivars were collected and added to the existing collection of 135 germplasm.

2.1.13.3 Marigold

Five genotypes of French marigold were added to the existing germplasm. Three male sterile lines of African marigold are being maintained for breeding programme.

2.1.13.4 Bougainvillea

Twenty-one new varieties were collected from NBRI, Lucknow for maintaining at National Bougainvillea Repository, IARI, New Delhi.

2.2 BIOSYSTEMATICS AND IDENTIFICATION SERVICES

2.2.1 *Herbarium Cryptogamae Indiae Orientalis* (HCIO)

Enrichment of repository of fungal biodiversity. Three hundred twenty-four specimens of fungal diseases of various groups were accessioned in HCIO raising the total number of specimens to 49,161. The four new species added towards fungal biodiversity were: *Corynespora bombacina*, *C. clerodendrigena*, *C. moracina* and *C. ficigena.*

2.2.2 Indian Type Culture Collection (ITCC)

Maintenance and new additions. About 3750 fungal cultures belonging to Mastigomycotina, Zygomycotina, Ascomycotina and Deuteromycotina were maintained at ITCC. The culture collection was further enriched with 45 different fungal cultures, including *Botryodiplodia theobromae, Collectotrichum sublineolum*, *Pestalotia gupini* and *Xylaria* sp.

Culture supply and identification services. Five hundred twenty authentic fungal cultures belonging to different groups, viz., Zygomycetes (58), Hyphomycetes (160), Ascomycetes (43), Penicilli (42), Aspergilli (63), Coelomycetes (34) and Fusaria (120) were supplied to various users. Besides, 340 cultures were identified up to species level.

Characterization of fungal species. Two rust species, viz., *Puccinia pimpinellae* and *P. chaerophylli* infecting the family *Umbeliferae* were morphologically described. Molecular markers such as RAPD, ITS and CoxI were found useful for species level identification or demarcation of *Aspergillus flavus, Capillosclerotium*, *Chaetomium, Copialongicollus gravillea, Fecundostilbum sacchari, Fusarium, Pestalotiopsis, Pestalotia, Polyrostrata indica, Proliferosphaera capsici,* and *Trichoderma virens.* CoxI was identified as a suitable marker for developing DNA barcode for *Fusarium* spp.

2.2.3 Insect Biosystematics

A world checklist of Hymenoptera associated with *Pieris* sp. was compiled. The checklist includes a total of 80 species under 32 genera acting as natural enemies, among which 56 species belonging to 19 genera, 8 families and 3 super families act as parasitoids; 5 species under 3 genera, 2 families and 2 super families act as predators; and 19 species under 10 genera, 5 families and 2 super families act as hyperparasites. More than 435 abstracts/full papers/references have been included and the checklist has further been augmented with the latest valid names and synonyms, host or alternate host, stage parasitized or predated on, locality or country, season incidence or bionomics and references.

Further taxonomic studies of 26 species under 13 important Indian genera of natural enemies, *viz*., *Brachymeria albotibialis, B. bengalensis, B. excarinata, B. femorata, B. inermis, B. lasus, Oomysus sokolowskii, Pteromalus puparum, Trichomalopsis apanteloctena, Trichogramma brassicae, Trichogramma chilonis , Trichogramma dendrolimi, Trichogramma embryophagum, Trichogramma pretiosum, Trichogramma evanescens, Cotesia ruficurus, C. glomerata, Campoletis chloridae, Diadegma fenestrale, Goryphus basilaris, Hyposoter ebeninus, Pimpla instigator, Eumenes petiolata, Eumenes dimidiatipennis, Polistes hebreus* and *Vespa orientalis* were undertaken.

In Hemiptera, a new species *Krisna pampadumparaensis* found in *Ficus exasperate* was collected from Pampadumpara, Kerala.

2.2.4 Nematode Biosystematics and Identification services

New Isolates of Steinernema* and *Heterorhabditis. Two new strains of *Steinernema,* one each from Tamil Nadu and Maharashtra were assigned to the genera *Steinernema* and *Heterorhabditis*. Morphological and molecular characterisation of two populations of *Heterorhabditis* from Gujarat and Meghalaya revealed their close resemblance with *H. bacteriophora* and *H. indica*, respectively**.**

Identification and documentation of nematode biodiversity in Himachal Pradesh and Wellington (Tamil Nadu). Root-knot nematode *Meloidogyne incognita* was found to be predominant on vegetables, while *Helicotylenchus* and *Hoplolaimus* were found to be predominant on wheat. *Scutellonema brachyurus* was identified from Wellington.

A survey of potato growing areas around Delhi and Hapur (Uttar Pradesh) revealed the presence of only ectoparasitic nematodes *Tylenchorhynchus, Helicotylenchus* and *Hoplolaimus* with 56%, 60% and 43% frequencies, respectively. These areas were absolutely free from any cyst nematode.

New nematode species. Two new species, viz., *Tylenchorhynchus bambusi* sp.n. and *Helicotylenchus raipurensis* sp.n. from the rhizosphere of rice in Raipur, Chhattisgarh were described and illustrated. Nematode Identification Aids in the form of a check list, a compendium and a dichotomous key to the 22 known species of *Siddiqi* was developed. A checklist of all the 114 species of *Tylenchorhynchus* (including 60 Indian species) along with their respective synonyms was developed.

The National Nematode Collection was maintained and augmented by the addition of 50 type slides comprising 74 females, 13 males and 5 juveniles belonging to 8 genera and 22 species, thus bringing the total Type Accessions up to 2303.

Nematode identification service. Altogether 230 nematode specimens of plant parasitic, free-living and entomopathogenic nematodes received from Chhattisgarh, Jammu & Kashmir, Delhi, Gujarat and Haryana were identified.

3. CROP AND RESOURCE MANAGEMENT AND ENVIRONMENT

Judicious management of various resources, such as crops, soil, water, nutrients, microbes, etc. is of paramount importance for sustaining productivity and protecting the environment. These resources have been under severe constraint due to their indiscriminate exploitation for the sole purpose of increasing productivity; thus resulting in declining factor productivity, poor soil health and other resource degradation problems. All these aspects need to be dealt in an integrated manner in a multidisciplinary mode for the development of appropriate agro-technologies while maintaining or enhancing the resource quality.

3.1 AGRONOMY

3.1.1 Green Manuring and Zinc Fertilization in *Basmati* Rice

In a field experiment conducted to study the effect of green manuring crops and zinc fertilizer sources on the productivity of rice cv. Pusa Basmati 1, the highest yield was recorded with the incorporation of *Sesbania aculeata*, which was superior to *Crotalaria juncea*, *Vigna unguiculata* and summer fallow. Green manuring increased the grain yield by 0.54 t to 1.39 t/ha. Zinc fertilization had a significant positive effect on the grain yield as well as harvest index. Application of EDTA–chelated Zn (12% Zn) recorded significantly higher yield and harvest index as compared to other Zn-applied treatments. It also resulted in higher Zn concentration in rough rice grain and its uptake, followed by $ZnSO_4.7H_2O$ (21% Zn).

Effect of green manuring and zinc fertilization on yield and harvest index of *Basmati* rice

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Green manuring			
Sesbania aculeata	5.87	10.39	36.1
Crotalaria juncea	5.29	10.02	34.5
Vigna unguiculata	5.02	9.75	34.0
Summer fallow	4.48	9.26	32.6
SEm±	0.03	0.11	0.17
CD (*P*=0.05)	0.10	0.48	0.52
Zn sources			
Control	4.41	9.01	32.9
$ZnSO_4.7H_2O$ (21% Zn)	5.35	10.23	34.3
$ZnSO_4.H_2O$ (33% Zn)	5.20	10.07	34.1
ZnO (82% Zn)	4.85	9.58	33.6
$ZnSO_4.7H_2O$ + ZnO (50% + 50%)	5.09	9.86	34.3
EDTA–chelated Zn (12%)	5.98	10.72	35.8
SEm±	0.08	0.27	0.18
CD (P=0.05)	0.23	0.78	0.53

3.1.2 Performance of Wheat as Influenced by Preceding Crops under Organic and Inorganic Nutrition

The effect of *kharif* crops, viz., maize, soybean, and maize + soybean was studied on the succeeding wheat crop grown with six nutrient levels, viz,. control, recommended dose of fertilizers (RDF), 75% recommended dose of nitrogen(RDN) through FYM, 75% RDN through vermicompost, 75% RDN through leaf manure, and 50% RDN through FYM + 50 % RDF. Wheat, preceded by soybean, produced significantly higher yields compared to that of other systems at all levels of nutrients. Significantly higher yield was also obtained with 50% of N equivalent applied through FYM + 50% RDF, which was on a par with that of 100% RDF. Root dry weight, root volume and root density, and residual soil fertility were relatively higher with 75% RDN equivalent through FYM, vermicompost or leaf manure. No significant differences were observed in maize-grain equivalent yield (MGEY) of soybean, and maize + soybean intercropping system. Significantly higher MGEY was recorded with FYM (50% N equivalent) + 50% RDF and FYM (75% N equivalent) compared to that of other treatments applied to previous wheat. Nutrients from organic sources and combination of inorganic and organic sources applied to wheat resulted in higher MGEY compared to that of the recommended dose of nutrients through fertilizers

and control. However, the residual fertility was the highest in sole crop of soybean > maize + soybean > sole maize.

During *kharif,* no significant differences were observed in maize grain equivalent yield from maize, soybean, and maize + soybean intercropping system. Significantly higher MGEY was recorded from FYM (50% N equivalent) + 50% RDF) compared to that of the remaining nutrient management treatments applied to previous wheat, except FYM (75% N equivalent), which was on a par with that of FYM (50% N equivalent) + 50% RDF. Nutrients from organic sources and combination of inorganic and organic sources applied to wheat resulted in higher MGEY compared to that of RDF and control. However, the residual fertility was highest in soybean, followed by intercrop and maize.

Maize-grain equivalent yield (t/ha) as influenced by nutrients applied to previous wheat

Nutrients applied to wheat	Soybean	Maize	Maize + soybean	Mean
Control	1.81	1.64	2.08	1.84
RDF (N,P,K)	2.29	2.22	2.55	2.35
FYM (75% N equivalent)	3.29	3.05	3.21	3.18
Vermicompost (75% N equivalent)	2.85	2.79	2.87	2.84
Leaf manure (75% N equivalent)	2.78	2.67	2.76	2.73
FYM (50% N equivalent) + 50% RDF	3.39	3.43	3.31	3.38
Mean	2.74	2.63	2.79	
	System	Nutrients	System x nutrients	
CD (P=0.05)	NS	0.37	0.51	

3.1.3 Agronomic Biofortification through Zinc Nutrition in Maize-Wheat Cropping System

The effect of four treatments of Zn, i.e., control (no Zn), soil applications @ 12.5 and 25.0 kg $ZnSO_4$/ha and foliar applications of 0.5% $ZnSO_4$ at flag leaf stage and one week after first spray, on the productivity and quality of maize PEHM 2 and wheat (DBW 17 and PBW 343) was studied in successive cropping seasons in *kharif* and *rabi* 2009-10. With zinc application the yield as well as nutrient and protein levels in grain were higher than those obtained with no Zn. The highest yield as well as protein and nutrient concentration in maize were recorded with 25 kg $ZnSO_4$/ha followed by 12.5 kg $ZnSO_4$/ha, and foliar application. In wheat, no significant differences were observed in yield and harvest index owing to Zn applied in preceding maize. Grain yield of wheat varieties significantly increased owing to direct application of 25 kg $ZnSO_4$/ha. Direct application of $ZnSO_4$ to wheat did not show any difference in protein content and pearling index but showed gluten strength with 25 kg $ZnSO_4$/ha. These parameters remained unaffected with $ZnSO_4$ applied in preceding maize. Concentrations of Fe, Zn, Cu and Mn in the grain were significantly higher due to soil application of $ZnSO_4$ in preceding maize and also due to directly applied $ZnSO_4$ in wheat. The variety PBW 343 contained higher amounts of Fe, Zn and Cu, but DBW 17 was superior in respect of Mn concentration.

Effect of $ZnSO_4$ application on yield and shelling of maize

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Shelling (%)
Control	2.03	2.52	77.5
12.5 kg $ZnSO_4$/ha (soil application)	2.41	3.16	80.9
25.0 kg $ZnSO_4$/ha (soil application)	2.63	3.68	82.7
Foliar spray of 0.5% $ZnSO_4$	2.14	3.08	79.3
CD (P=0.05)	NS	NS	NS

3.1.4 Winter Maize-based Cropping Systems for Enhanced Profitability under Different Fertility Levels

A comparative evaluation of the profitability of the sole crop of maize and its intercropping with fenugreek, potato and coriander was done. It was noticed that there was significant improvement in maize grain and potato tuber yields with increasing NPK levels from 150:65:65 kg to 187:81:81 kg/ha. Addition of FYM @ 10 t/ha with 150:65:65 kg/ha NPK also resulted in enhancement of maize and potato yields, while yields of fenugreek and coriander showed significant improvement with the application of NPK 187:81:81 kg/ha over 150:65:65 kg/ha. Productivity efficiency was maximum in maize+potato, followed by maize + fenugreek. However, net returns and B: C ratio were maximum in maize+ fenugreek cropping system.

3.1.5 Evaluation of Sweet Sorghum-based Cropping Systems

The effect of four N levels, viz., 0, 50, 100 and 150 kg/ha was evaluated on grain, fodder, sugar and bio-ethanol

Yields of maize and intercrops and total system productivity at different fertility levels

Treatment	Maize Grain yield (t/ha)	Intercrop yield			Production efficiency (kg/ha/day)	Net returns (x10³ ₹/ha)
		Fenugreek (t/ha)	Coriander (t/ha)	Potato (t/ha)		
Intercropping system						
Sole maize	6.03	-	-	-	37.68	46.99
Maize + fenugreek	5.96	6.75 (5.68)	-	-	72.75	95.47
Maize + potato	4.71	-	-	23.29 (9.80)	90.75	93.29
Maize + Coriander	5.34	-	8.18 (5.17)	-	65.56	84.86
CD (P=0.05)	0.66				3.41	
Fertility levels (N, P_2O_5, K_2O kg/ha)						
150:65:65	4.96	6.44 (5.42)	7.74 (4.89)	20.34 (8.56)	60.50	71.41
187:81:81	5.61	6.67 (5.61)	8.37 (5.28)	24.33 (10.24)	68.00	82.54
150:65:65+10t FYM /ha	5.97	7.15 (6.02)	8.44 (5.32)	25.21(10.61)	71.63	86.60
CD (P=0.05)	0.23	0.52	0.51	0.63	3.32	

Data in parentheses are maize-grain equivalent yield

production of two varieties, viz. RSSV 9 and SSV 84 and one hybrid CSH 22 SS of sweet sorghum. Results revealed that fodder yield (stripped fresh leaf), fresh biological yield and juice yield of sorghum improved significantly up to 150 kg N/ha, whereas spikelet weight, spikelet length, grain yield, cane yield and juice yield showed marked improvement only up to 100 kg N/ha. Among the genotypes, hybrid CSH 22 SS recorded significantly higher values of spikelet length and green fodder yield, grain yield, cane yield, juice and fermentable sugar, followed by RSSV 9 and SSV 84. Hybrid CSH 22 SS recorded the highest net returns (₹52,910/-), which were 31% and 55% higher than those of the varieties RSSV 9 and SSV 84, respectively. Sweet sorghum-wheat system was found significantly superior to sweet sorghum - chickpea / mustard cropping system.

Productivity of sweet sorghum genotypes under different levels of N

Treatment	Grain yield (t/ha)	Fodder yield (t/ha)	Cane yield (t/ha)	Expected ethanol yield (KL/ha)	Net returns (x10³ ₹/ha)
N levels (kg/ha)					
0	1.07	10.0	55.5	1.33	22.5
50	1.67	12.6	65.0	1.63	33.1
100	2.26	15.2	74.5	2.24	47.8
150	2.57	16.4	77.8	2.44	53.6
CD (P=0.05)	0.15	1.4	5.0	0.15	5.6
Genotypes					
RSSV 9	1.74	13.2	65.8	1.89	37.9
SSV 84	1.64	11.4	54.0	1.22	24.9
CSH 22 SS	2.32	16.0	84.8	2.62	55.0
CD (P=0.05)	0.10	1.7	4.0	0.11	0.53

3.1.6 Nutrient Management and Moisture Conservation under Rainfed Conditions

In a field experiment, three cropping systems (pearlmillet, clusterbean and pearlmillet + clusterbean) were evaluated under two moisture conservation practices (flat sowing + mulching and ridge and furrow), and four nutrient management practices (control, 100% RDF, leaf and cow-dung mixture compost @ 10 t/ha and leaf compost @ 10 t/ha). Results showed that pearlmillet + clusterbean intercropping system gave the highest pearlmillet-equivalent yield in comparison to sole pearlmillet and sole clusterbean. In terms of growth and yield, ridge and furrow-sown crops remained statistically on a par with flat sowing + mulching treatment. The highest productivity was recorded with leaf compost, followed by leaf and cow-dung mixture compost.

In a study on aquafertilization under rainfed conditions, *taramira* + lentil intercropping recorded significantly higher *taramira*-equivalent yield over the sole crop of *taramira.* Aqua-fertilization with 20,000 liters of water with 60 kg N + 40 kg P_2O_5/ha recorded the highest *taramira* equivalent yield. Consumptive use and water-use efficiency of *taramira* were also the highest under this treatment.

Effect of aqua–fertilization, intercropping system, and fertility levels on yield of *taramira* + lentil intercropping system

Treatment	*Taramira* equivalent yield (t/ha)	Consumptive use (mm/day)	WUE (kg/ha-mm)
Cropping system			
Taramira	1.42	212.5	6.68
Taramira + lentil	1.56	220.6	7.07
CD (P=0.05)	0.12		
Aqua-fertilization			
Dry sowing	1.34	210.2	6.43
15,000 liters water/ha	1.50	220.4	6.81
20,000 liters water/ha	1.63	225.6	7.23
CD (P=0.05)	0.14		
Fertility levels			
Control	1.31	206.4	6.34
30 kg N + 20 kg P_2O_5/ha	1.46	213.1	6.84
30 kg N + 20 kg P_2O_5/ha + PSB	1.54	222.2	6.93
60 kg N + 40 kg P_2O_5/ha	1.64	223.3	7.34
CD (P=0.05)	0.04		

In another study, intercropping of Ethiopian mustard + chickpea (1:4) gave significantly higher mustard-equivalent yield compared to that of sole mustard and sole chickpea. Application of 60 kg P_2O_5 + 30 kg S/ha gave significantly higher yield compared to that of the control and 30 kg P_2O_5/ha. Moisture conservation with FYM + organic mulch + kaolin spray 6% was found superior to no mulch.

Effect of moisture conservation and nutrient management on yield (t/ha) of Ethiopian mustard and chickpea intercropping system

	Ethiopian mustard	Chickpea	Mustard equivalent yield
Cropping system			
Sole mustard	2.04	-	2.08
Sole chickpea	-	1.03	1.57
Mustard + chickpea (1:4)	1.93	0.68	2.28
CD (P=0.05)	NS	0.09	0.16
Moisture conservation			
No mulch	1.94	0.83	1.92
FYM + organic mulch + kaolin 6%	2.03	0.94	2.18
CD (P=0.05)	0.16	0.07	0.16
Fertility levels			
Control	1.77	0.68	1.81
30 kg P_2O_5/ha	1.88	0.85	2.06
30 kg P_2O_5 + 15 kg S/ha	2.03	0.93	2.14
60 kg P_2O_5/ha	2.07	0.97	2.18
60 kg P_2O_5 + 30 kg S/ha	2.18	1.02	2.24
CD (P=0.05)	0.15	0.10	0.17

3.1.7 Water Economization in Potato and Cauliflower through Planting and Irrigation Methods

Planting of potato on flat-bed and irrigation in furrow recorded significantly higher tuber yield (31.8 t/ha). Consumptive use of water was less in this treatment (41.00 cm) and water-use efficiency was higher (778 kg/ha-cm) resulting in a saving of 13% water. Irrigation at 70 mm CPE recorded significantly higher tuber yield (31.5 t/ha). However, consumptive use of water was less in the treatment where irrigation was applied at 80 mm CPE (41.60 cm) and

water-use efficiency was higher (715 kg/ha-cm). Consumptive use of water was less with 4.0 cm irrigation depth (42.03 cm) with higher water-use efficiency (714 kg/ha-cm). Net returns (₹1,19,944/-) and B:C ratio (1.7) were higher when 6.0 cm irrigation was applied.

In a similar study on cauliflower, planting on flat-bed and irrigation in furrow recorded significantly higher curd yield (14.3 t/ha). Consumptive use of water was less in this treatment (14.18 cm) and water-use efficiency was higher (1007 kg/ha-cm), resulting in a saving of 18% water. Net returns (₹67,576/-) and B:C ratio (3.6) were also higher under this treatment. Irrigation at 25 mm CPE recorded significantly higher curd yield (14.3 t/ha). However, consumptive use of water was less in the treatment where irrigation was applied at 35 mm CPE (14.57 cm) with higher water-use efficiency (902 kg/ha-cm). Net returns (₹67,464/-) and B: C ratio (3.6) were higher under the treatment where irrigation was applied at 25 mm CPE. Irrigation depth of 6.0 cm irrigation recorded significantly higher curd yield (17.93 t/ha). However, consumptive use of water was less with 4.0 cm irrigation depth (13.62 cm) with higher water-use efficiency (916 kg/ha-cm). Net returns (₹71,484/-) and B:C ratio (3.8) were higher when 6.0 cm irrigation was applied.

Marketable yield and consumptive use of water of cauliflower as influenced by different treatments

Treatment	Marketable yield (t/ha)	Consumptive use of water (cm)	Water-use efficiency (kg/ha-cm)	Net returns ($x10^3$ ₹/ha)
Planting method				
Flat planting and irrigation	13.2	17.38	760	60.68
Furrows planting and irrigation in furrows	14.3	14.18	1007	67.57
CD (P=0.05)	0.67			
Irrigation regime				
35 mm CPE	13.2	14.57	902	60.32
25 mm CPE	14.3	16.98	844	67.46
CD (P=0.05)	0.67			
Irrigation depth				
4.0 cm	12.5	13.62	916	56.30
6.0 cm	15.0	17.93	837	71.48
CD (P=0.05)	0.67			

3.1.8 Conservation Agricultural Practices for Improving Productivity under Irrigated Ecosystem

In an experiment to compare the performance of conventional transplanted rice and direct-seeded rice cv. PRH 10 with and without *Sesbania* brown manuring, it was revealed that growth of rice was better under transplanted than direct-seeded conditions. Mixed-sown *Sesbania* with direct-seeded rice produced biomass of 10-12 t/ha (fresh weight) and 1.4-1.6 t/ha (dry weight) at 25 days of growth. Initial growth of rice plants was adversely affected because of mixed-sown *Sesbania* and the yields of grain and straw of rice were relatively lower than direct-seeded crop without *Sesbania*. Transplanted crop produced grain yield of 5.35-5.40 t/ha, which was 0.8-1.0 t/ha more than that of the direct-seeded crop. The decrease in yield was due to reduction in growth and yield attributes, particularly panicles/m^2, grains/panicle, panicle length and panicle weight.

In another experiment, the effects of tillage, method of sowing and residue management were studied in 3 major non-rice cropping systems, viz., maize-wheat, cotton-wheat and pigeonpea-wheat. The crops of maize cv. Maharaja, cotton cv. BG-II (Nikki) and pigeonpea cv. Pusa 992 were sown on 6th July, 30th May and 30th June, 2010, respectively under flat or raised-bed (narrow and broad) with or without wheat residue application. Among the three *kharif* crops, cotton was the best in terms of maize-equivalent yield, followed by pigeonpea and maize. Cotton gave almost two times more maize-equivalent yield than pigeonpea, and about three-times more than maize. Growing of all crops on broad-beds (140 cm, 2 rows) was superior to growing them on narrow-bed (70 cm, 1 row) ,and both these methods of sowing, were better than the conventional flat-sowing. The per cent increase in yield of maize, pigeonpea and cotton under broad-bed was 26.7-29.0, 28.3-34.4 and 34.8-39.6, respectively over that of flat sowing.

3.1.9 Feasibility of Double Cropping through Conservation Agriculture Practices under Rainfed Ecosystem

An experiment was initiated from *kharif* 2010 to evaluate different cropping systems with crop residue or *Leuceana* mulching under zero-till rainfed conditions. Three *kharif* crops, viz., pearlmillet cv. Pusa Composite 443, clusterbean cv. Pusa Navbahar and mungbean cv. Pusa Vishal

were sown with the onset of monsoons in the first fortnight of July, which were followed by three *rabi* crops, viz., mustard cv. Pusa Vijay, chickpea cv. BGD 72 and wheat cv. PBW 175 sown in the third week of October. Residues of previous wheat crop and fresh *Leuceana* twigs were applied at 10 t/ha after sowing of the *kharif* crops. Pearlmillet produced the maximum yield of 2.23 t/ha under *Leuceana* mulching, which was 28.9% and 54.8% more than that under wheat residue and no-residue conditions, respectively. Similarly, the green pod yield of clusterbean increased from 7.60 t/ha under no residue to 10.08 t/ha under *Leuceana* mulching. On the other hand, the seed yield of mungbean ranged from 0.75 to 0.92 t/ha, and was not influenced by the mulching treatments. Pearlmillet-equivalent yield was the highest in the case of clusterbean (4.31-5.72 t/ha), followed by mungbean (2.76-3.12 t/ha) and pearlmillet (1.44-2.23 t/ha). It was found that mulching with crop residue or *Leuceana* was beneficial for conserving soil moisture not only for the current crop of pearlmillet and clusterbean but also for the subsequent *rabi* crops of mustard, chickpea and wheat.

3.1.10 Tillage and Residue Management in Cotton-Wheat Cropping System

In a study initiated in 2008-09, the effects of different tillage and residue management practices were recorded on the performance of cotton and wheat, grown in a sequence. Treatments included combinations of conventional (CT) or zero tillage (ZT) on flat or raised-bed, without and with residues of wheat (5 t/ha), cotton (4 t/ha), and cotton + wheat. Seed cotton yield was 3.0-3.5 t/ha in the first cycle (2008), but was reduced to about half (1.5-2.0 t/ha) in the second cropping cycle (2009) owing to adverse weather conditions. In the third cycle (2010), the yields were moderate (2.2-2.6 t/ha) under conditions of high seasonal rainfall. Zero tillage was as good as conventional tillage for cotton when residues of both the crops were retained on the soil surface. Cotton sown on raised-bed resulted in significantly higher yield (8-20%) compared to that of flat sowing. Wheat yields were more stable in all cropping cycles, and were little affected by tillage. However, the yields were comparatively lower under raised bed planting (5-8%) than under flat-sown conditions.

Effect of tillage and residue management on the performance of cotton in the third cropping cycle (2010)

Treatment	Bolls/plant	Seed cotton yield (t/ha)	Stalk yield (t/ha)
Tillage			
CT-flat	32.5	2.28	4.88
CT-bed	32.4	2.59	4.88
ZT-flat	30.3	2.23	4.95
ZT-bed	32.7	2.65	4.43
CD (0.05)	NS	0.33	NS
Residue application			
No residue	31.4	2.13	4.28
Wheat residue	29.7	2.30	4.96
Cotton residue	33.6	2.59	4.63
Wheat + cotton residue	33.2	2.77	5.28
CD (P=0.05)	2.16	0.20	0.31

3.1.11 Validation of DSSAT Model in Simulating the Impact of Irrigation and Nitrogen in Chickpea

A field experiment was conducted during *rabi* 2009-10 to assess the impact of three irrigation regimes, viz., rainfed, irrigation at pre-flowering and irrigation at pre-flowering and pod formation stages and two N levels, viz., 0 and 20 kg/ha on chickpea cv. Pusa 372. The field observed data were simulated using DSSAT model. Results indicated significant increase in chickpea yield due to irrigation at flowering and pod formation stages. DSSAT model made a perfect simulation of rainfed crop (R^2= 0.91) and stress at pod formation stages (R^2= 0.89). In no-stress crop (3 irrigations), simulation was also reasonably good but exhibited a relatively lower correlation value (R^2= 0.82). The crop response to N fertilization was not marked (1.15 t/ha in no N and 1.21 t/ha in 20 kg N/ha).

3.1.12 Direct and Residual Effects of N on Wheat in Bt Cotton-Wheat System

An experiment was conducted on wheat to assess the residual effect of two Bt-cotton hybrids grown under 4 N levels, and direct effect of 4 N levels. Results indicated that the yield of wheat grown after two Bt cotton hybrids did not differ significantly. Wheat grown after cotton fertilized with 120 or 180 kg N/ha produced markedly higher grain yield compared to that of no-N and 60 kg N/ha fertilized cotton, indicating significant residual effects of N. Wheat responded to direct application of N up to 150 kg/ha. The system productivity of Bt-I cotton-wheat was markedly higher than

that of Bt-II cotton-wheat, and thus gave more net returns. The system productivity also increased significantly with each successive increase of N level to cotton up to 180 kg/ha.

3.1.13 FYM Enrichment and Biomass Utilization

A Biomass Utilization Unit was established in 2009-10 to supply good quality compost to different divisions / units of IARI. This Unit efficiently used waste biomass and crop residues from IARI farm and leaf litter of the trees for preparation of improved quality compost. During 2010-11, through effective coordination with the Divisions of Agronomy, Agricultural Engineering, Microbiology, Soil Science and Agricultural Chemistry, and cow dung supplying agencies, this Unit prepared about 4,000 t of good quality FYM and residue mixed compost . This saved a sizeable amount of money (approx. ₹15 lakhs), which was earlier spent for procurement of manure from outside agencies. A Turning and Mixing Machine and an FYM Loader were designed to mix and turn the unchopped residue with cow dung and microbial consortium. The entire Unit is now mechanized for processing and distribution of manure.

3.1.14 Studies on Tillage and Micronutrient Application in Wheat in Central India

A study at Regional Station, Indore showed that tillage did not cause significant variation in grain and biomass yields of wheat genotypes. Zero-tillage fetched the highest net returns (₹ 30,508/ha), followed by minimum tillage (₹ 29,738/ha) and conventional tillage (₹ 26,969/ha).

Another study showed that the application of 0.5 kg B/ha was on a par with the application of 1.0 kg B/ha, which recorded significantly higher grain yield compared to that of control.The application of 5 kg Zn/ha, being on a par with 10 kg Zn/ha (5.05 t/ha), recorded significantly higher grain yield (5.06 t/ha) over that of control (4.79 t/ha). *Durum* and bread wheat varieties did not differ significantly for grain and biomass yields.

3.1.15 Response of New Wheat Genotypes to Agronomic Management

In field experiments at Regional Station, Pusa, Bihar, none of the 3 new wheat genotypes, viz. , HD 2997, DBW 46 and RSP 561 was superior to HD 2967 in terms of yield under normal as well as late-sown conditions. Further, increasing the number of irrigations up to 5 enhanced the yield of HD 2997 significantly but DBW 46 and RSP 561 responded only up to three irrigations. Four new wheat genotypes, viz., DBW 51, DBW 52, NW 4035 and HI 1563 did not prove superior to the best checks under late-sown irrigated conditions. Under saline and alkali soil conditions, the new genotype, KRL 240 proved superior to the best check under heavy dose of N (150 kg N/ha) but was not better than the check (KRL 213) under lower level of N (120 kg N/ha).

3.1.16 Varietal Evaluation under Zero and Conventional Tillage Conditions

Twelve wheat varieties comprising seven for normal-sown and five for late-sown conditions, were tested under conventional as well as zero tillage. Under conventional tillage, with the crop sown on 9th December, 2009, the varieties identified were: DBW 39 (4.07 t /ha), HD 2733 (3.86 t/ha), PBW 373 (3.84 t/ha), HP 1731 (3.83 t/ha), WH 2045 (3.82 t/ha), HUW 468 (3.77 t/ha), HD 2824 (3.73 t/ha) and HP 1761 (3.69 t/ha). In zero tillage condition when the crop was sown on 14th December, 2009, the six varieties, viz., DBW 39 (2.66 t/ha), HD 2733 (2.56 t/ha), HP 1761 (2.54 t/ha), HD 2824 (2.44 t/ha), HP 1744 (2.3t t/ha) and HUW 468 (2.24 t/ha) gave better yield.

Significant response to biofertilizer seed treatment with *Azotobacter* and phosphorus solubilizing bacteria was seen on wheat yield under zero-till conditions but the response was more when these biofertilizers were applied along with 50% of recommended dose of chemical fertilizers.

3.1.17 Evaluation of Rice Breeding Lines and System of Rice Intensification

Eight newly-bred rice lines from RBGRC, IARI, Aduthurai were tested along with two local checks of similar duration at Pusa, Bihar. The mean maturity period of the entries ranged from 140 to150 days and the yield of all the lines was significantly better than that of the local checks. In particular, the lines ET 4 and ET 3 having a yield of 5.97t and 5.89 t/ha, respectively, gave 0.5 t/ha more yield than the check varieties, viz., Pusa 44 and Sweta. In almost drought like conditions during *kharif* 2010, the SRI method of rice cultivation did not show significant yield advantage over conventional cultivation.

3.2 SOIL MANAGEMENT

3.2.1 Phosphorus Transformation under Varying Tillage and Residue Management in Pigeonpea-Wheat Cropping System

A field experiment was conducted in a sandy loam soil (Typic Haplustept) to study the tillage and crop residue management on pigeonpea yield, P uptake, and P forms in rhizosphere and non-rhizosphere soils. The experiment was laid out in split-plot design in which tillage ,viz,. conventional tillage flat-bed (CT-F) and raised-bed (CT-B) and zero tillage flat-bed (ZT-F) and raised-bed (ZT-B) constituted the main plot, and residue management practices, viz., no residue (R_0), residues of both pigeonpea and wheat (Rp+w), residue of pigeonpea (Rp), and residue of wheat (Rw) constituted the sub-plot treatments. Pigeonpea grain yield was significantly higher when residues of both the crops were applied. Application of crop residues significantly increased the P uptake under CT and ZT over that of the tillage treatments without residue. Depletion in solution-P (0.05 *M* $CaCl_2$ extractable) content under all the treatments in rhizosphere soil indicated appreciable uptake from rhizosphere by plants as compared to non-rhizosphere soil. Olsen-P, solution-P and $NaHCO_3$-P of rhizosphere soil showed a significant positive relationship with total P uptake. Different P fractions in the soil indicated mobilization of inorganic-P in other forms of P. Residual-P fraction of both rhizosphere and non-rhizosphere soil was not affected and remained the same as initial content. Zero tillage significantly increased the organic P content of surface soil, whereas inorganic P content decreased. Higher content of all the P fractions was recorded in rhizosphere soil as compared to non-rhizosphere soil. The highest acid and alkaline phosphatase enzyme activities were found in ZT-B with Rp+w in rhizosphere soil as compared to non-rhizosphere soil.

3.2.2 Nanoclay Composite for Nutrient Management

Smectitic clay. Absorption bands in the range of 3400-3700 per cm were attributed to the stretching of –OH, 3700 due to structural OH and 3400 due to adsorbed water. The absorption band at 1641 per cm was attributed to –OH bending of H_2O, which indicated the presence of water in their structure. The absorption bands in the range of 970-450 per cm were attributed to –OH bending and/or M-O (M denotes Si or other metal cations existed in various clays). The vibration band observed at 1027 per cm was due to the Si-O stretching.

Hydrogel. The observed bands at 3439 per cm were due to N-H stretching of acrylamide unit, 2923 per cm due to the C-H stretching of acrylate unit, 1690 per cm due to carbonyl moiety of the acrylamide unit. The hydrolysis of amide group was confirmed by the appearance of absorption bands at 1558 per cm which were attributed to –COO.

Nanoclay composite. The shifting of absorption bands of –OH stretching of NCC in the range of 3440-3600 per cm to 3170-3000 per cm took place after the incorporation of various clays into the polymer network. This might be due to H-bonding between clay-OH and polymer NH group. Weakening of the absorption bands at about 1030 per cm due to Si-O of clays took place after the incorporation of various clays into the polymer network. The absorption band at 1690 per cm ascribed to –CO of polymer shifted to 1717 per cm in the spectra of polymer/clay, which indicated that the interaction between clays and polymer network had some influence on the chemical environment of –CO. This might have some influence on the physico-chemical properties of the corresponding nanoclay-polymer composites (NCPCs).

X ray diffraction analysis. The XRD pattern of nanoclay (line a) showed a strong peak at 2è = 7.0, which corresponded to a basal spacing of 12.6 Å, which was also found when clay was mixed physically with polymers (line b). After reaction, this peak disappeared in polymer/clay composites (line d) almost like that of pure hydrogel (line c). This happened because of the exfoliation of smectite into individual layer by the entering polymer into the inter-layer position, indicating a strong interaction between nano-smectitic clay with polymer.

3.2.3 Recovery of Added Nutrients by Conventional Fertilizer and Nanoclay Polymer Composite

In an incubation study of nanoclay polymer composite (NCPC) fertilizer, a significant increase was observed in cumulative N and P recovery from soils due to the addition of different NCPCs (T_1, T_2 and T_3) over conventional urea and DAP application in the long-run. At 35 days of incubation, the cumulative mineral N recovery ranged from 76.3 mg/kg soil under conventional urea (T_4) to 105.7 mg/kg soil under T_3 (NCPC III). The cumulative mineral N

recovery from soils receiving NCPC III was significantly higher compared to the soils receiving the other two NCPCs (I and II).

Effect of NCPC on cumulative mineral N recovery (mg/kg) in three different soils at 35 days

Treatment	Soils			Mean
	Alfisol	Inceptisol	Vertisol	
T_1: NCPC I	103.1	111.5	82.9	99.1
T_2: NCPC II	108.0	107.5	74.5	96.7
T_3: NCPC III	113.6	113.8	89.8	105.7
T_4: Urea (conventional)	79.6	79.5	69.9	76.3
Mean	101.0	103.1	79.3	
CD (P=0.05)	Treatment = 6.1	Soils = 5.4	Interaction = 10.4	

NCPC I, NCPC II and NCPC III represent NCPC synthesized from kaolinite, mica and smectite dominated clay, respectively

Cumulative P recovery after 35 days ranged from 3.87 mg/kg under conventional DAP application to 6.27 mg/kg under NCPC III. In this case also, the cumulative P recovery from the soils receiving NCPC III was significantly higher compared to the soils receiving the other two NCPCs (I and II).

Effect of NCPC on cumulative P recovery (mg/kg soil) in three different soils at 35 days

Treatment	Soils			Mean
	Alfisol	Inceptisol	Vertisol	
T_1: NCPC I	3.25	9.80	3.66	5.57
T_2: NCPC II	3.17	9.78	3.64	5.52
T_3: NCPC III	4.22	10.18	4.42	6.27
T_4: DAP (conventional)	1.13	8.33	2.16	3.87
Mean	2.94	9.52	3.47	
CD (P=0.05)	Treatment = 0.34	Soils = 0.28	Interaction = NS	

3.2.4 Effect of Nanocomposite Slow Release Fertilizer on Yield of Pearlmillet

Addition of fertilizer as NCPC and as conventional chemical fertilizer resulted in significantly higher yield of pearlmillet grown in all the three soils compared to that of control (6.8 g/pot). The highest biomass yield (31.2 g/pot) was recorded with higher dose of fertilizer as NCPC (T_2). Addition of N and P as NCPC at higher doses increased the biomass yield of pearlmillet by 45.1% over that of conventional fertilizer at the same dose. On the other hand, lower dose of NCPC increased the biomass yield by 48.3% over that obtained with lower dose of conventional fertilizer. The biomass yield of pearlmillet at lower dose of fertilizers as NCPC (T_3) (21.8 g/pot) remained statistically on a par with that obtained with higher dose of fertilizers (21.5 g/pot) as conventional form (T_4).

Biomass yield of pearlmillet (g/pot) as affected by fertilizer treatments in three different soils

Treatment	Soils			Mean
	Alfisol	Inceptisol	Vertisol	
T_1:Control	3.0	12.0	5.4	6.8
T_2:NCPC 60-40	27.7	36.8	29.0	31.2
T_3:NCPC 30-20	16.6	29.6	19.4	21.8
T_4:Urea-DAP 60-40	15.5	31.4	17.6	21.5
T_5:Urea-DAP 30-20	11.3	20.6	12.2	14.7
Mean	14.8	26.1	16.7	
CD (P = 0.05)	Treatment = 3.2	Soils = 2.5	Interaction = NS	

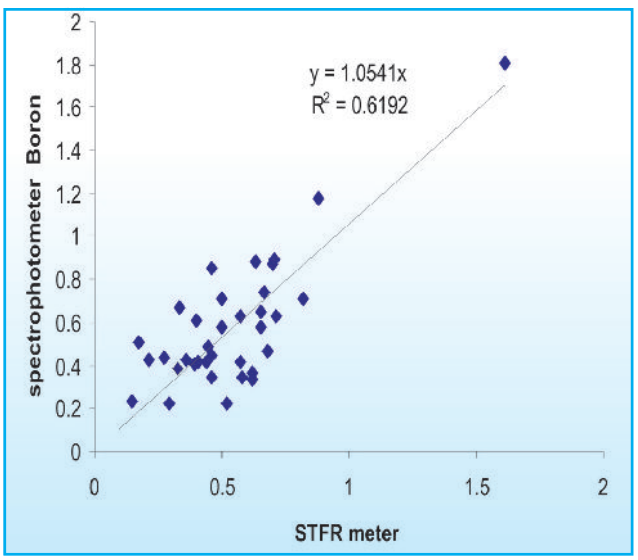
3.2.5 Impact of Temperature and Moisture Regimes on Nitrogen Mineralization

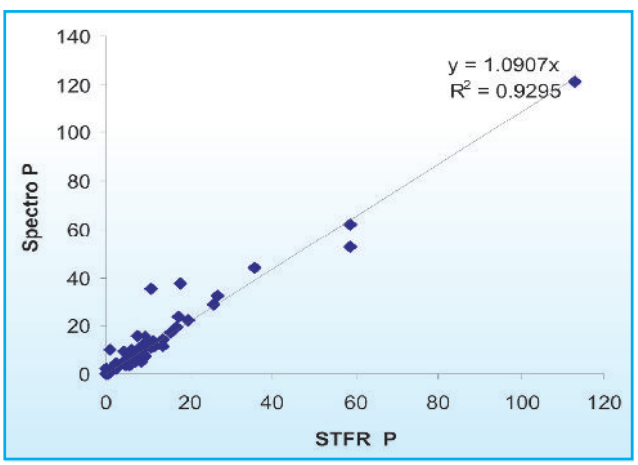
A laboratory incubation experiment was conducted to study the interactive effects of temperature and moisture regimes on N mineralization in an alluvial soil amended with urea and organic manures. Nitrogen was added @ 60 mg N/kg of soil through urea, FYM, *Sesbania*, rice and wheat residue, and also through integrated sources (urea and above-mentioned organic materials), where urea N was substituted by these organic materials to the extent of 25% and 50%. Incubation was carried out at two soil moisture regimes, viz., field capacity and 2.5 cm standing water, and two temperatures, viz., 20 °C and 35°C for 0, 1, 2, 4, 8, and 12 weeks. Results indicated that on an average, KCl extractable mineral N content in soils was significantly higher in the case of all the N sources compared to that of control, except 100% crop residue. By and large, among the organic and integrated sources, irrespective of the level of substitution of urea-N, FYM and *Sesbania* showed relatively higher values of extractable N as compared to crop residues. With increase in temperature from 20 to 35°C, mineral N content in soil decreased from 31.2 to 28.4 mg/kg and N content in soil across all the N sources during entire incubation period

decreased from 38.9 (field capacity) to 20.7 mg/kg (2.5 cm standing water). Thus, organic sources having lower C:N ratio released higher mineral N content as compared to organics having higher C:N ratio.

3.2.6 Digital Soil Test and Fertilizer Recommendation Meter (STFR)

An instrument called Digital Soil Test and Fertilizer Recommendation Meter (STFR) was developed by which soil testing for organic C, nitrate, P, K, S, Zn and B can be done quantitatively in field as well as in laboratory. Fertilizer recommendations can also be obtained for specific crop and target yield from this instrument, the performance of which was found to be satisfactory.





Relationship between STFR–measured nutrients and conventional method

3.2.7 Field Evaluation of Enriched Compost and Chemical Fertilizers in Wheat-Soybean Cropping System

A field experiment was carried out to determine the effect of enriched compost and chemical fertilizers applied as sole organic sources *vis-à-vis* balanced and integrated nutrient management in wheat-soybean cropping system. Eight treatments consisting of T_1: control; T_2: 100% RDF; T_3: ordinary compost @ 5 t/ha; T_4: enriched compost @ 5 t/ha; T_5: 50% RDF + ordinary compost @ 2.5 t/ha; T_6: 50% RDF + ordinary compost @ 5 t/ha; T_7: 50% RDF + enriched compost @ 2.5 t/ha; T_8: 50% RDF + enriched compost @ 5 t/ha were applied with three replications in a randomized block design. Wheat was grown during *rabi* season 2009-10 as the first crop and soybean was grown on residual fertility during *kharif* 2010. Recommended doses of NPK fertilizers (RDF) were applied to wheat. Results revealed that yields of wheat and soybean due to integrated use of enriched compost and chemical fertilizers increased significantly over that obtained with the application of ordinary compost as well as 100% RDF. Treatments receiving 100% RDF and 50% RDF + enriched compost @ 5 t/ha resulted in 23.1% and 37.2% additional grain yield of wheat, respectively over that of control. These treatments also resulted in 38.6% and 61.1% additional grain yield of soybean, respectively, over that of control. Soils amended with integrated use of enriched compost and chemical fertilizers significantly improved available P and K in soils, which resulted in higher uptake of P and K. It was concluded

Yield (t/ha) of wheat and soybean as affected by application of composts and chemical fertilizers

Treatment	Wheat		Soybean	
	Grain yield	Straw yield	Seed yield	Stover yield
T1	3.33	6.53	0.94	2.34
T2	4.10	8.30	1.30	2.94
T3	3.95	7.97	1.29	3.68
T4	4.12	7.50	1.27	3.70
T5	4.22	8.00	1.34	3.98
T6	4.25	8.42	1.35	4.22
T7	4.38	8.33	1.40	3.95
T8	4.58	8.97	1.52	4.33
CD (P=0.05)	0.422	1.38	0.096	0.440

that enriched compost using crop residues mixed with rock phosphate and waste mica could substitute 50% of chemical fertilizers.

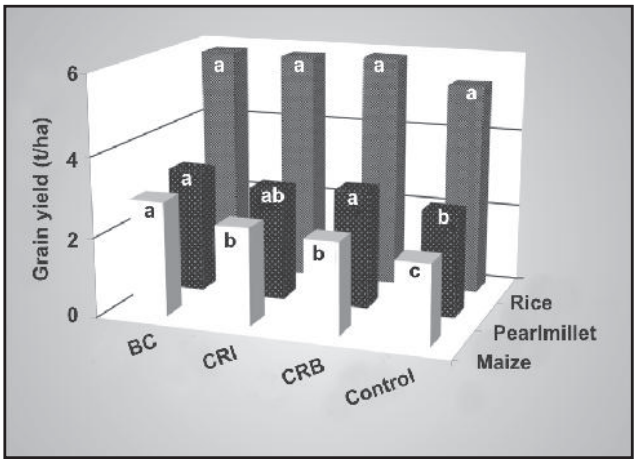
3.2.8 Effect of Biochar on Yield of Different Crops

A low-cost pyrolysis kiln was developed at the Institute for making biochar. The biochar prepared from the previous wheat crop at about 400°C was applied along with NPK fertilizers on succeeding maize (NPK::180:80:80), pearlmillet (NPK::100:40:40) and rice (NPK::120:60:60). Application of biochar (BC) prepared from wheat straw @ 1.9 t/ha along with the above recommended doses of NPK significantly increased the yield of maize, and this treatment was superior to either crop residue incorporation (CRI) or open crop residue burning (CRB) treatments. In the case of pearlmillet and rice, the yields with BC were on a par with those obtained either with CRI or CRB treatments. However, all the crop residue management treatments exhibited significantly higher yield of pearlmillet compared to that of control.

A low-cost pyrolysis kiln developed at IARI

3.2.9 Effect of Nanoparticles on Soil Organisms and their Activities

Effects of two types of metal oxide nanoparticles (ZnO and Fe_2O_3), and a carbon-based nanoparticle (fullerene, C60) on soil enzyme activities and microbial groups were assessed. The nanoparticles were incorporated in an inceptisol and a vertisol to give a final concentration of 0.066% (w/w) for ZnO and Fe_2O_3 nanoparticles, and 0.013% (w/w) for fullerene (C60) nanoparticles. Bacterial population was lower in soils treated with nanoparticles of ZnO than Fe_2O_3 or fullerene. The population of ammonia oxidizing bacteria was found to be higher in the case of ZnO and fullerene treated soils. Nanoparticles of Fe_2O_3 showed lower urease activity, whereas ZnO showed higher values. The behaviour of nanoparticles was found to be influenced by the type of soils and high temperature and pressure as prevalent during autoclaving.



Effect of wheat biochar on yield of maize, pearlmillet and rice

3.3 INTEGRATED NUTRIENT MANAGEMENT

3.3.1 Long -term Fertilizer Experiments

A long-term experiment established at IARI farm in 1971-72 was continued with maize-wheat cropping system. Ten treatments comprising sub-optimal (50% of recommended rate) to super-optimal (150% of recommended rate) NPK, fertilizer NP or N alone, NPK supplemented with FYM, S or Zn, and unfertilized-control were evaluated. Optimal (100% of recommended rate) NPK for maize or wheat was 120-26-33 kg N-P-K/ha. Farmyard manure @ 15 t/ha was applied to maize, and $ZnSO_4$ @ 10 kg/ha was applied to wheat each year.

Crop response to fertilizers. Analysis of long-term yield trends revealed an increasing significance of balanced

fertilizer use for sustaining crop productivity. The yield responses to P, K and S in maize and wheat were much greater during 2010-11 compared with the averaged response over the last 15 years. Application of 150% of recommended NPK over optimal (100% of recommended) NPK gave an additional yield of 0.53 t maize/ha and 0.83 t wheat/ha during 2010-11, whereas the corresponding average yield gain for the period from 1995-96 to 2009-10 was 0.35 t and 0.43 t/ha, respectively. Similarly, the yield gains owing to conjoint use of FYM and NPK increased with the passage of time because of the decline in soil health and inadequacy of recommended fertilizer rates. Such changes were more apparent in wheat as the yield responses in maize varied partly because of the adoption of high-yielding cultivar PEHM 5 over the erstwhile Ganga Safed 2. Nonetheless, results suggested for an upward revision of fertilizer recommendations to achieve high yield goals and minimize soil nutrient mining.

Mean and current yields of maize and wheat under different fertilizer options

Treatment	Maize yield (t/ha)		Wheat yield (t/ha)	
	Mean yield (15 yrs)	Current yield (2010)	Mean yield (15 yrs)	Current yield (2010-11)
50% NPK	1.77	2.40	3.91	3.69
NPK	2.18	3.21	4.50	4.75
150% NPK	2.53	3.75	4.93	5.58
NP	1.92	2.88	4.14	4.19
N	1.65	2.34	3.77	3.38
NPK+FYM	2.59	3.91	4.96	5.54
NPK+S	2.32	3.38	4.63	5.04
Unfertilized	1.17	1.55	2.37	2.10
CD (P=0.05)	-	0.39	-	0.31

Soil fertility status. Except for 50% NPK, N alone or unfertilized plots, soil organic C was either maintained at initial level (0.44%) or showed a build-up in different treatments. The highest organic C (0.56%) was recorded under NPK+FYM, followed by 0.47% under 150% NPK. Available P content under 150% NPK or NPK+ FYM was greater than that under other treatments. Available K content also varied in accordance with annual input as well as crop productivity levels, and was in the range of 183-287 kg/ha. Continuous skipping of K led to K mining from soil, and consequently available K under NP plots was significantly lower than that under N alone, and was comparable with that under unfertilized-control. DTPA-Zn was the highest under NPK + Zn, followed by NPK+FYM plots.

Economics. Balanced and adequate fertilization resulted in higher economic returns compared to unbalanced and inadequate fertilizer use. Among the fertilizer treatments, the lowest annual net returns (ANR) of ₹ 18,189/ha were obtained with N alone, whereas application of 100% recommended NPK produced ANR of ₹ 41,426/ha. The highest ANR of ₹ 54,509/ha was recorded with 150% NPK, which further established that: (i) the present fertilizer recommendations are no longer optimal for intensive cropping systems, and (ii) an enhancement in fertilizer input is economically viable. The annual net returns under NPK+FYM (₹ 42,822/ ha) were lower compared with 150% NPK owing to relatively higher cost of FYM.

Economics of fertilizer use options in maize-wheat system during 2010-11

Treatment	Cost of cultivation* ($x10^3$ ₹/ha)	Annual returns ($x10^3$ ₹/ha)	
		Gross	Net
50% NPK	49.37	72.24	22.87
NPK	51.90	93.33	41.43
150% NPK	54.43	108.94	54.51
NP	51.31	83.49	32.19
N	49.36	67.55	18.19
NPK+FYM	66.90	109.72	42.82
NPK+S	53.81	98.49	44.68
Unfertilized	46.84	42.85	- 3.99

* Inclusive of standard fixed and operational costs for maize and wheat

3.3.2 Enhancing N-use Efficiency in Pearlmillet-Wheat System

A field experiment on pearlmillet-wheat cropping system on a sandy loam Typic Haplustept showed that fertilizer N-use efficiency could be enhanced with modification of N application schedules. Instead of conventional 3-splits, i.e., basal dressing + 2 top dressings, the skipping of basal N for one additional top dressing resulted in substantial increase in agronomic efficiency and recovery efficiency of N in pearlmillet. It was also possible

to curtail 30-45 kg N/ha in pearlmillet or wheat with the use of organics, viz., FYM or sulphitation pressmud (SPM) at 10 t/ha or *Sesbania* green manuring.

3.3.3 Customization of Fertilizer Levels and Assessment of Soil Ecology

Site-specific customization of fertilizer levels was attempted for maximizing wheat yields and improving soil ecology. After harvest of maize crop (with no fertilization), soil samples were analyzed to assess the base levels of available nutrients. It was observed that the experimental site had 219 kg available N (low), 14 kg P (medium) and 183 kg K/ha (medium). With respect to the availability of micronutrients, except Fe (2.84 mg/kg), none was found to be deficient (1.17 mg Zn/kg, Cu 0.93 mg/kg, and Mn 6.41 mg/kg). Keeping in view the initial soil fertility, the levels of fertilizers for wheat cv. HD 2329 were adopted as 100% recommended doses of NPK (i.e. 120:60:40), 125% NPK, 150%NPK, 175% NPK and 200% NPK. Foliar application of 3% $FeSO_4$ was made thrice during the period of crop growth.

It was observed that fertilizer application above 150% NPK with or without Fe resulted in lodging of wheat towards maturity. Application of super-optimal K did not help the plant to withstand lodging. Soil samples obtained during wheat growth showed weak changes in organic C and several other biochemical indicators in response to different levels of fertilization. Organic C content varied narrowly in the range of 0.23-0.30% in soils at tillering stage, 0.4-0.7% at flowering and declined to around 0.28% at maturity. Increase in organic C at flowering stage seemed to be a transient phenomenon possibly due to high activity of root growth and release of readily oxidizable root mucigels and exudates. Activity of soil enzymes, e.g., dehydrogenase, urease, and nitrate reductase, showed no uniform trend. At CRI stage, dehydrogenase activity was almost similar (0.7-0.8 µg TPF/g soil/h). Urease activity was found to have a negative trend with increasing NPK. In contrast, nitrate reductase activity showed a positive response with increasing NPK levels.

3.3.4 Effect of Sewage Sludge on Wheat Yield and Soil Properties

Sewage sludge @ 2.5 t, 5 t, and 10 t/ha alone and along with 50% NPK was applied to wheat cv. HD 2687. Significant increase in wheat yield was observed with sewage sludge treatments over that of control. The highest yield was obtained in recommended dose of NPK, followed by that in sewage sludge @ 10 t/ha + 50% NPK, which was on a par with that obtained in sewage sludge @ 5 t/ha + 50% NPK. Application of 50% recommended dose of NPK yielded on a par with that yielded by sewage sludge @ 2.5 t/ha + 50% NPK, which showed that a lower dose of sewage sludge alone or along with NPK was not sufficient to increase the yield. The soil pH did not differ significantly among the treatments, except in T_6, which recorded significantly lower values. Application of sewage sludge along with 50% NPK improved available N significantly. The available P was

Effect of sewage sludge on wheat yield and soil properties after harvest

Treatment	Yield (t/ha)	Soil properties			
		pH	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1: Control	2.74	7.8	270	12.8	184
T_2: Recommended dose of NPK (100%)	4.83	7.6	250	17.8	210
T_3: 50% RDF	4.05	7.7	267	14.0	190
T_4: Sewage sludge @ 2.5 t/ha	2.69	7.5	275	13.2	188
T_5: Sewage sludge @ 5 t/ha	3.12	7.6	280	14.6	218
T_6: Sewage sludge @10 t/ha	3.14	7.3	310	13.2	215
T_7: Sewage sludge @ 2.5 t/ha + 50% RDF	4.07	7.4	300	14.8	190
T_8: Sewage sludge @ 5 t/ha + 50% RDF	4.39	7.4	290	15.6	220
T_9: Sewage sludge @ 10 t/ha + 50% RDF	4.55	7.5	286	16.2	210
CD (P = 0.05)	0.21	0.4	15.6	0.18	11.6

significantly higher in all treatments compared to that of control but available K in control was on a par with T_3, T_4 and T_7. Application of sewage sludge @ 10 t/ha along with 50% RDF not only increased the yield but also improved soil available nutrients thereby saving 50% NPK fertilizers.

3.3.5 Improvement of Nitrogen-use Efficiency through Soil and Plant Processes Diagnostics

Studies revealed a relatively higher ammonia content than nitrate in soil samples collected from spots having *Brachiaria humidicola* growth in IARI farm. There was a distinct higher concentration of ammonia on locations with proliferating *Brachiaria humidicola* pasture grass compared to that in the adjacent soils without grass. The effect of root extracts of *Brachiaria humidicola* on nitrification inhibition in different soils in laboratory incubation studies showed that the root extract with 70% ethyl alcohol inhibited nitrification in soil to the extent of 90% for three weeks and with 5 units of extract, the inhibition was 100% for a month. Application of different amounts of 70% alcohol extract to soil showed a linear increase in per cent inhibition of nitrification, and with 5 ml extract application, the nitrification inhibition was nearly 100% for four weeks in alluvial soil. The fertilizer N-use efficiency in rice with the application of 70% alcohol and buffer extracts of roots of *Brachiaria humidicola* was nearly 21% higher (53% NUE) than that under no application (32% NUE). The SPAD index at maximum tillering stage of rice was linearly related with grain yield at harvest. A build-up of ammonia concentration in field air at a height of 1.5 m from ground surface was observed from about 46 µg/m^3 to 265 µg/m^3 during mid-November to mid-December and up to 855 µg/m^3 during mid-December 2010 to mid-February 2011. The higher ammonia concentration in air was associated with longer smoggy days.

3.4 WATER MANAGEMENT

3.4.1 Rainwater Harvesting

A master plan was drawn up to work out rainwater harvesting at IARI farm based on a study of the rainfall pattern during the last 35 years and single day rainfall events, which produce runoff. The average rainfall at IARI farm for the last 35 years is 720.8 mm. During this period, 17 years had rains above average. As per estimates, about 56.3 ha-m of runoff is generated at IARI farm, which can be utilized for rainwater harvesting. As there is a natural slope from north, east and southern sides of the campus towards the west, there will be a tendency of natural flow of the runoff from all these sides towards the west. Four major drainage channels transmit the excess runoff to the drain.

Since the quality of water in the aquifers beneath the proposed site for recharge pond was found to be within acceptable limit, artificial recharge of these aquifers with rainwater would further ensure delivery of water within the acceptable quality. This exercise would bridge about 10% of the gap between the total demand and supply at IARI.

3.4.1.1 Rainwater harvesting system for open-field and protected cultivation

A rainwater harvesting system in the form of 3000 m^3 lined reservoir, 1500 m^3 unlined reservoir and 10,000 m^3 recharge field was designed and installed for 10 ha catchment area at CPCT farm. The total rainwater harvested during the monsoon season (July-September) was 630 lakh liters, of which, 450 lakh liters was recharged as ground water and the remaining 180 lakh liters was used for drip fertigation of open field and greenhouse grown with different horticultural crops.

Geomembrane sheet lined water reservoir

Geomembrane sheet covered with bricks

Analysis of installation costs for different types of rainwater harvesting reservoirs

Type of reservoir	Cost of installation (₹/liter)	Estimated life (years)	Use
Lined	3.50	50-60	Storage and reuse in crops
Unlined	0.10	10-15	Storage and ground water recharge
Unlined with geo-membrane sheet and brick lining	0.35	25-30	Storage and reuse in crops

3.4.1.2 Ground water quality and quantity enhancement due to ongoing water harvesting techniques

Groundwater quality and quantity enhancement of the several ongoing water harvesting techniques designed and installed at the project farm of CPCT, IARI were studied. The ground water quantity was measured and the quality checked through the depth of water table and Ec-pH index, respectively.

Ground water quality and quantity estimation at different sites around the project farm

Site selected	Depth of water table (m)	EC (dS/m)	pH
Near the reservoir	17	1.30	7.6
NASC complex	18	3.90	7.4
Project orchard	18.5	2.80	7.5

3.4.2 Research on Climate Change

3.4.2.1 Climatic parameters, reference evapo-transpiration (ET_0) and crop water requirements (ETc)

ET_0 and ETc of pigeonpea, pearlmillet and rapeseed were estimated using CROPWAT package of FAO with the observed data at Palam and IARI . Data of about three decades were used to examine the trend of ET_0 and ETc. Analysis revealed that ET_0 and ET_c exhibited declining trend in both the cases if estimated with prevailing values of all the climatic parameters. However, the estimated values were slightly higher for Palam than for IARI. Therefore, it would not be appropriate to evaluate the impact of climate change on crop water requirement in terms of rise of temperature only.

3.4.2.2 Water resource characterization and identification of climatic risk for Dhar District

Water resources in the Dhar district could be divided in to major sources: tube well (48%), wells (25%), canals (5%), ponds (4%) and others (18%). Water related risks and problems with respect to climate change were identified and suitable mitigation measures planned. These risks were: (i) shortage of irrigation water availability in Nalcha block after December, and (ii) over-exploited zone for groundwater in Nalcha, Manawar and Badnawar blocks, and falling water tables in Nalcha, Manawar, Sardarpur and Badnawar blocks.

3.4.2.3 Environment monitoring and estimation of water requirement inside a polyhouse through internet

A study was undertaken on the effect of climatic variability on evapotranspiration and schedule of irrigation of drip-irrigated Capsicum in a naturally ventilated polyhouse by the use of web-enabled automatic weather station. Web-enabled automatic weather station having sensors for real time online measurement of soil temperature, soil moisture, ambient temperature, humidity, leaf wetness and solar insolation was installed inside the polyhouse. The system was also equipped with transmission of process parameters, including SMS on a mobile phone. *Capsicum* was transplanted inside the polyhouse and crop evapotranspiration was estimated. The concept encompasses data acquisition through a sensor network, data storage, post-processing and online transmission of data to multiple users logged on to web-browsers. It was concluded that the total crop water requirement of *Capsicum* inside a polyhouse was about 20-40% less than that outside the polyhouse.

Polyhouse having web-enabled automatic weather station with *Capsicum* crop

Total water requirement of *Capsicum* at various crop growth stages

Stage	Days after transplanting		ET_c, mm/day		Saving in ETc in the polyhouse (%)
	Outside	Inside	Outside	Inside	
Initial	0-25	0-30	1.20	0.72	40.0
Development	26-55	31-65	2.45	1.85	24.3
Middle	56-95	66-150	5.03	3.50	30.4
Maturity	96-120	150-220	4.58	2.40	47.6

3.4.3 Irrigation Water Management

3.4.3.1 Estimation of crop coefficients and effective rainfall for enhancing water-use efficiency of maize

An experiment was conducted on a set of two weighing-type lysimeters of 1.3 m × 1.3 m surface area and 1 m depth, with maize cv. HQPM-1 during *kharif* 2010 to measure the hourly evapotranspiration. The K_c values for four major and distinct crop growth stages, viz., initial (1 to 20 DAS), development (21 to 45 DAS), mid-season (46 to 80 DAS) and late season (81 to 105 DAS) were calculated to be 0.55, 1.35, 1.23 and 0.75, respectively. The observed crop coefficient values from the lysimeter could be used for scheduling irrigation at IARI farm in particular, and semi-arid regions of northern India in general.

3.4.3.2 Effect of planting method on yield of maize-based cropping system

Yield performance of maize and groundnut on ridge planting was superior to that on flat planting, irrespective of the cropping system under both rainfed and irrigated conditions. Similarly, irrigation given at grain formation and dough stages produced higher yield as compared to that obtained under rainfed conditions. However, the response to irrigation was more pronounced in groundnut than in maize. Maize-equivalent yields were higher under intercropping compared to those under sole cropping. Water-use efficiency of the system was higher under intercropping compared to that under sole crop because of the additional yields of the intercrop without irrigation.

3.4.3.3 Nutrient and irrigation management in soybean-wheat cropping system

Phosphorus application significantly influenced the growth, nodulation, yield attributes and yield of soybean over those of control. Incorporation of crop residue had a significant effect on wheat yield, irrespective of irrigation schedule as compared to that under residue removal. However, the response to residue management was more under assured irrigation water supply than under limited supply situation. Irrigation regimes had a significant effect on the grain yield of wheat under both residue incorporation and residue removal of previous crop. Nevertheless, it was found that 2 irrigations applied at CRI and flowering gave significantly less yield as compared to 5 irrigations applied at critical stages or based on soil moisture depletion and IW : CPE ratio of 0.9.

3.4.3.4 Nitrogen-use efficiency and yield of maize under deficit irrigation

Nitrogen-use efficiency in maize crop with different levels of N under varying irrigation levels was estimated during *kharif* 2010. The irrigation regimes were: water application at 0 (W1), 50 (W2), 75 (W3) and 100% (W4) soil moisture deficit (SMD); while the N levels were: 0 (N1), 75 (N2), 150 (N3) and 225 (N4) kg/ha. It was observed that varying N rates affected the grain yield and NUE for N2 and N3 (75 kg and 150 kg N/ha). However, the differences in yield and NUE were non-significant for N3 and N4 treatments. Maximum grain yield of 6.05 t/ha was obtained at full irrigation (W4) with 225 kg N/ha (N4). Maximum NUE was obtained for W4N3 treatment combination with 10.2 kg grain/kg N. The results also showed that increasing N levels under full irrigation reduced the N-use efficiency. The NUE decreased with increasing N level beyond N3 (150 kg/ha).

3.4.3.5 Application of poor quality water through micro-irrigation

Experiments were conducted to study the effect of waste water reuse through micro-irrigation on crop yield, soil quality and system performance, and use of saline water in cotton. The waste water was treated through 3 different types of filtration processes, viz., media type, disk type and combined media and disk type filters. All the filtration processes significantly ($P<0.001$) reduced both total coliforms and *E. coli* population by 12-20% and 15-25%, respectively, as observed against their populations in untreated waste water. Maximum cauliflower yields of 62.0 t, 61.4 t, and 61.1 t/ha were observed with waste water under surface and sub-surface drip at 15 cm and 30 cm depths of placement of drip laterals, respectively. The data revealed that 5% more yield was recorded under waste use with savings of 28.3%, 21.1%, and 38.3% of N, P_2O_5, and K_2O, respectively, compared to that under ground water use. However, waste water-produced vegetables cannot be

Application of domestic waste water in cauliflower

consumed raw because of the presence of *E. coli* and coliforms. The concentration of all heavy metals found in cauliflower was lower than their permissible limit as prescribed by FAO/WHO and Indian standards.

Saline treatments were imposed in cotton by irrigating with water that was salinized with NaCl : $CaCl_2$. The electrical conductivity of the irrigation water was 1.5 (control), 5.0, 8.0 and 11.0 dS/m. Three types of drip system were: surface drip, and sub-surface drips (depths of placement at 15 cm and 30 cm). Increasing soil salinity from 1.5 to 11.0 dS/m reduced the yield significantly to the tune of 30.0%, 44.8% and 50.7% in surface and sub-surface drip laterals placed at 15 cm and 30 cm depth, respectively. Saline water can be used for irrigation of crop which is not possible through conventional method of irrigation.

Effect of saline water and lateral depth on cotton yield and yield components

Treatment	Yield (t/ha)	Earliness (%)	Boll weight (g)	No. of bolls/plant
Year				
2009	1.99 [a]	41.5 [a]	4.09 [a]	36.6 [b]
2010	1.79 [a]	45.5	3.83 [b]	40.9 [a]
Salinity				
Ec_1=GW	1.93 [a]	46.3 [a]	3.99 [a]	43.7 [a]
EC_2=5 dS/m	2.18 [a]	44.2 [a]	4.06 [a]	42.8 [a]
EC_3=8 dS/m	2.14 [a]	43.1 [a]	4.02 [a]	39.9 [a]
EC_4=11 dS/m	1.30 [b]	40.3 [a]	3.77 [a]	28.6 [a]
Dripper depth				
D1=0 cm	1.89 [a]	43.1 [a]	4.01 [a]	38.2 [a]
D2=15 cm	1.91 [a]	45.2 [a]	3.97 [a]	40.1 [a]
D3=30 cm	1.85 [a]	42.2 [a]	3.91 [a]	38.0 [a]
CV (%)	16.4	14.5	8.6	19.1

Data with the same letters in each column and treatment do not have significant difference

Application of saline water through sub-surface drip in cotton

3.4.3.6 Saline water irrigation, root zone salinity and maize yield

Salinity in root zone increases owing to waterlogging conditions, and irrigation with saline groundwater in non-waterlogged areas. Field experiments with three levels of irrigation water salinity (existing tube well water, 2 dS/m and 4 dS/m) and three maize varieties (PEHM 2, PEHM 5 and HPQM1) were conducted to evaluate the effect of saline water irrigation on root zone salinity. Average root zone salinity in the beginning and end of the growing season was 0.84 dS/m and 0.25 dS/m, respectively.

3.4.4 Groundwater Studies

3.4.4.1 Prediction of nitrate-N leaching to the groundwater

Nitrate leaching to the groundwater of IARI farm was studied by using the Hydrus1-D model. The model was simulated for the experimental blocks under rice-wheat and maize-wheat cropping systems. Under irrigated condition, the model parameters were calibrated up to 120 cm depth (0-30, 30-60, 60-90, and 90-120 cm) by using the observed data of moisture and soil nitrate content of one cropping season. Further, the model was validated using the primary data of cropping systems of two more seasons. The simulations for soil water movement showed that the water was moving up to 180 cm beyond the crop root zone during *rabi* season and up to 270 cm during *kharif* season. Similarly, the nitrate movement in the vadose zone was up to 180 cm both during *rabi* and *kharif* seasons. The nitrate leaching below 120, 150 and 180 cm depths under wheat crop was 22.7 kg, 21.0 kg and 10.8 kg/ha, respectively, whereas under maize it was 25.1 kg, 24.2 kg and 16 kg/ha, respectively. In rice, nitrate leaching below 120 cm was observed to be the highest (28.5 kg/ha). Nitrogen leaching increased with the increase in fertilizer doses and decreased with the increase in the depth of soil profile below the root zone. The percentage increase of optimum fertilizer dose and N leaching below different depths for rice, wheat and maize crops were fitted by second order polynomial equation (R^2 = 0.99). The fitted polynomial equation can be used for generation of N-leaching scenarios pertaining

to varying fertilizer doses exceeding the recommended dose for different crops.

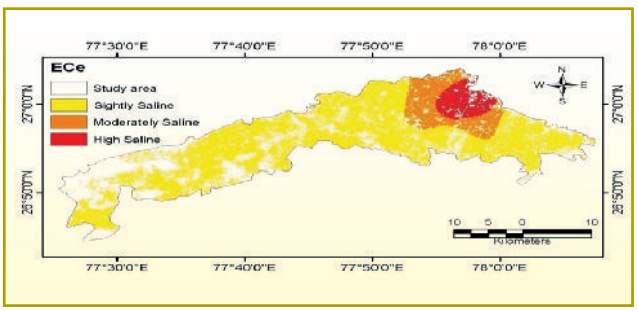
3.4.5 Application of GIS and Remote Sensing in Watershed Management

3.4.5.1 Estimation of silt yield index and sub-watershed prioritization by the use of RS and GIS

A highly degraded watershed was identified in the Dhassan-Betwa river catchment in Bundelkhand region following the post-project evaluation of 98 IWDP watersheds. Various data sources (field surveys, RS and GIS analysis) were utilized for delineation of 29 micro-watersheds (MWS), land use and land cover, slope and drainage area mapping. Sediment yield index (SYI), mean annual runoff, and watershed prioritization were the main objectives of the study. The SYI from 29 micro-watersheds was quantified from the sub-watershed No. 2C2F4 (AISLUS, 1990)/ (media sub-watershed) in Bina river catchment - a tributary of Dhasan and Betwa rivers (with land area of 1040 km^2) by using hydrologic modeling, RS and GIS. The media sub-watershed, the largest one of the four such watersheds in Bina river catchment, was delineated into 29 micro-watersheds and watershed prioritization was attempted based on the SYI. The 29 micro-watersheds were categorized into four categories of very high (3 MWS), high (4 MWS), moderate (15 MWS) and low (7 MWS) soil erosion index. It was concluded that the first priority for treatment should be given to the MWS having the highest SYI, while there were opportunities for restoration of nearly 21 micro-watersheds if timely soil and water conservation measures are taken.

3.4.5.2 Development of guidelines for integrated planning and management of irrigation and drainage systems

Based on IRS-P6 LISS III satellite data of three dates, viz., February, May and October 2009, mapping of land degradation and land use/land cover was done using remote sensing and GIS for 80,000 ha area of Kheragarh tehsil of Agra district, U.P. Three remote sensing derived indices, such as normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and soil brightness index (SBI) were used for identifying vegetation, waterlogged area and salt-affected land, respectively. Decision Tree Classifier (DTC) incorporated these derived indices for delineating and mapping different types of degradation. Severely salt-affected area was found to be 3248 ha (6.9%), while moderately saline area was 6534 ha (13.8%). Also, the area with ESP greater than 15% was 7793 ha (16.4%). The study suggests that these degraded areas could be reclaimed by a blend of both chemical amendments (gypsum) and sub-surface land drainage technology.



Spatial variability of ECe in the study area

3.4.5.3 Generation of digital database of canal commands and delineation of low productivity areas by the use of geospatial tools

The digital database was created for major distributaries under Western Yamuna Canal Commands (WYCC) of Haryana and the areas under different land uses were delineated using RS images. As observed from the generated map and digital data base of the WYCC, Jhajjar district is fed by branch and sub-branch canals having length of 57.1 km, distributaries of 60.4 km length, and minor canals and water courses spanning a length of 1405 km. It was observed from the analyzed land use map (derived from satellite imagery December 2008, IRS P-6) of the study area that the area under lakes, ponds and canals was 56.63 km^2 and agricultural land was 123.8 km^2. The normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and normalized difference salinity index (NDSI) were used to delineate the zones of low productivity in the study area. Further, the geo-processing operation was undertaken to integrate different feature classes and generate an attribute table filled with all the database of canal command for subsequent linkage with models for the development of a spatial DSS for enhancing agricultural productivity.

3.4.6 Micro-irrigation Studies

3.4.6.1 Water management through micro-irrigation under deficit irrigation

A field experiment was conducted to study the effect of water stress in onion. The onion cv. Pusa Red gave optimum yield under deficit water supply situations. Under water stress

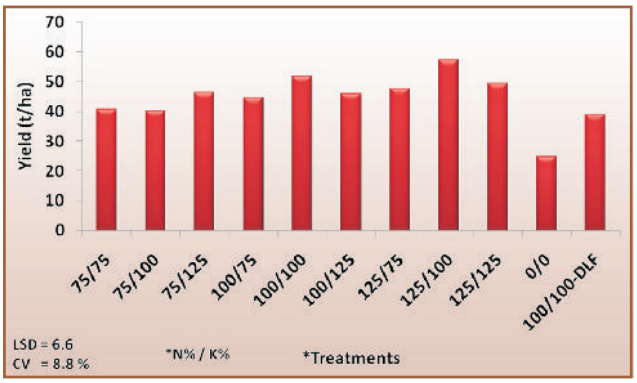
up to 60% at maturity stage, the crop gave a yield of 39.2 t/ha. Maximum water-use efficiency 85.50 kg/m^3 was obtained through drip irrigation under deficit irrigation. Average water requirement of *rabi* season onion (October to May) was 60 cm with an average productivity of 10.38 t/ha. The productivity can be enhanced from 10.8 to 28.1 t/ha with a saving of 27.2 cm of water with sub-surface drip system. This saving of water is sufficient to irrigate 0.5 ha additional area of onion.

Another experiment was conducted on potato var. Kufri Badsah to study the effect of different levels of irrigation water and their frequency on potato yield and quality. Optimal or no-stress irrigation was calculated as the net amount of irrigation required to refill the soil moisture deficit with daily application of irrigation water. Water requirement of the potato was estimated to be 26.8 cm. Maximum potato yield (52 t/ha) was obtained under alternate day irrigation. Maximum specific gravity (1.08) and dry matter (18.4%) were observed with biweekly and weekly irrigation with 40% water deficit. Simulation was done by using FAO AquaCrop model to predict crop productivity, water requirement and water-use efficiency of potato crop under micro irrigation during 2008-09 and 2009-10 under variable water supply and irrigation frequency conditions. The model performed satisfactorily in water stress and non-water stress treatments.

Potato experiments under deficit irrigation

3.4.6.2 Fertigation study in sweet pepper

A study was done on nutrient distribution in soil and the economics of production of sweet pepper in low cost naturally ventilated greenhouse. Fertilizer was applied through fertigation as per the treatment every week. The N, P and K requirements were 320 kg, 150 kg and 360 kg/ha, respectively, under fertigated greenhouse. The results of seven harvests showed that application of 100% N with 125% K produced the highest yield (57.3 t/ha), which was on a par with that of 100% N/100% K (51.9 t/ha). It was followed by 125% N/75% K (47.7 t/ha), 75% N/125% K (46.3 t/ha) and 100% N/125% K (45.8 t/ha). The lowest yield (24.8 t/ha) was in no application of N and K. The yield from dry liquid fertilizer (DLF), 100% N/100% K was 38.9 t/ha, which was on a par with that of 100% N/75% K (44.5 t/ha), 75% N/75% K (40.6 t/ha) and 75% N/100% K (40.2 t/ha).



Sweet pepper yield with different fertigation treatments

3.4.6.3 Nitrogen management in garlic cultivation under drip irrigation

A field experiment was carried out during 2008-2010 to study the response of garlic to four N levels in the basins of 4 m x 3 m size. Drip irrigation system was laid out with 60 cm lateral to lateral spacing and 50 cm emitter spacing. Soil and plant samples were collected periodically before and after fertigation. Field data were used for calibration and validation of HYDRUS–2D simulation model. Simulations were carried out for five soil types and three fertigation levels with an emitter discharge range of 1-4 l/h. A total of 45 scenarios were set for the study. Results revealed that emitter discharge rate did not affect N distribution in sandy-clay loam and loam soils. Application of 80 kg N/ha provided the best distribution in all soils. More N leaching was observed with 4 l/h emitter discharge rate in the sandy loam soil with fertigation of 120 kg N/ha. The optimum physical condition for N distribution was suggested to be medium-textured soil (like sandy-clay loam and loam) for an emitter discharge of 2.5 l/h.

3.5 ORCHARD MANAGEMENT

3.5.1 Effect of Arbuscular Mycorrhiza Fungi and Helper Bacteria in Lemon

In lemon cv. Kagzi Kalan, different combinations of biofertilisers were repeated to improve plant performance. *Glomus intraradices* along with *Azotobacter* + PSB showed

the maximum colonization (100%), closely followed by mixed strain with *Azotobacter* and PSB (58%). Root biomass was significantly higher in all the treatments receiving mycorrhiza and helper bacteria compared to that of control.

Effect of AMF and helper bacteria on root biomass of lemon

Based on the variations in plant height, treatment with *Glomus intraradices* + *Azotobacter* + PSB-T14 (87 cm) was found better for plant growth. Maximum leaf area (21.9 cm^2) was recorded in the plants treated with *Glomus intraradices* + *Providentia* sp. + *Anabaena iyengarji* (T12). With the combination of *Glomus intraradices* with *Azotobacter* and PSB both the photosynthetic rate (18.4 µmol/m^2/s) and the chlorophyll content (1.89 mg/100 g) were found to be the highest. Microbial biomass carbon (MBC), alkaline phosphatase activity and fluorescein diacetate (FDA) levels were found to be higher in the rhizosphere soil of plants treated with AMF, bacteria and cyanobacteria compared to those of control, indicating the improvement in soil quality by the use of these microbial combinations.

3.5.2 Evaluation of Citrus Rootstocks against Graded Levels of Salinity

Seven-month-old, uniform-sized seedlings of the citrus rootstocks, Sour orange (*Citrus aurantiam*), Attani- 2 (*C. rugulosa*), *Troyer citrange* (*C. sinensis* x *Poncirus trifoliata*), Billikhichlli (*C. reshni*) and RLC 6 (*C. jambhiri*) were irrigated at 70% field capacity with water containing 0, 50, 100, or 200 mM NaCl for 180 days. Growth in terms of plant height and the number of leaves decreased with the increasing levels of salinity in all the rootstocks. The depression in plant height was the greatest in salt-susceptible *Troyer citrange* and Billikhichlli at higher levels of salinity. However, in salt-tolerant Sour orange and Attani- 2, NaCl caused minimum depression in plant height. Defoliation was maximum in the salt susceptible *Troyer citrange* and Billikhichlli. At higher levels of salinity, maximum increase in superoxide dismutase (SOD) and peroxidase (POD) activities was found in the salt-susceptible, *Troyer citrange*. Leaf proline contents increased most in Attani- 2, Sour orange, and RLC-6 at higher levels of

Sodium and chloride content in leaves and roots in different citrus rootstocks after 180 days of applying NaCl

Rootstock	Control		50 mM NaCl		100 mM NaCl		200 mM NaCl	
	Na (%)	Cl %)	Na (%)	Cl (%)	Na (%)	Cl (%)	Na (%)	Cl (%)
Sour orange								
Leaves	0.50	0.72	0.99	1.56	1.21	2.17	2.00	2.75
Roots	0.31	0.59	0.72	0.91	0.82	1.52	0.94	1.72
Attani-2								
Leaves	0.31	0.75	0.88	1.68	1.18	2.27	1.97	2.90
Roots	0.4	0.45	0.91	0.97	1.04	1.63	1.21	1.82
Troyer citrange								
Leaves	0.41	0.47	0.81	1.35	1.39	2.01	1.87	2.44
Roots	0.05	0.28	0.14	0.92	0.22	1.66	0.30	2.16
Billi khichlli								
Leaves	0.50	0.60	1.69	1.95	1.97	2.31	1.99	2.52
Roots	0.37	0.35	0.70	1.29	1.00	1.87	1.03	2.33
RLC-6								
Leaves	0.49	0.67	0.87	1.74	1.14	2.06	1.89	2.35
Roots	0.03	0.23	0.11	0.82	0.21	1.14	0.22	2.24

Potassium and calcium contents in leaves and roots in different citrus rootstocks after 180 days of applying NaCl

Rootstock	Control		50 mM NaCl		100 mM NaCl		200 mM NaCl	
	K (%)	Ca (%)	K (%)	Ca (%)	K (%)	Ca (%)	K (%)	Ca (%)
Sour orange								
Leaf	2.04	3.11	2.05	2.46	2.02	1.99	1.98	0.97
Root	2.38	2.39	2.09	2.27	1.73	2.19	0.97	2.35
Attani-2								
Leaf	2.03	1.47	1.81	1.63	1.67	1.32	1.75	1.03
Root	2.77	0.97	2.34	1.01	1.70	1.09	1.63	1.23
Troyer citrange								
Leaf	0.86	1.99	0.87	1.55	0.77	0.90	0.71	0.81
Root	1.18	0.57	0.88	0.55	0.76	0.55	0.69	0.52
Billikhichlli								
Leaf	1.32	1.55	1.04	1.40	1.96	1.12	1.33	1.02
Root	1.60	0.78	1.39	0.81	0.82	1.53	0.81	0.93
RLC-6								
Leaf	0.73	1.99	0.97	1.21	1.13	1.04	1.21	0.95
Root	1.27	0.54	1.11	0.56	0.92	0.55	0.65	0.55

salinity. The concentration of Na^+ ions in leaf tissues increased to a maximum in Attani - 2, while in root tissues, RLC-6 and *Troyer citrange* had increased Na^+ content. The maximum increase in leaf Cl^- ions was observed in *Troyer citrange*, and the minimum in RLC-6 at 200 mM NaCl. Overall, salinity tolerance increased in the following order: *Troyer citrange* < Billikhichlli' < RLC-6 < Attani-2 < sour orange.

3.5.3 Effect of Polyamines on Salt Susceptible Citrus Rootstocks under NaCl Stress

An experiment was conducted to determine the effect of polyamines on salt susceptible citrus rootstock *Troyer citrange* exposed to NaCl. The plants were maintained until 160 days in plastic pots under water containing 0 or 50 mM

Effect of NaCl stress, putrescine, spermidine and spermine on nutrients acquisition in salt susceptible rootstock of *Troyer citrange*

Treatment	Na (%)		Cl (%)		K (%)	
	Leaf	Root	Leaf	Root	Leaf	Root
Control	0.16	0.18	0.46	0.24	1.37	0.39
NaCl	0.22	0.37	0.69	0.67	1.22	0.31
Put	0.14	0.13	0.32	0.21	2.05	0.37
Put + NaCl	0.19	0.28	0.35	0.38	1.61	0.45
Spd	0.14	0.13	0.38	0.22	1.48	0.52
Spd + NaCl	0.18	0.32	0.48	0.42	1.38	0.42
Spm	0.12	0.11	0.35	0.17	2.17	0.75
Spm + NaCl	0.17	0.24	0.57	0.52	1.52	0.67
SEm ±	0.01	0.01	0.03	0.02	0.04	0.03
CD (P=0.05)	0.03	0.03	0.09	0.06	0.13	0.10

NaCl in the presence or absence of 1.0 mM putrescine (Put), spermidine (Spd) or spermine (Spm). Salt stress reduced the plant height, number of leaves and dry mass of shoots and roots, and increased the accumulation of Na^+ and Cl^- and decreased the concentration of K^+ both in root and leaf tissues, resulting in the reduction of K^+/Na^+ and K^+/Cl^- ratio. Exogenous polyamines reduced Na^+ and Cl^- concentration and enhanced K^+ and Ca^{2+} concentration, both in leaf and root tissues, resulting in improvement in plant height, number of leaves and dry mass of shoot and root under both saline and non-saline conditions. Polyamines mainly Spm and Spd were found more effective in restricting the accumulation of Na^+. However, Put had more pronounced effect on restricting Cl^- accumulation and enhancing the accumulation of K^+ in leaf tissues under saline condition. Application of Spm was found more effective in enhancing the activity of SOD and proline content, while CAT activity was maximum in Put treated plants in the presence of NaCl.

3.6 PROTECTED CULTIVATION TECHNOLOGY

3.6.1 Vegetable Crops

3.6.1.1 Evaluation of insect-proof net house for hybrid seed production in cucumber

Insect-proof net house made with the use of 40 mesh U.V. stabilized nylon net was compared with open field conditions for hybrid seed production in cucumber (var. Pant Shankar Kheera 1) during rainy and post-rainy seasons of 2010. Insect-proof net house grown cucumber seed crop was 99.0% free from cucumber mosaic virus and fruit fly damage. On the other hand, the open field seed crop was severely affected by cucumber mosaic virus and fruit fly. Average hybrid seed yield under insect-proof net house was 11.8 g/plant (142.6 kg/ha), while the seed yield under open field conditions was 3.9 g/plant (47.0 kg/ha).

Cucumber crop inside insect proof net house

Cucumber crop outside insect proof net house

3.6.1.2 Evaluation of insect-proof net house for hybrid seed production in bittergourd

Insect-proof net house and open-field conditions were compared for hybrid seed production of bittergourd (var. Pusa Hybrid 1) during the summer season, 2010. Insect-

Bittergourd crop inside insect proof net house

Bittergourd crop outside insect proof net house

Comparison of cucumber seed crop under open-field and insect-proof net house conditions (var. Pant Shankar Kheera 1)

Crop condition	Date of transplanting	Date of first harvesting of crossed fruits	Hybrid seed yield (g/fruit)	Average number of fruits/plant	Hybrid seed yield (g/plant)	Hybrid seed yield (kg/ha)	Incidence of virus (%)
Insect-proof net house	30.7.2010	21.10.2010	4.40	2.7	11.88	142.56	1.0
Open-field	30.7.2010	30.10.2010	2.8	1.4	3.92	47.04	98.0

Comparison of bittergourd seed crop under open-field and insect-proof net house conditions

Crop condition	Date of transplanting	Date of first harvesting of crossed fruits	Hybrid seed yield (g/fruit)	Average number of fruits/plant	Hybrid seed yield (g/plant)	Hybrid seed yield (kg/ha)	Incidence of virus (%)
Insect-proof net house	09.2.2010	04.05.2010	9.4	3.3	31.0	232.0	NIL
Open-field	09.2.2010	28.04.2010	4.8	1.5	7.2	54.0	54.0

proof net house grown seed crop was completely free from incidence of virus and fruit fly. The hybrid seed yield under insect-proof net house was 9.4 g/fruit, 31.0 g/plant and 232 kg/ha. On the other hand, the seed yield under open field seed crop was 4.8 g/fruit, 7.2 g/plant and 54 kg/ha.

3.6.1.3 Suitability of walk-in-tunnels for off-season cultivation of bottlegourd during peak winter season

Walk-in-tunnels are temporary and low-cost protected structures made by using 0.5" GI pipes of 20 feet length after bending them in semi-circle shapes and erected on pieces of tor. These pipes are erected at a distance of 2.0 m, and thereafter transparent plastic of 180-200 micron thickness is covered over the pipes. The width of the tunnel is kept 4.0 m and the length 2.5–3.0 m, taking into consideration the need for better cross ventilation in the tunnel, the availability of plastic size (7x30 m), and proper pollination by honey bees inside the structure. The plastic is covered over the pipes in the first week of December. The total cost involved on a 100-120 m^2 walk-in-tunnel is ₹13,000–14,000/-. The life of the plastic is usually 5-6 years, whereas the life of the GI pipes is 20-25 years. Walk-in-tunnels are technically suitable for off-season cultivation of various cucurbits, such as bottlegourd and, summer squash. Seedlines of bottlegourd var. Pusa Naveen were transplanted in the third week of October at a spacing of 150 x 90 cm and the transparent plastic was covered over the tunnel in end-November and continued up to mid-February 2011. Walk-in-tunnels were found technically suitable and economical for complete off-season cultivation of bottlegourd in northern plains of India.

Bottlegourd crop under walk-in-tunnel during complete off season

3.6.1.4 Techno-economic suitability of off-season cultivation of summer squash under walk-in-tunnel

Walk-in-tunnels were evaluated for techno-economic suitability for complete off-season cultivation of summer squash var. Australian Green during the peak winter months. Twenty-day old seedlings of summer squash were transplanted at a plant spacing of 150 cm x 50 cm in the last week of October 2010 and walk-in-tunnels were erected over the crop in the first week of December. The first harvesting of fruits was started in the second week of December and it continued up to the second week of February 2011.

3.6.1.5 Suitability of insect-proof net house for cultivation of parthenocarpic cucumber

An insect-proof net house fabricated with the design of a greenhouse was evaluated for its techno-economic suitability for the cultivation of parthenocarpic cucumber during the post-rainy season of 2010. Seedlings of the cucumber var. Kian were raised in plug trays and 25-day old seedlings were transplanted at raised beds in the insect-proof net house at a spacing of 40 cm x 30 cm. The plants

Economics of off-season bottlegourd cultivation under walk-in-tunnels

Crop	Date of transplanting	Date of first harvesting	Total period of harvesting	Fruit yield (kg/100m²)	Gross income (₹/100 m²)	Cost : benefit ratio
Bottlegourd	18.10.2010	25.11.2010	25.11.2010 to 15.02.2011	310.00	7750	1:2.60

Economics of summer squash cultivation under walk-in-tunnels

Crop	Date of transplanting	Date of erection of walk-in-tunnels over the crop	Date of first harvesting	Period of harvesting	Fruit yield (kg/100 m²)	Gross income (₹/100 m²)	Cost: benefit ratio
Summer squash	25.10.2010	01.12.2010	10.12.2010	10.12.2010 to 20.02.2010	260.0	6500	1:2.10

Cucumber crop under insect proof net house fabricated in greenhouse design

were vertically trellised like a greenhouse cucumber crop. Insect-proof net house was found technically and economically suitable for growing excellent virus-free parthenocarpic cucumber crop during the post-rainy season under Delhi conditions.

irrigation was severely damaged by powdery mildew in the month of April, whereas there was no incidence of powdery mildew under drip irrigation.

3.6.2 Flower Crop

3.6.2.1 Mother stock and media studies in Chrysanthemum plug plant propagation

Propagation of self-rooted cuttings and mother stock of Chrysanthemum raised in standard media comprising coco peat, perlite and vermiculite in 3:1:1 ratio took 18 days against 23 days taken by those raised in sand beds under long day (LD) as well as short day (SD) conditions. The results revealed that the plugs took less time (16 days in Snowball and Thai Chen Queen and 14 days in Zembla under

Economics of cucumber cultivation under insect-proof net house during post-rainy season

Crop	Date of transplanting	Date of first harvesting	Date of last harvesting	Total fruit yield (t/1000m^2)	Gross income (₹/1000 m^2)	Cost : benefit ratio
Parthenocarpic cucumber	25.09.2010	28.9.2010	20.12.2010	3.0	90,000	1:2.8

3.6.1.6 Effect of methods of irrigation on seed yield and quality in carrot

An experiment was conducted to compare the effect of two methods of irrigation, i.e., surface irrigation and drip irrigation, on plant growth, seed yield and seed quality in carrot var. Pusa Rudhira during *rabi* season 2009-10. Seed crop of carrot under drip irrigation method gave significantly higher seed yield and seed quality compared to those of surface irrigated crop. Under drip irrigation, 30% water and 35% fertilizers were saved against the values observed in the surface irrigated crop. Carrot seed crop under surface

Mother stock and media studies in Chrysanthemum plug

Effect of methods of irrigation on growth and seed yield of carrot

Method of irrigation	Number of primary umbles/ plants	Number of secondary umbles/ plants	Seed yield/ plant (g)	1000 -seed weight (g)	Seed yield (t/ha)	Incidence of diseases	Water/fertilizer saving (%)
Drip irrigation	11.5	65.8	30.5	5.5	1.53	NIL	Water 30% fertilizer 35%
Surface irrigation	9.1	48.5	24.6	4.8	1.23	Powdery mildew in the month of March-April	NIL

long days as compared to the time taken by the plugs raised under short days, causing delays by 6, 3 and 4 days in respective varieties. However, the same terminal cuttings raised under pure sand beds took longer time (6 more days in Snowball and Thai Chen Queen and 4 days in Zembla) under short day conditions. The period of establishment was faster, taking 2 days less in all the cases when propagated under long days and bare-rooted conditions.

3.6.3 Drip Irrigation

3.6.3.1 Techno-economic evaluation of low pressure drip irrigation system for protected cultivation

Low pressure drip irrigation system was techno-economically evaluated for 500 m^2 and 1000 m^2 naturally ventilated greenhouse and compared with pressurized drip irrigation system installed in a semi-climate controlled greenhouse for the same area. The benefit : cost ratio was found to be the highest (2.5:1) for low pressure drip irrigation system installed in 1000 m^2 naturally ventilated greenhouse and the lowest (1.3:1) for pressurized irrigation system installed in the 1000 m^2 semi-climate controlled greenhouse.

Techno-economic evaluation of drip irrigation system for protected cultivation

Type of greenhouse	Area of greenhouse (m^2)	Type of drip irrigation	Benefit: cost ratio
Naturally ventilated	500	Low pressure	2:1
Naturally ventilated	1000	Low pressure	2.5:1
Semi-climate controlled	500	Pressurized	1.5:1
Semi-climate controlled	1000	Pressurized	1.3:1

3.6.3.2 Standardization of crop water productivity and fertigation scheduling of tomato var. Pusa Rohini

Total crop water requirement was found to be 2400 m^3 per ha for tomato grown under pressurized drip irrigation system. Two sets of tensiometers at 30 cm and 60 cm depth were found suitable for fertigation scheduling of one ha area. Fertigation dosage and scheduling were standardized. The total number of irrigations during the entire duration of crop (Oct-Mar) were 36. The crop water productivity was found to be 17.5 kg/m^3 and the total yield was 42 t/ha.

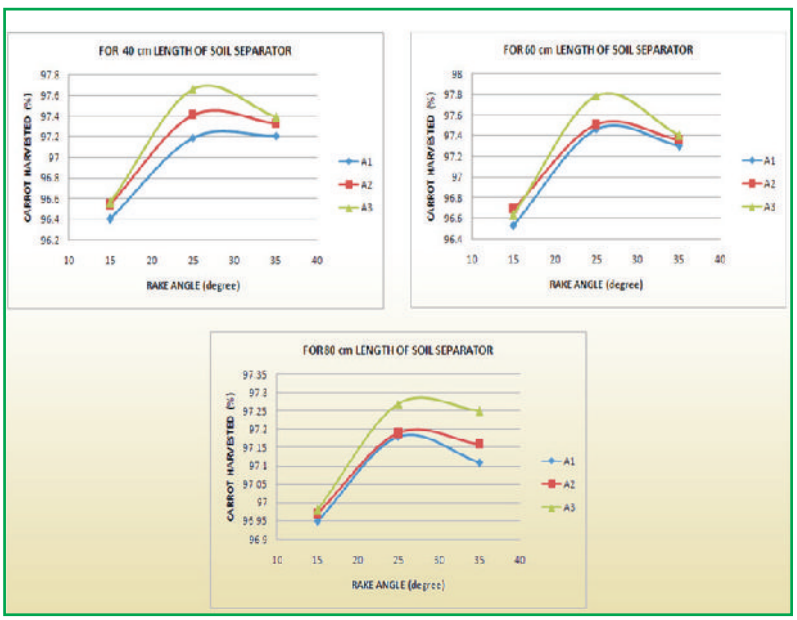
Standardization of crop water productivity and fertigation dosage for tomato

Crop	Crop water requirement (m^3)	Yield (t/ha)	Crop water productivity (kg/m^3)	Fertigation dosage (kg/ha)		
				N	P	K
Tomato	2400	42.0	17.5	111	67	133

3.7 AGRICULTURAL ENGINEERING

3.7.1 Evaluation of Single Row Mechanical Carrot Harvester

An experiment was conducted with three levels of moisture (15%, 12% and 9%) for different lengths of soil separator (40, 60 and 80 cm), three levels of rake angle (15°, 25° and 35°) and three different angles of soil separator (0°, 10° and 20°). Mechanical harvesting at a soil moisture content of 12% gave a maximum of 97.03 percentage carrot harvesting and 5.48 percentage of damage. A minimum soil separation index of 0.26 was obtained at a moisture content

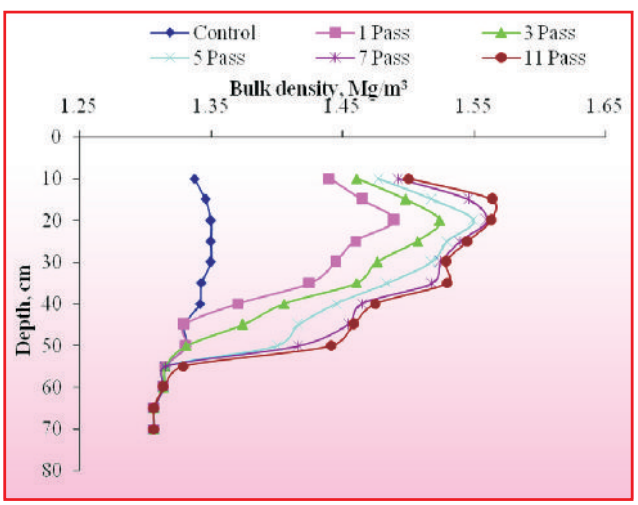


Effect of different variables on carrot harvesting at different levels of machine design parameters

of 12% for different combinations of machine variables. Soil moisture content significantly affected the performance parameters of harvester at different levels of machine parameters. The machine design parameters were further optimized at an optimum moisture content of 12%. The maximum percentage of carrot harvesting was 97.4 at 60 cm length of soil separator at a rake angle of 25° and an angle of soil separator of 20°. A minimum soil separation index of 0.23 could be obtained at 80 cm length and 20° angle of soil separator. An average power requirement for the operation of carrot harvester at a speed of 2.3 km/h was 4.44, 5.3 and 5.75 kW at a rake angle of 15°, 25°, and 35°, respectively.

3.7.2 Influence of Sub-surface Compaction on Wheat

A study was done to determine the pattern of sub-surface soil compaction due to varying levels of normal load on soil tire interface and number of passes of tractor rear wheel on the same track. Four levels of normal loads of 2.71, 3.69, 4.67 and 5.65 kN on a half chassis simulator of a tractor were mounted and the simulator was test run for 1, 3, 5, 7 and 11 of passes in an indoor soil bin. A statistical model was developed and validated using the data from field experiments on sub-surface soil compaction by 1, 6, 11 and 16 test runs of a 35 hp tractor with different normal loads, i.e, 4.40, 6.40 and 8.40 kN at soil tire interface on the same track by using a completely randomized block design. A composite compaction index was also developed using bulk density and penetration resistance data from different treatment combinations.



Variation in bulk density with depths at varying number of passes at normal load of 5.65kN

In the soil bin experiment, it was observed that bulk density in 0-15 cm depth zone increased continuously up to 11 passes. The compaction was caused by transmittance of stresses developed at soil tire interface and in compacted soil, the stresses could be transmitted effectively. At the highest normal load of 5.65 kN and maximum of 11 passes, the sub-soil layer of 15-30 cm experienced maximum compaction with bulk density of 1.55 Mg/m^3. The maximum compaction was obtained at a soil depth of 15-30 cm. In the field experiment, the bulk density in 0-15 cm depth zone continuously increased with the increase in the number of passes. At lower depths below 30 cm, the impact of higher load and higher passes was more visible. The compaction process owing to increased load and multiple passes almost terminated below 45 cm. A maximum of 17.5% decrease in germination count was observed owing to compaction by 11 passes of tractor with 8.40 kN normal load. The variation in passes from 1 to 16 at a load of 8.40 kN resulted in 16.40% decrease in wheat yield. It was also observed that 51-61% of wheat roots were confined to upper 0-15 cm, 17-20% in 15-30 cm and the rest 22-28% in below 30 cm soil layer. In sub-soil layer of 15-30 cm, the root length density decreased by 23.2% with an increase in sub-soil compaction index from 0.42 to 0.71. A reduction of 22.7% in grain yield was obtained with the increase in sub-soil index from a minimum of 0.42 to a maximum of 0.71.

3.7.3 Development of Equipment for Mechanization of Compost Preparation and Handling

3.7.3.1 Compost turner-cum-mixer

A compost turner-cum-mixer is a trailing and offset type machine used for thoroughly mixing the cow dung, farm residues and biomass for FYM preparation. The main components of the equipment are mixing rotor, hydraulic system to operate the rotor, water tank to store water and culture, and side tank for weight balancing. The rotor is made of a 400 mm diameter and 9 mm thick seamless pipe fitted with projections made of high carbon steel blades over its body surface. A total of 42 blades arranged in a helical path facilitated thorough mixing and turning of the

material. The helical arrangement helped in reducing the load with appropriate mixing of compost. The design takes care of the dynamics of compost handling in an efficient manner. The rotor mounted on a frame make it a complete mixing unit. Rubber pads are provided for partially covering the mixing unit to check the spillage of compost while mixing. To facilitate safe transport of the equipment both off- and on- the road, a rotor unit is hinged at one end to be lifted vertically with the help of a hydraulic system. A water pump is provided to facilitate sprinkling of water over the compost material. As this machine is an offset type, a side tank full of dead weight of concrete helps to counter balance the weight of the rotor unit particularly while lifting and lowering. The equipment is operated by a tractor of 70 hp.

Specifications

Component	Dimensions
Mixing rotor diameter (mm)	400
Length of rotor (mm)	2670
Rotor shaft diameter (mm)	63
Length of rotor shaft (mm)	2870
Hydraulic system with base plate, hoses (5 nos.) and direction control valve (5 nos.)	1000 mm stroke,63 mm cylinder dia
No. of blades over rotor surface	42 (nos.)
Length of blade (mm)	260
Width of blade (mm)	80
Dimension of water tank (mm)	1220 x 1350 x 1250
Side tank (mm)	1250 x 730 x 760

Advantages

- Efficient turning of farm residues and animal dung.
- Saves one month's time in compost making in comparison to traditional method.
- Makes it possible to break the bulk amount of farm residues by way of thorough mixing with soil.
- The capacity of compost turner-cum-mixer is 3000 t/day.
- Can save the Institute more than ₹ 10-15 lakh per annum.

3.7.3.2 Tractor-mounted loader

The loading of compost is labour intensive. In addition, manual loading is costly and delays the operation. The design of a tractor front-mounted loader was modified for handling cow dung, biomass and ready compost and was custom built from a manufacturer. It is used for lifting and carrying of compost material up to a height of 3 m. The bucket volume is about 0.5 m^3 and capacity is 600 kg. The capacity of machine is 12 t/h. It takes 15 man-h for loading a truck load of compost while tractor mounted loader takes only 0.5 machine-h.

3.7.3.3 Sieving machine for compost

A machine for sieving the compost for separating the finer grades for different uses was designed and fabricated. The machine is able to sieve the compost in different sizes. It is powered with a single phase 1.0 hp motor.

Specifications

Component	Dimensions (mm)
Length of cylindrical screen	1800
Diameter of cylindrical screen	650
Length of chute	1260
Total length of machine	3900
Total width of machine	820
Sieve size	5 mm × 5 mm

Advantages

- Separation in different sizes adds to the value of compost.
- The smaller grade is used in pots and in other uses.

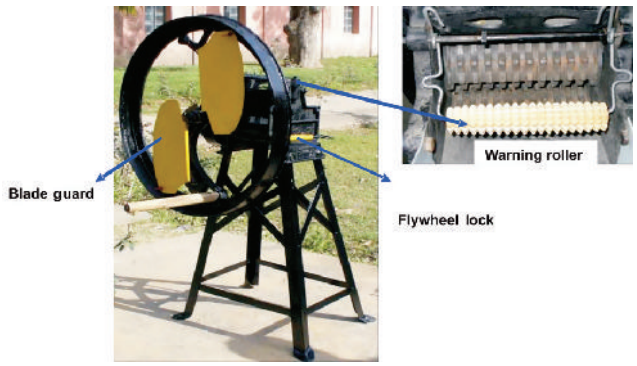
Compost turner-cum-mixer

Compost loader

Compost sieving machine

3.7.4 Development of Safety Interventions for Chaff Cutter Injuries

Chaff cutter is an extensively used machine in Indian rural households to feed draft and milch animals. A survey was conducted in four villages of Ghaziabad district to determine the casual factors that are responsible for chaff cutter related injuries. It was observed that major injuries were caused by children playing with the machine and while

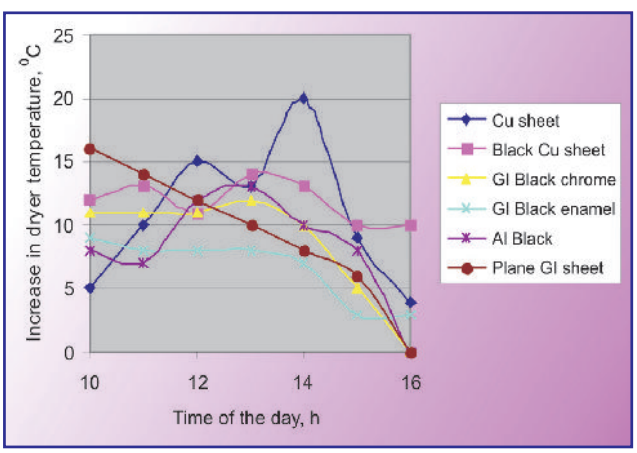


Chaff cutter safety interventions

feeding the fodder. Based on the survey results, three interventions, viz., blade guard, flywheel lock and warning roller, were developed to prevent the injuries in chaff cutter. (i) The blade guard is made up of mild steel sheet which can be attached to the two existing blade bolts, and can be unflapped for sharpening the blade, (ii) flywheel lock is a mechanical lock that prevents rotation of the flywheel in non-working mode, and (iii) warning roller consists of a serrated wooden roller that gives a warning when the hand is in danger zone while operating the chaff cutter. These interventions can be retrofitted on old machines and can be part of new machines as well.

3.7.5 Studies on Efficient On-farm Utilization of Solar Energy

Studies on the effect of selective coatings on efficiency of solar cabinet dryer were conducted. The selective coatings were used to provide maximum absorptivity and minimum emmissivity. Different selective coatings such as copper sheet, black copper sheet, G.I. sheet with black chrome paint, G.I. sheet with black enamel paint, aluminum black sheet and plane G.I. sheet were used. Hourly temperatures of ambient, collector plate and drying chamber were measured. Hourly values of beam and diffuse solar radiations were also measured. It was found that the temperature of the drying chamber with copper sheet was higher, followed by the temperatures of drying chambers with black copper sheet, aluminum black sheet and G.I. sheet with black chrome paint.



A comparison of the increase in temperatures of drying chambers

3.7.6 Modified Pulse Polisher

A small capacity pulse polisher was modified and tested for polishing of pigeonpea pulse. The machine consists of a roller made of leather strip, a concave covered with leather sheet, a feed hopper and a frame. The machine is operated at an optimum speed of 900 rpm with 2 hp electric motor. The machine gave an output of 84 kg/h. The roller dimensions are 15 cm x 45 cm. The overall dimensions of the machine are 80 cm x 50 cm x 130 cm. Liquid glucose and soft stone powder is added during polishing of pigeonpea pulse.

3.7.7 Pitting Machine

A pitting machine was designed for making scratches in the husk of the pulse grain for better penetration of oil and water between the husk and cotyledons. The purpose of this treatment is to loosen the husk prior to dehusking.

The machine consists of a feed hopper, an emery roller and a perforated concave. All these parts are fitted to an angle iron frame. The machine is run with a 2 hp, 3 phase, 1425 rpm electric motor. The cleaned pulse grains fed from the hopper enter into the gap between the roller and concave, and come out from the outlet attached to the lower end of the machine. The machine performs well at a speed of 900 rpm. The pitting capacity of the machine is 100 kg/h. The roller dimensions are 20 x 40 cm and it is made of 60 mesh fused aluminum oxide. The overall dimensions of the machine are 120 cm x110 cm x 50 cm. The machine is suitable for pitting, dehusking, splitting of pulse grains and polishing of wheat grains.

3.7.8 Farm Operation Services

The Farm Operation Service Unit (FOSU) managed all field operations including field preparation, sowing, harvesting and threshing in 750 acres of IARI farm with the use of indigenous and imported machines. A new laser levelling technology was developed for field levelling and

approximately 300 acres of farm land was levelled. In addition, tillage and other operational activities such as digging of water harvesting pond at CPCT unit, transportation of farm produce from different fields to Pusa Produce Sale Centre, and providing water tanker facility to IARI staff for social welfare activities were undertaken. Sowing of the experimental fields was accomplished in time during *rabi* season.

The FOSU has acquired a multi-crop harvester (combine) and trained 5 drivers for operating this machine. The combine can harvest and thresh many crops such as rice, wheat, soybean, greengram, blackgram and pearlmillet. The combine was tested successfully during *kharif* 2010 for rice and soybean.

A massive programme of cleaning the non-cropped areas of IARI farm, viz., farm road sides, bunds and channels, *mela* sites, *nala* sites, and security roads, was undertaken through manual, chemical and mechanical measures.

3.7.8.1 Irrigation system management

The Unit has reduced the dependence on canal water through development and renovation of old tubewells at IARI farm. For efficient distribution of irrigation water and to improve the conveyance efficiency of irrigation system, 2850 m of *pucca* channels were constructed. These channels saved 20-30% of irrigation water which was wasted because of the seepage or/conveyance of water in unlined field channels. These channels were provided with check gates at every 10 m distance to have ease of application of irrigation water by the users. Irrigation water to all the fields was provided by 18 tubewells linked by two big water reservoirs of 10 lakh gallons capacity each. More than half dozen skilled personnel were engaged in irrigation system management.

The FOSU introduced online indenting facility through IARI intranet for operations of farm machinery and equipment, and irrigation system on the experimental farms.

3.7.8.2 Biomass/crop residue management

The FOSU, with close collaborative efforts of the Divisions of Agronomy and Agricultural Engineering, initiated work on the collection and transportation of crop residues and other biomass produced at the IARI farm for preparing FYM. The requisitions for the job are duly received from different divisions/units through a designated procedure. The Unit has lifted approximately 800 trolley - loads of crop residues/biomass from various corners of the farm and transported them to the site of "Biomass Utilization Unit" for value addition. This innovation has led to complete utilization of farm residues and other biomass on the campus and their conversion to FYM. This initiative has led to self-sufficiency in the supply of FYM. The Unit is also providing loading and unloading facility for supply of FYM to various fields in the farm.

3.8 POST-HARVEST TECHNOLOGY AND MANAGEMENT

3.8.1 Response of Individual Fruit Bagging Before Harvest on Post-harvest Quality

3.8.1.1 Pomegranate

Individual fruits of pomegranate cv. Sindhuri were bagged with white, red, yellow and blue colored cellulosic recyclable bags 85 days prior to harvest. The fruits were taken out of the bags after harvest for further observations. Fruit bagging considerably reduced cracking, scratching and development of bacterial spots with reduced incidence of sun burning. After 35-days of storage at 10^0C, higher juice recovery, seed softness and anthocyanin content were recorded in fruits bagged with white coloured bags compared to those recorded in unbagged control and yellow or blue coloured bags. About 20% higher marketable fruit yield was

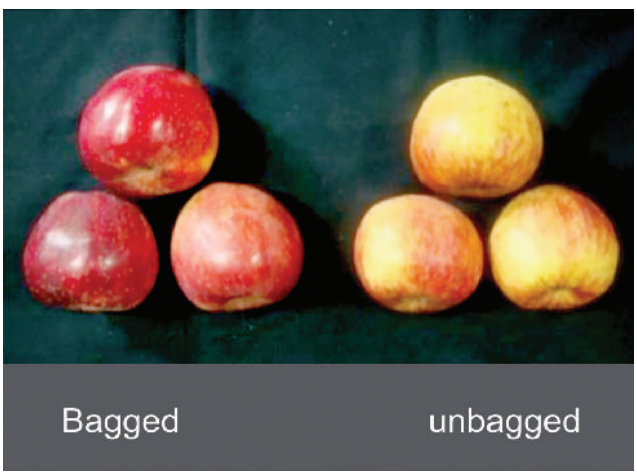
Effect of pre-harvest fruit bagging on post-harvest quality of pomegranate

Component	Bagged fruit	Unbagged fruits
Fruit cracking (%)	2.5	8.5
Sun burning (%)	0	4.0
Scratches (%)	3.15	25.4
Bacterial spot (%)	2.0	6.0
Juice recovery (%) (whole fruit basis)	60.10	61.18
Total anthocyanin (mg/100g)	178.25	162.35
No. of marketable fruits harvested/tree	84.60	71.40

obtained from bagged trees in comparison to that obtained from control. White coloured bags were found better than red and blue coloured bags with respect to post-harvest quality attributes.

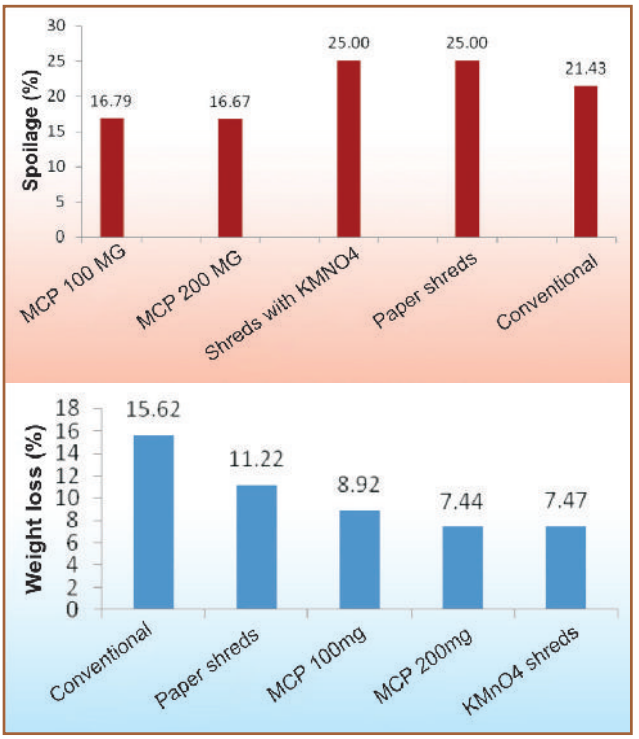
3.8.1.2 Apple

Fruits of apple cv. Royal Delicious were bagged with white, yellow, red and blue coloured recyclable cellulosic bags or brown paper bags 30 days before harvesting. Fruits were taken out of the bags after harvest for further observations. Apples covered with red or yellow coloured bags exhibited intense red colour at harvest. At the end of 6 months of storage (at 2°C, 85-90% RH), the incidence of bitter pit was found to be 1.8-2.0% in red or yellow coloured cellulosic bags, 12.8% in brown paper bags as against 14.6% in unbagged control fruits. The symptoms of bitter pit appeared on the 3rd month of storage in control (unbagged), whereas it took 6 months in fruits where pre-harvest fruit bagging was done.



3.8.2 Packaging of Mango for Long Distance Marketing

Mango fruits of cv. Langra were harvested at optimum maturity from the commercial orchard at Saharanpur (U.P.) and packed in 4-5 kg 3 ply CFB boxes with newspaper shreds as cushioning material between the layers. Similarly, separate lots were packed by using newspaper shreds treated with 8% $KMnO_4$. A new method of in-package application of 1-MCP in pouch was developed and evaluated. The mangoes with in-package 1-MCP were transported along with conventional packaging by road from Saharanpur to Kolkata



Effect of packaging on weight loss and spoilage of mango cv. Langra during long-distance transportation

market. The packages were evaluated on the 5th day after harvest in Kolkata. Results revealed approximately 5% reduction in spoilage and 8% check in weight loss by the use of this innovative technology for distance marketing.

3.8.3 Packaging and Storage of Tomato Powder

A process for the production of tomato fruit powder was standardized on a laboratory scale. The product was dried up to 4.5% moisture at 58 ± 2°C for 10 hours in a cabinet dryer. The lycopene content in the dried tomato powder was found to be 43.35 mg/100 g. The stability of lycopene in the product was found to be 76-81% when these were packed in 200 gauge HDPE or 400 gauge LDPE film bags and stored at ambient conditions up to 4 months or at 7°C up to 6 months, respectively. The rehydration ratio, NEB and sensory score of the best lot were found to be 1:2.93, 1.625 O.D at 420 nm and 8.6, respectively.

3.8.4 *Aonla* Fruit Powder – A High Value Product

Aonla fruits were shredded manually and dried in a cabinet drier at 50°C for 5 h after pre-treatment of 15 min autoclaving or 5 min of water blanching. The dried shreds

Market sample of *aonla* powder

Pusa Aonla Powder

were powdered in a hammer mill and packed in 200 g LDPE bags. The powders were evaluated for vitamin-C content and compared with two branded and one locally produced *aonla* powder available in the market. *Aonla* powder prepared by using blanching treatment (Pusa Aonla Powder) recorded the highest amount of Vitamin C (~1400 mg/100g) as against 140-180 mg/100 g in the market samples. The colour of Pusa Aonla Powder had the highest whiteness index (Hunter L- value >88) as compared to that observed in market samples (Hunter L values ranging from 63-68).

3.8.5 Development of Roasted Soy Nuts

Plain, salted and spicy roasted soy nuts were developed from whole grains of two types of soybean with yellow and black coloured seed coat. The soy grains were first soaked in water at ambient temperature and then roasted in microwave at different power levels. The roasted soy nuts were evaluated for various quality characteristics. These were found to be highly acceptable on sensory evaluation. The products had high antioxidant values and were rich in micronutrients, viz., Ca, Fe, and Na. Roasting did not significantly reduce the nutritional value with respect to total antioxidants (only 10% reduction) and micronutrients (approximately 30% reduction). These properties were found to be higher in black soybean than in yellow soybean.

3.8.6 Development of Ready-to-eat Puffed Pearlmillet Product

Pearlmillet based ready-to-eat puffed product was developed through extrusion processing. Consumption of 100 g of this product can meet approximately 25% of the RDA of Fe and Zn requirements of women. The product

Ready-to-eat Puffed Pearlmillet Product

could to be a boon to the huge human population suffering from celiac diseases due to gluten allergy. The developed product was found to be highly acceptable on organoleptic evaluation by people of different age groups. No addition of oil was done in the product. Various quality characteristics of the product like moisture content, expansion ratio, bulk density, antioxidants and phenol contents, ash content, and lypoxygenase activity were determined. The moisture content in the extruded product was found to be in the range of 1.25-4.5%. Expansion ratio was found between 2 and 3 showing good expandability. The bulk density varied from 51 to 82 kg/m^3. Apart from being a rich source of micronutrients (Fe=4.51 mg/100 g, Zn=2.73mg /100 g), the product was found to be a rich source of total antioxidants (0.1 Mole Trolox /100 g) and phenolics (76.5 mg/100 g). The standardized extrusion process resulted in very low lypoxygenase activity, which is an indicator of good shelf-life.

3.8.7 Development of Protein and Micronutrient Rich Cookies from Composite Flour

Protein rich cookies were prepared from wheat flour by incorporating soy flour @ 10, 20, 30 and 40% by weight. Similarly, micronutrient enriched cookies were prepared by using pearlmillet flour, soy flour and chickpea flour along with wheat flour. All the variants were evaluated for their chemical characteristics such as moisture content, protein, fat, ash, micronutrients as well as physical parameters like

weight, thickness, width, spread ratio and colour. Cookies having 20% soy flour scored the highest organoleptic score, followed by pearlmillet incorporated cookies. Since they are fat rich products, their packaging and storage stability are important aspects.

3.8.8 Post-harvest Technology and Management for Flowers

The drying technique was standardized for four cultivars of chrysanthemum, viz., Vasantika, Gauri, Maghi White and Jayanti. The flowers were embedded in sand and silica gel and dried in hot air oven for 48 h, microwave oven for 90 seconds and in shade for 7 days. The flowers of cv. Vasantika when embedded in silica gel and dried in shade showed maximum moisture loss (96.1%), while minimum moisture loss was observed when drying was done in shade + silica gel. It was also observed that the flowers showed minimum size reduction (11.1%) under hot-air oven + slica gel, followed by hot-air oven + sand.

The flowers of cv. Gauri showed maximum moisture loss (82.9%) when embedded in sand and dried in hot air oven, followed by those embedded in silica gel and kept in hot air oven for 48 hours for drying. However, in these treatments, reduction in flower size was more compared to flowers dried in microwave oven.

The flowers of cv. Maghi White when embedded in silica gel and dried in hot air oven for 48 hours showed maximum moisture loss (72.9%) and minimum reduction in flower size (23.1%), followed by the flowers embedded in sand and dried in hot air oven for the same duration.

The flowers of cv. Jayanti when embedded in silica gel and dried in hot air oven for 48 hours showed maximum moisture loss (87.0%) and minimum reduction in flower size (18.0%), followed by those dried in hot air oven + sand, but in this case the reduction in flower size was quite high.

The drying technique was also standardized for marigold cv. Pusa Arpita. The experiment consisted of nine treatments including four embedding media, viz., sand, silica gel, borax and boric acid; four drying techniques like hot air oven, microwave oven, shade-drying and air-drying. The treatment duration was 70 h for hot air oven at 45°C, 6 minutes for microwave oven and 7 days at ambient conditions for shade and air drying. The flowers which were dried in air lost maximum moisture content (87.4%) and flower size (46.7%), but the flowers when embedded in silica gel, sand or boric acid and dried in shade had better quality in terms of flower shape, size and retention of colour.

3.9 MICROBIOLOGY

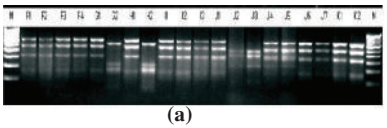
3.9.1 Diversity Analysis of Microbes in Extreme Environments and Bioprospecting for Novel Molecules and Genes

3.9.1.1 Bacterial diversity in Leh cold desert

A total of 9 bacterial samples were collected from different sites in Leh. The average population of bacteria at different locations on 10 different media ranged between $2.3x10^2$ and $1.3x10^8$ cfu/ml water or g of soil. Based on the varied colony morphology, viz., colour, shape, margin, 117 different morphotypes were selected. These included 15

Standardization of drying technique for marigold cv. Pusa Arpita

Drying technique	Fresh weight (g)	Dry weight (g)	Moisture loss (%)	Fresh size (cm)	Dry size (cm)	Reduction in size (%)
Hot air oven + silica gel	2.22	0.50	77.47	3.83	3.02	21.14
Hot air oven + sand	2.40	0.64	73.33	3.87	2.87	25.83
Microwave oven + silica gel	3.25	0.69	78.76	3.89	3.12	17.67
Microwave oven + sand	2.34	0.65	72.22	3.41	2.92	14.36
Shade + silica gel	2.99	0.59	80.26	3.96	3.36	15.15
Shade + sand	2.48	0.50	79.83	3.73	3.16	15.28
Shade + borax	2.54	0.54	78.74	3.88	2.79	28.09
Shade + boric acid	3.27	0.45	86.24	4.18	3.25	22.24
Air drying	3.18	0.40	87.42	3.90	2.08	46.66
Mean	2.74	0.55	79.36	3.85	2.95	22.94



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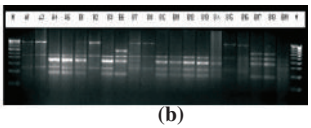

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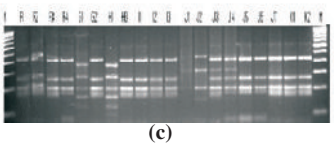


(c)

16S rDNA PCR-RFLP analysis of Leh isolates with Hae III (a), Hha1 (b) and AluI (c)

Bacillus isolates and 17 *Bacillus thuringensis* isolates obtained after enrichment. Screening of the isolates for low temperature tolerance revealed that 9 isolates could tolerate 4°C temperature. Based on 16SrDNA PCR-RFLP analysis with three restriction endonucleases *Alu*I, Hae III and *Hha*1, all the isolates were grouped into 29 clusters.

Based on 16S rDNA sequencing, the following isolates were identified: *Lysinibacillus fusiformis, Lysinibacillus sphaericus*, *Vibrio metschnikovii*, *Brevibacterium* sp., *Bacillus simplex*, *Pseudomonas stutzeri*, *Bacillus firmus*, *Bacillus psychrosaccharolyticus*, *Alishewanella* sp., *Bacillus anthracis*, *Paenibacillus* sp., *Pseudomonas frederiksbergensis*, *Arthrobacter* sp., *Bacillus firmus*, *Paenibacillus* sp., *Planococcus donghaensis*, *Bacillus firmus*, *Bacillus pumilus*, *Pseudomonas putida*, *Paenibacillus terrae*, *Arthrobacter sulfurous*, *Lysinibacillus* sp., *Bacillus subtilis*, *Pseudomonas* sp. and *Arthrobacter* sp.

3.9.1.2 Diversity analysis of actinomycetes in Sambhar salt lake and Bikaner soil

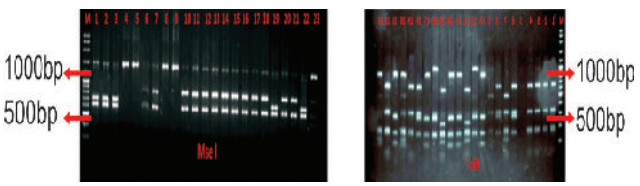
Five salt-tolerant actinomycetes isolated from Sambhar salt lake (Rajasthan) and Bikaner soil were screened quantitatively for production of xylanase and endoglucanse using cellulose, congress grass and paddy straw as substrate. *Streptomyces* sp. Mic98 and *Streptomyces globosus* Mic198 produced high amounts of xylanase (85.91 IU/g substrate) and endoglucanase (198 IU/g substrate), respectively, with the use of congress grass as substrate. *Streptomyces flaveus* Mic 1 inhibited three plant pathogenic fungi, viz., *Macrophomina phaseolina, Fusarium oxysporium* and *Rhizoctonia bataticola.*

3.9.1.3 Bioprospecting of bacteria for biotic stress tolerance

The bacterial isolates grouped into fluorescent and non-fluorescent types were screened for their biocontrol potential *in vitro* against two pathogens, viz., *Rhizoctonia bataticola* causing charcoal rot in soybean and *Xanthomonas oryzae* causing bacterial blight in rice. The bacteria showing positive inhibition of the pathogens under *in vitro* conditions were selected for further studies. Fluorescent bacteria were subjected to PCR amplification by the use of specific primers for genes coding for antibiotics – 2,4, diacetyl phloroglucinol, phenazine, pyrollnitrin and pyoluteorin. None of the isolate was found positive for phenazine and pyoluteorin. A potent biocontrol isolate neither fluoresceing nor producing the four antibiotics tested, was identified. This bacterium will be studied for production of novel metabolites, which are antifungal/ antibacterial in nature.

3.9.1.4 Diversity analysis of cyanobacteria in Sambhar salt lake

16S rRNA PCR-RFLP analysis of microalgal strains obtained from Sambhar lake with three restriction enzymes *Dpn* II, *Hin*f and *Mse*I revealed limited diversity among the isolates.



16S rRNA PCR-RFLP analysis of selected cyanobacterial isolates with restriction enzymes *Mse*I and *Hin*f

The salt-tolerant isolates were subjected to gene amplification for superoxide dismutase. Four isolates showed the amplification of gene product of about 600 bp.

Amplification of superoxide dismutase gene from salt-tolerant microalgae

3.9.1.5 Diversity and functions of anaerobic microorganisms involved in NH_3 oxidation, Fe and Mn reduction

Anaerobic microbial processes such as anaerobic NH_3 oxidation, Fe reduction, and Mn reduction because of their contributions through elemental cycling to plant productivity require better appreciation. Most soils, which support plant growth, always have less oxygen ranging from microaerophilic conditions to anoxic conditions. When the microscale measurements of potential nitrification rates were performed using soil samples spiked with different metal salts of nitrate and incubated for 30 days, the rates were in the range of 0.2-12.1 µg NO_2 produced/g/h. Most metals (Zn, Cu, Cd, and Pb) are inhibitory to the soil nitrification process under non-flooded conditions. On the contrary, the soil samples under flooded conditions even in the presence of certain metal salts supported nitrification suggesting the role of anaerobic microorganisms in ammonium oxidation in nitrification. To facilitate the isolation of microorganisms which mediate anaerobic ammonium oxidation, the soils were enriched by repeated additions of ammonium nitrate to the soil microcosms spiked with metals. Iron reduction mediated by anaerobic microorganisms depends on redox reactions triggered by the precipitation and dissolution of Fe-rich minerals. To assess the potential microbial Fe reduction, the amorphous ferrihydrite was added exogenously to soil at the levels ranging from 100 to 1500 µg/g. Ferrous ion concentrations in the soil amended with ferrihydrite after 10 days of incubation ranged from 0.5 to 22.4 µmol/g and showed temporal changes.

3.9.1.6 Optimisation of conditions for pigment biosynthesis in cyanobacteria

Cyanobacteria produce a range of value-added products, including carotenoids, pigments, vitamins, lipids and polysaccharides, all having commercial application in one or the other form. Earlier studies have revealed that *Anabaena* and *Nostoc* strains produced more amounts of phycocyanins and allophycocyanin pigments. Four strains, viz., *Anabaena* sp. (10W), *Nostoc* sp. (13R), *Nostoc* sp. (21R) and *Anabaena* sp. (CCC 162) were selected and conditions for maximizing phycobilin synthesis in these cyanobacteria were optimized in response to nutrient availability, salt stress, mixotrophy, etc. Of the different Fe sources studied, phycocyanins (PC) increased with the increasing concentration of ferric ammonium citrate while increased concentration of $FeCl_3$ and $FeSO_4$ resulted in decreased synthesis of PC. NH_4^+ salt grown cultures yielded more PC than NO_3^- grown cultures. The presence of salt (NaCl) stress had detrimental effect on PC synthesis and a concentration of 0.5M was inhibitory for the growth of all organisms studied. There was enhanced production of PC when the cultures were grown mixotrophically in the presence of 0.5% glucose.

In another study, phycocyanin rich cyanobacterial strains were identified on the basis of comparative studies undertaken from two districts (Bareilly and Rampur) of Rohilkhand region of U.P. The influence of varied temperature, light intensity and CO_2 concentration was studied on total phycobilins and phycocyanin concentration for optimization of production protocol. The influence of addition of Zn and glutamine supplementation alone or in combination indicated enhancement in phycobilins.

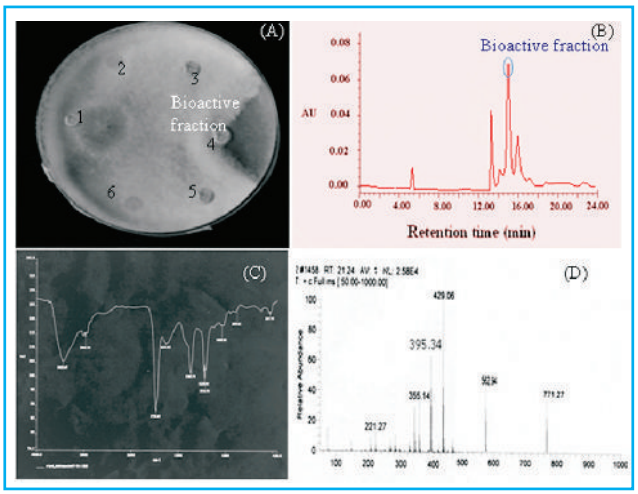
Enhanced production of phycocyanin by supplemental Zn and/or glutamine; Zn: 0.50 mg/L as $ZnSO_4$, glutamine (1mM)

Strain	Phycocyanin (µg/g dry weight) production			
	Control	Zn	Glutamine	Zn + glutamine
Phormidium sp.	1086.2	1782.2	1984.2	2504.3
Lyngbya sp.	1051.0	1691.3	1831.4	2306.3
Anabaena sp.	832.2	1491.4	1573.7	2107.2

3.9.1.7 Purification and characterization of novel fungicidal compound from *Anabaena laxa*

Cyanobacteria are known to produce a large number of bioactive metabolites, which serve as feeding deterrents and help in enhancing competitiveness in the environment. *Anabaena laxa* was earlier reported to produce fungicidal compound (s). Thin layer chromatography (TLC) and reverse phase high - performance liquid chromatography (HPLC) of the partially purified methanolic extracts of *A. laxa* indicated the active component to be a peptide. The Fourier Transform Infrared (FTIR) spectrum and mass fragmentation pattern using GC-MS revealed considerable similarities with those of majusculamide C isolated from an alga, *Lyngbya majuscula*. The isolated majusculamide C like compound was found to be soluble in solvents, such as methanol, dichloromethane and acetone, but insoluble in water. This is the first report of synthesis of a majusculamide C like fungicidal compound by the cyanobacterial strain,

Anabaena laxa , which may serve as a useful allelochemical and aid in its proliferation in soil.



Fungicidal activity of the TLC purified metabolite from A. laxa, against Pythium debaryanum (B) HPLC analyses (C) Fourier transform infrared spectroscopy (FTIR) and (D) GC-MS spectra of the bioactive fraction

3.9.2 Microbes for Nutrient Management

3.9.2.1 Organic farming in rice-based cropping system through microbial inputs

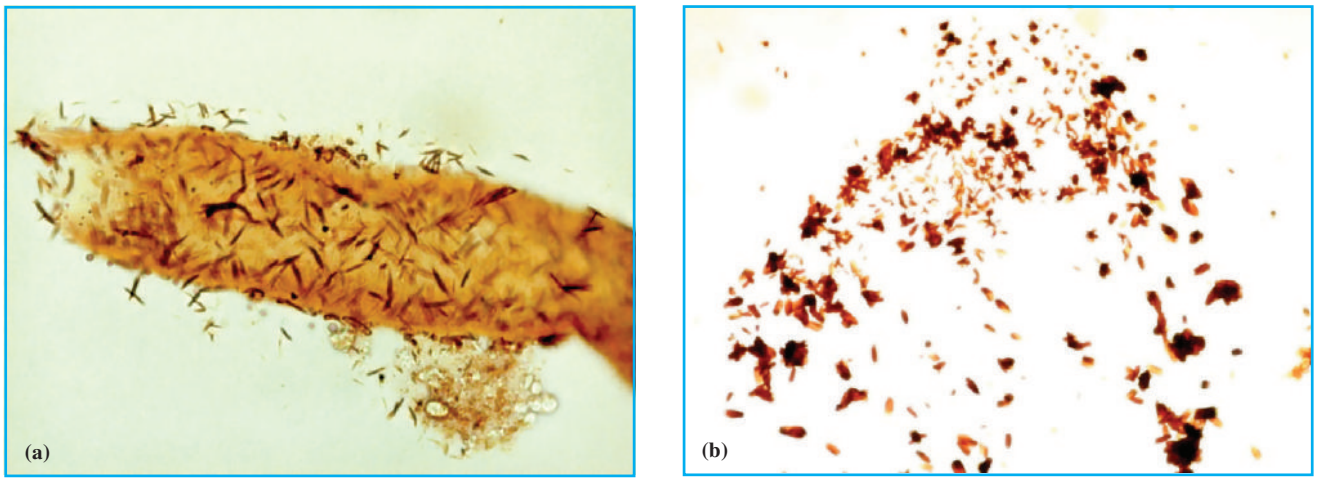
Basmati rice cv. Pusa Basmati 6 was grown under organic, integrated nutrient management (INM) and chemical fertilization during *kharif* 2010. It was found that the grain yield under organic management, i.e., application of four organic inoculants (blue green algae, *Azolla*, vermicompost and FYM) was the highest (4.57 t/ha), followed by the yield under INM (4.46 t/ha) and chemical fertilization (4.26 t/ha). The concentration of micronutrients, (Fe, Zn and Mn) and their uptake in rice grain increased significantly with organic farming over those of INM and chemical fertilization. The incidence of brown plant hopper (BPH) was lower in treatments having organic management compared to that in INM and chemical fertilization. An increase in population of beneficial insects like spiders was recorded under organic farming. Vegetable crops like cauliflower, broccoli, cabbage, garden pea and carrot were grown in rice-based cropping system. These crops grown under organic management with organic inputs, viz., biofertilizers (*Azotobacter/ Rhizobium*), vermicompost and FYM gave yields on a par with those of INM and chemical fertilization. The analysis of soil (0-15 cm) indicated that organic management resulted in higher values of field capacity and available water content of soil. Lower bulk density was observed in organic treatment compared to that in inorganic treatment. Higher amount of soil organic C was observed in organic treatment compared to that in inorganic treatment. Among the vegetable crops, carrot had the highest microbial biomass C (367.9 µg/g) under INM as well as organic management. Likewise, maximum ß-glucosidase activity (17.33 µg pNP/g/h) was observed in carrot under INM management. All the microbial activity parameters, viz., microbial biomass C (760.78 µg C/g soil), dehydrogenase (73.976 µg TPF/g/h), FDA hydrolase (0.751 µg flourescein/ g/h), acid phosphatase (105.75 µg pNP/g/h) and alkaline phosphatase (144.13 µg pNP/g/h) were found to be the highest in plots with organic practices of rice cultivation.

3.9.2.2 Development of biofilmed biofertilizer

Biofilms of Trichoderma and Pseudomonas. Using *Trichoderma viride* and *Pseudomonas fluorescens* biofilms were developed and their conditions optimized. These biofilms were further characterized for their biocontrol activity and attributes *vis-a -vis* individual partners of the biofilm. The biofilms were found to be superior in the biocontrol of *Alternaria solani*, a plant pathogenic fungus. The biofilms showed both HCN and siderophore production.

Microscopic examination of the biofilms prepared by inoculating the cultures either simultaneously or sequentially, did not show any difference in their pattern of growth or attachment of *Pseudomonas fluorescens* on the mycelia. Up to 3 days after inoculation of *Pseudomonas fluorescens*, a few cells were observed to attach to the myelia of *Trichoderma* in both static and dynamic cultures. After 6 days, all *Pseudomonas* cells attached with high cell densities to form biofilms. They remained attached till 18 days, following which there was a disintegration of the biofilms.

Biofilms of Piriformospora indica and PSB. Different growth media were evaluated for their potential to support the formation of the biofilms of *Piriformospora indica* and *P. striata,* at different time intervals (up to 5 weeks). The bioflim dry weight recorded at two weeks incubation was maximum (94 mg/50 ml) in Enriched Soil Medium (ESM), followed by that in Kaefer's Broth (89 mg/50 ml). *In vitro* analysis of the biological activity of the bioflims generated on different growth media at different incubation times as assessed by the FDA analysis revealed a significant variation



Formation of biofilms of *Trichoderma viride* and *Pseudomonas fluorescens* a. Attachment of *P. fluorescens* to *T. viride* after 6 days of incubation, and b. disintegration of biofilms after 18 days of incubation

ranging from 2,438 to 1,05,160 µg FDA/g dry weight of bioflim/h. The corresponding samples showed an acid and alkaline phosphatases activity of 2,295–4,638 µg PNP/g dry weight of bioflim/h. This indicates that the growth medium and the incubation period affect the bioefficiency of the bioflim generated.

3.9.2.3 Profiling of *Azolla* in relation to enhancing its utility in crop production

Anabaena-Azolla system is utilized as inoculants for rice crop in *kharif* season. It produces a lot of biomass that is rich in nutrients and can be exploited for plant growth promotion. Significant variation in the metabolite profile of *Azolla* extracts in terms of phenolic compopunds such as anthocyanin, flavonoids, carotenoids and sugar and protein content was observed in different seasons. The metabolite profile in turn influenced the antimicrobial activity as evident from the well diffusion assay by the extracts against the pathogen, *Rhizoctonia solani*. Extracts prepared from the plants grown during the summer months did not show any antimicrobial activity against *Rhizoctonia solani,* whereas the extracts prepared from the plants grown during the winter months showed significant antimicrobial activity against the pathogen. The proteomic analysis of the plants collected from two different seasons was performed and the data revealed differential expression of several proteins in response to seasons. Therefore, the possible involvement of some proteins, peptides or small molecules in relation to the antimicrobial activity may not be ruled out. Imposing the organism with abiotic stress factors such as salinity, pesticide and waste water resulted in an increase in the metabolite profile of the organism. Seasons as well as the stress factors also influenced the non-enzymatic antioxidant profile of the organism. The extracts were tested positive for the presence of phenols, flavonoids, coumarins, sterols, tannins and lipids.

The aqueous extracts were prepared from dried *Azolla* biomass (2%) and their effect was studied on the germination of rice and wheat seeds, and also on the growth of rice seedlings. *Azolla* extracts increased the rate of germination of rice seeds by 15%. Amendment of growth medium (1:1) with *Azolla* extracts significantly increased the shoot length by 110-135% over that of control and the chlorophyll content in rice seedlings. Significant effect of extracts was also observed on the germination of wheat seeds during winter months.

3.9.2.4 Genotypic influence on chickpea *Rhizobium* interaction

Four out of 14 *Mesorhizobium* strains collected from different locations (ICRISAT, Gulburga, Sehore, Rahuri, Ludhiana and Hisar) showed positive effect for nodulation in chickpea var. BG 256 under phytotron conditions. Interaction of four *Mesorhizobium* strains (IC 76, IC 2018, IC 2058 and IC 2099) with nine chickpea genotypes (BG 2024, K 850, DCP 92-3, IPC 2004-98, ICC 4918, ICC 4948, RSG 888, JG 315 and ICCV 92944) for symbiotic parameters was further carried out. Out of four strains, IC

4958 showed higher ARA activity (70.72 n moles C_2H_4 produced/h/mg dry weight of nodules). Among the different genotypes, significant differences in ARA activity ranging from 8 to 161 n moles C_2H_4 produced/h/mg dry weight of nodules were observed. A field experiment was carried out to screen 33 chickpea genotypes for BNF. Nodulation and growth parameters were recorded at different crop growth stages. Among the genotypes, the nodule weight ranged from 40 to 176 mg/plant at 60 DAS. The observed difference in nodulation potential among chickpea genotypes could be due to the difference in quantity and quality of root exudates. Some of the genotypes (PUSA 1053, PUSA 1003, PUSA 256 and PUSA 391) showing high and low nodulation were selected to study the composition and concentration of their root exudates.

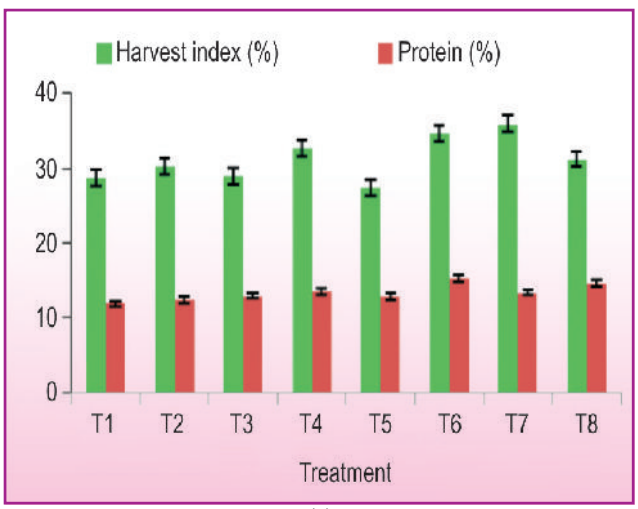
3.9.2.5 Microbes mediated biofortification of wheat crop

Three bacterial strains, viz., *Providencia* sp., *Bacillus* sp., and *Brevundimonas* sp., and three cyanobacterial strains, viz., *Anabaena* sp., *Calothrix* sp. and *Anabaena* sp. along with ½ recommended dose of N and full dose of P and K fertilizers were evaluated in a pot experiment. Promising treatments were taken up for field evaluation. A significant enhancement in plant biometrical parameters, protein content and nutritional parameters was recorded in all the treatments involving microbial inoculation. In terms of protein content, inoculation of *Providencia* sp., followed by the treatment having three cyanobacterial strains recorded significantly higher values. In terms of micronutrient content of wheat plants, a significant enhancement in Cu, Zn and Fe was recorded in all inoculated treatments over those recorded in fertilizer controls. Inoculation with *Providencia* sp. recorded a higher value of Zn (41.7 mg/kg) compared to that recorded in absolute control besides a three-fold increase in Fe (271.9 mg/kg) and Cu (99.0 mg/kg) values over those of absolute control. The study illustrates the multiple benefits of PGPR inoculation in integrated nutrient management strategies of wheat in terms of quality and yield improvement, savings on N and micronutrient enrichment.

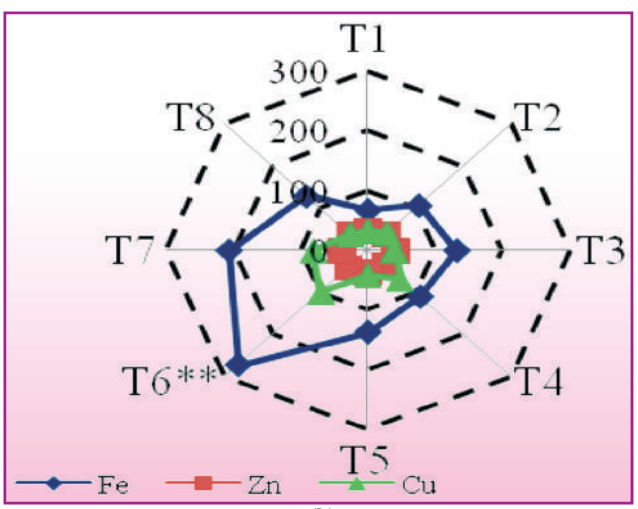
3.9.2.6 Phytate mineralizing microbes and their role in P nutrition

Of the 22 bacterial and 8 fungal strains isolated from diverse substrates, 6 bacterial and 3 fungal isolates were found efficient for hydrolysis of P from sodium phytate. Compared to bacteria, fungi were relatively more competent to mineralize sodium phytate. However, pH changes during mineralization by bacteria and fungi were in the same range of 3.2 - 5.2.

The independent variables such as carbon concentrations, pH and temperature and substrate concentration of the medium were optimized to favour high production of phytase. Low concentration of glucose influenced the Pi liberation in most of the fungal isolates.



(a)



(b)

Effect of microbial inoculation on (a) harvest index and protein content of wheat; (b) micronutrient content [T1: Absolute control; T2: Full dose $N_{120}P_{60}K_{60}$; T3: $N_{60}P_{60}K_{60}$; T4: $N_{90}P_{60}K_{60}$; T5: $N_{60}P_{60}K_{60}$ + *Anabaena* sp.; T6: $N_{60}P_{60}K_{60}$ + *Providencia* sp. PW5; T7: $N_{60}P_{60}K_{60}$ + *Anabaena* sp + *Providencia* sp; and T8: $N_{60}P_{60}K_{60}$ + *Anabaena* sp.+ *Calothrix* sp. + *Anabaena* sp.]

Growth of three fungi at different pH ranging from 2.0 to 7.0 revealed that each isolate had its different pH and temperature optima. F1 isolate showed preference to pH 5.5 and could grow well at 37° C. An increase in temperature from 37 °C -45°C caused a decrease of >30% in phytase activity. Moreover at high temperature, the period to attain maximum phytase activity was also prolonged. The fungal isolate F2 showed pH and temperature optima to be 6.0-7.0 and 37°C, respectively. An increase of temperature from 37 °C to 45°C reduced the phytase activity by 7%. Fungus F3 had the pH and temperature optima of 4.5°C and 30°C, respectively. The increase in temperature from 30 °C to 37°C reduced the Pi liberation capacity of fungus by 23%. Supplementation of the medium with increasing concentration of sodium phytate improved the phytase activity of all the three P mineralizing fungi. The effect was observed up to 0.4% for two isolates. A pH of 5.5 and substrate concentration of 0.6% were optimum for F1. Positive interaction between pH and substrate concentration indicated that both these parameters influenced phytase activity.

3.9.2.7 Screening of soybean germplasm for nodulation parameters with native homologous soil rhizobia

A field experiment was conducted to screen the moisture-stress tolerant germplasm for BNF parameters. Among the 30 germplasm lines screened for BNF parameters, three lines showed nodule number above 50 per plant. The maximum nodule number was observed in line 1 (59/plant), followed by that in line 2. Four germplasm lines (1, 2, 25 and 26) gave high nodule mass of more than 195 mg/plant. Root dry weight (0.92 g/plant) and shoot dry weight (9.9 g/plant) were observed to be maximum in line 1.

3.9.2.8 Development of *Azotobacter* bioinoculants for saline soils

Azotobacter strains tolerant to salt-stress were selected for use as bioinoculants under salt-stress conditions. A differential response on the plant growth promoting activities of five isolates with varying concentrations of chlorides and sulphates of sodium, calcium and magnesium was observed. At 0.3M concentration of NaCl, there was an increase in IAA production by H11, A24 and A32 cultures, whereas at 1.5M concentration, IAA production was severely inhibited. Higher concentrations of $CaCl_2$ also had an inhibitory effect on IAA production. At 0.2M concentration of $MgCl_2$, there was an increase in IAA production by H12, H13 and A11 cultures. With the exception of A24, higher concentrations of $MgCl_2$ had an inhibitory effect on IAA production. The phosphate solubilization capability of strains also varied with the concentration and type of salt. With the increase in concentration of NaCl, there was a decrease in P solubilization, However, isolate H12 showed tremendous increase in P solubilization at 1.5M concentration of NaCl. With the increase in concentration of $CaCl_2$, there was an increase in P solubilization, whereas higher concentrations of $CaSO_4$ had an inhibitory effect. In general, 0.2M concentration of $MgSO_4$ had a stimulatory effect on P solubilization ability of *Azotobacter* isolates. At higher concentration, with the exception of H13 and A24 cultures, a decrease in P solubilization ability was observed. In general, both sulphates and chlorides of sodium at higher salt concentrations had inhibitory effect on nitrogenase activity, HCN and siderophore production of *Azotobacter* isolates.

3.9.3 Microbial Degradation of Plastics and Agro-waste

3.9.3.1 Microbial degradation of low density polyethene

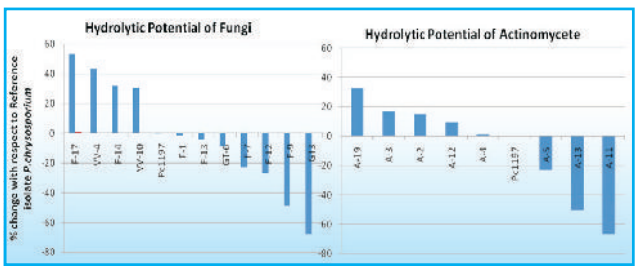
Bacteria and fungi that could degrade low density polyethene under optimized conditions were isolated. These isolates were further tested for hydrolytic activity through acetamide hydrolysis assay and fluorescein diacetate hydrolytic assay. Isolate P3 showed maximum FDA activity of 0.5 µg of fluorescein liberated/ml/h on the 3rd day of incubation, whereas isolate P2 showed maximum of 0.6 µg of fluorescein liberated/ml/h on the 5th day of incubation. The isolates were further characterized for hydrophobicity test following its growth in paraffin oil. Two isolates P1 and D5 showed positive hydrophobicity and adherence of 11.6% and 34.5%, respectively. Based on 16S rRNA gene sequencing, four promising bacterial isolates were identified as *Enterobacter cloacae* (2), *Brucella* sp. (1) and *Alcaligenes* (1). These isolates have been earlier implicated in degradation of heterocyclic amoines, resorcin and for biocontrol activity.

3.9.3.2 Microbial degradation of agro-waste through effective microbes

For developing an efficient microorganism (EM) concoction, naturally composting agro-waste samples were

used for isolating predominant lingo-cellulolytic fungi and actinomycete isolates. Based on submerged fermentation conditions, certain fungal isolates (11) and actinomycete isolates (8) having potential for releasing hydro-lytic enzymes were identified. Solid state fermentation with paddy straw as the sole C source was carried out to test these isolates. Different hydrolytic enzymes were estimated after 30 days of incubation. *Phanerochaete chrysosporium* isolate 1197 was used as the reference strain. Among fungal and actinomycete isolates, variable production of hydrolytic enzymes (units/g), viz., xylanase (8.1-590.9), CMCase (119.0-1355.7), FPase (4.9-408.5), and cellobiase (28.8-87.4) was recorded. Based on the overall production ability of hydrolytic enzymes, the fungal isolates, viz., F-17, VV-4, F-14 and VV-10 produced 53%, 43%, 32% and 30% , respectively, more than the reference strain *Phanerochaete chrysosporium* isolate 1197. Actinomycete isolates, viz., A-19, A-3, A-2, A-12 and A-4 produced 33%, 17%, 15%, 9% and 1%, respectively, more hydrolytic enzymes than the reference strain.

Nine identified fungal isolates having higher cellulolytic activity were:*Aspergillus fumigates, Aspergillus flavus, Aletrnaria alternate, Penicillium citrinum, Penicillium chrysogenum, Penicillium frequentance, Penicillium oxalicum, Curvularia lunata and Fusarium solan.*



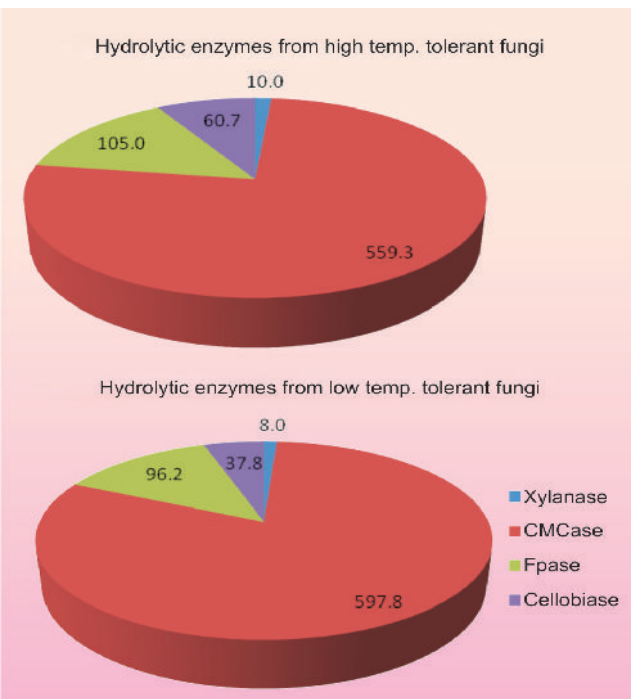
Hydrolytic potential of different fungi and actinomycetes

Several yeast, LAB and enriched photosynthetic bacteria were also isolated and screened for their potential to produce extracellular enzymes. Finally, fungal isolates (VV18 and F17), actinomycetes (C3 and A19), yeast (Y6), and *Lactobacillus* isolate were selected for the development of EM formulation. Enriched photosynthetic bacteria were also included in the formulation. The combination and permutation of all the cultures were evaluated for their ability to degrade paddy straw under solid state fermentation at 30°C for 15 days. The highest FPase activity (1.16 IU/g) and maximum C loss (12.5%) were observed in the treatment receiving a combination of all selected microorganisms.

3.9.3.3 Rapid composting technology of agro-waste at low and high temperatures

Maintenance of viable population of composting microorganisms is a bottleneck in composting of agro-waste when temperatures are either very high (42-45^{0}C in June-July) or very low (5-7^{0}C in December-February) and also when temperature rises to 70^{0}C or more during composting because of exothermic reactions. The issue is being addressed by isolating and characterizing bacterial and fungal isolates having hydrolytic potential from soil and water samples of extreme environments. Soil and water samples from the hot springs (90-95^{0}C) of Manikaran and cold desert (0-4^{0}C) of Rohtang Pass in Himachal Pradesh, and Leh were used for isolating predominant bacterial and fungal isolates.

Six fungal isolates (M22-27) were isolated as predominant culturable population from Manikarn hot spring water samples by processing and incubating them at 70^{0}C. The cumulative hydrolytic enzyme production (Xylanase, CMCase, FPase and Cellobiase) varied from 472 to 820 units/g, with the maximum in M-25 isolate. From Rohtang Pass and Leh region, a total of 12 different fungal isolates were identified (R 28-31 and L82-90) by processing and incubating them at 4^{0}C. The cumulative hydrolytic enzyme



production varied from 677 to 888 units/g and 629 to 773 units/g, with the maximum in R-29 and L-88 isolates, respectively. Using conserved ribosomal sequences, the isolates M-25, R-29 and L-88 were identified as *Byssochlamys nivea, Paecilomyces* sp. and *Eupenicillium crustaceum,* respectively.

Among the high temperature tolerant bacterial isolates, the isolate M 10 recorded the highest CMCase activity and the isolate M 75 the highest cellobiase activity. Hence, for any successful cellulosic bioconversion process, both the isolates have to be used in combination. Amylase activity was maximum in M 48 (0.14 units/mg protein), followed by that in M 10 (0.13 units/mg protein) and M 75 (0.12 units/mg protein) at 65°C. Xylanase enzyme activity was the highest in M 75 at 55°C (0.21 units/mg protein), followed by that in M 10 (0.13 units/mg protein) at 60°C.

3.9.3.4 Bioremediation of polycyclic aromatic hydrocarbons through bioaugmentation and biostimulation

Diverse groups of bacteria with a capability to degrade a range of polycyclic aromatic hydrocarbons (PAHs) were isolated from contaminated sites. On the basis of PAH degradation experiments, three potential microbes, viz., *Serratia marcescens* PAH-L11, *Streptomyces rochei* PAH-13 and *Phanerochaete chrysosporium* VV-18 were selected for consortium development. The microbial combination containing all the three selected microbial strains was found to have maximal microbial activity during growth in Tien and Kirk minimal medium containing PAH mixture (200 ppm). HPLC–based quantitation of PAH-dissipation was also carried out after 7 days of incubation at 35^0 C. In the case of microbial consortia, 50-72% degradation of anthracene, flourene and phenanthrene was observed. Degradation of pyrene was less (39%) compared to other PAHs. In another experiment, glucose, ammonium nitrate, yeast extract and sodium gluconate at 0.1% w/v were supplemented in Bushnell and Haas minimal medium containing PAH mixture (200 ppm). Maximum PAH degradation of 62-98% was observed for yeast extract within 7 days.

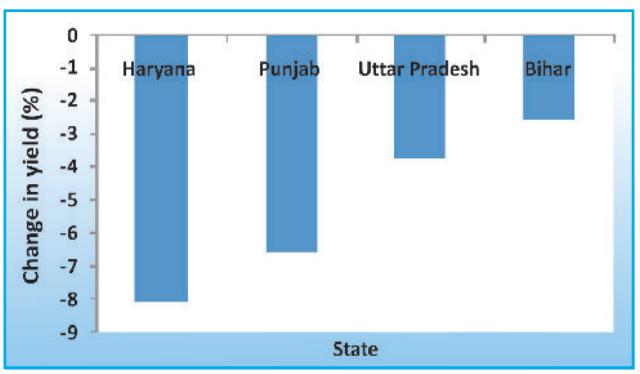
3.9.3.5 Development of novel microbe amended disease suppressive composts

The efficacy of microbe amended paddy straw compost and compost tea formulations for suppressing the diseases caused by plant pathogenic fungal consortium - *Fusarium oxysporum*, *Pythium debaryanum*, *P. aphanidermatum* and *Rhizoctonia solani* was evaluated in tomato. Comparative performance of the fungi challenged treatments revealed the superiority of both the compost mix and compost tea in enhancing the germination and biometrical parameters. Compost tea obtained after amendment with the synergistic cyanobacterium-bacterium combination (*Anabaena oscillarioides* and *Bacillus subtilis*) led to 40-50% enhancement in plant parameters. The amended composts and tea led to 22-28% reduction in disease severity as against the reduction observed in biological control (*Trichoderma* formulation) and chemical control (Thiram-Carbendazim). The activity of the plant defense enzymes, PAL and PPO, was enhanced by 8-10% in the treatments involving the use of amended composts. The studies reveal the potential of such novel microbe–fortified composts as effective biocontrol agents for sustainable and organic agriculture.

3.10 ENVIRONMENTAL SCIENCES

3.10.1 Regional Impacts of Climate Change on Cereal Crops

Climate change is projected to reduce irrigated wheat production in India by ~5% in a 2030 scenario. Losses are likely to be more in Madhya Pradesh (-15%), Uttar Pradesh (-7%) and Bihar (-8%) than in other states. Adaptation to climate change by sowing improved varieties and employing improved input and utilization efficiency not only can offset the negative climate change impacts, but also can improve the yields by about 13% in the 2030 scenario (non-conventional energy use in vogue). Maize yields in monsoon are projected to be adversely affected by rise in atmospheric temperature, but increased rainfall can partly offset those



Impact of climate change on irrigated rice in different states of north India

losses. An analysis done on sorghum also indicated that the yield loss due to rise in temperature is likely to be offset by projected increase in rainfall. However, complete amelioration of yield loss if the temperature rises beyond 2°C may not be attained even after substantial increase in rainfall. The analysis indicated that irrigated rice yield is likely to reduce up to 8% in Haryana, and Punjab, while the reduction in yield is likely be around 3-4% in U.P. and Bihar in the 2020 scenario.

3.10.2 Effect of Elevated Temperature and CO_2 on Growth, Yield and Quality of Crops

Rise in atmospheric temperature (+ 1 to + 3 °C) caused substantial reduction in yield of rice, groundnut and wheat at varying N levels. The crops showed greater thermal sensitivity for reproductive shoot growth than for vegetative growth. Contrary to this, elevated CO_2 (560 ppm) in the air enhanced the biomass and economic yield of rice, groundnut and wheat substantially at low, medium and high N levels owing to increase in leaf area, photosynthetic rate, spikes and grains/spike. Elevated CO_2 caused a reduction of grain protein content in rice and wheat, while it increased under high temperature.

3.10.3 Updated Inventory of Greenhouse Gases (GHG) Emission from Indian Agriculture

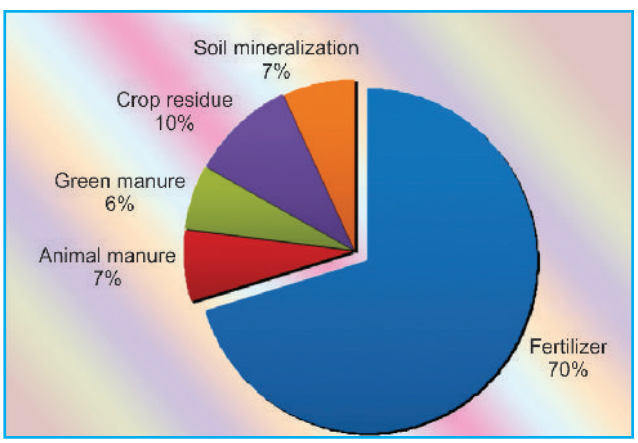
An inventory of GHG emission from Indian agriculture was updated. Indian rice fields covering an area of 43.9 million ha emitted 3.37 million tonnes of CH_4. Total N_2O emission from agricultural soils of India was 0.14 million tonnes. Nitrogenous fertilizer contributed 70% of N_2O emission. Burning of crop residues in field emitted 0.23 million tonnes of CH_4 and 0.006 million tonnes of N_2O.

Greenhouse gas emission (million tonnes) inventory from Indian agriculture

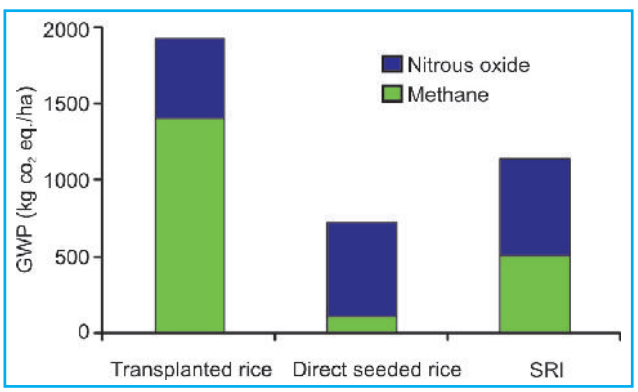
Source	Methane	Nitrous oxide	CO_2 equivalent
Rice cultivation	3.33	-	83.25
Agricultural soil	-	0.14	41.72
Crop residue burning	0.23	0.006	7.54
Total	**3.56**	**0.146**	**132.51**

3.10.4 Mitigating Methane Emission with Conservation Practices in Rice

On-farm experiments showed that the direct-seeded rice (DSR) and the system of rice intensification (SRI) are feasible alternatives to conventional puddled transplanted rice with good potential to mitigate GHG emission. The DSR reduced global warming potential (GWP) by 75% and saved 32% irrigation water compared to the conventional puddled transplanted rice without any yield loss. Human labour use was less by 45% and tractor use by 58% in the DSR as compared to those required for transplanted rice. The SRI reduced the methane emission by 64% and increased the N_2O-N emission by 23% as compared to conventional method. The global warming potential (GWP) was reduced by 28% in the SRI as compared to that in conventional method despite the increase in nitrous oxide. Water saving of 44% was observed with the SRI without any significant decrease in grain yield as compared to that obtained in conventional puddled transplanted rice.



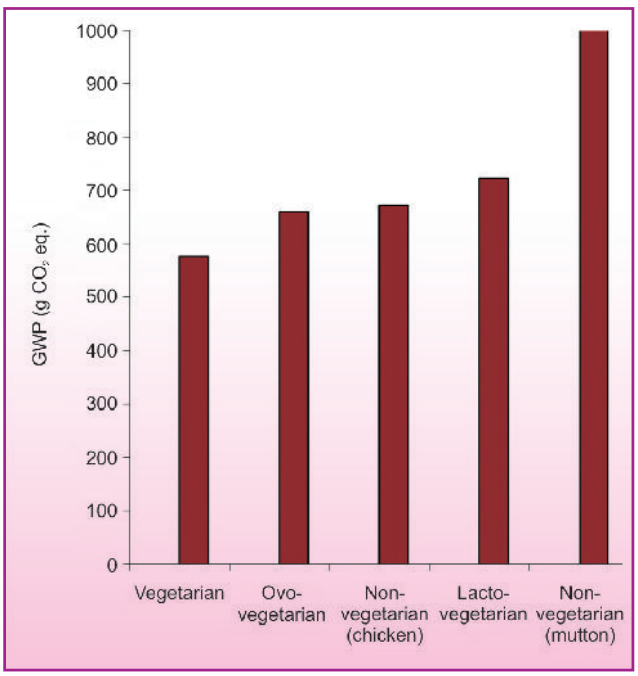
Contribution of different sources to nitrous oxide emission from Indian agricultural soils



Global warming potential in transplanted, direct-seeded rice and system of rice intensification

3.10.5 Carbon Footprint of Indian Foods

An analysis of GHG emission during the life cycle of foods showed that mutton emitted much greater GHG as compared to that of milk (11.9 times), fish (12.1 times), rice (12.9 times) and *chapatti* (36.5 times). A non-vegetarian meal with mutton emitted GHG 1.8 times of a vegetarian meal, 1.5 times of a non-vegetarian meal with chicken and an ovo-vegetarian meal, and 1.4 times of a lacto-vegetarian meal. Change in food habit thus could offer a possibility for GHG mitigation.



Global warming potential of various vegetarian and non-vegetarian meals in India

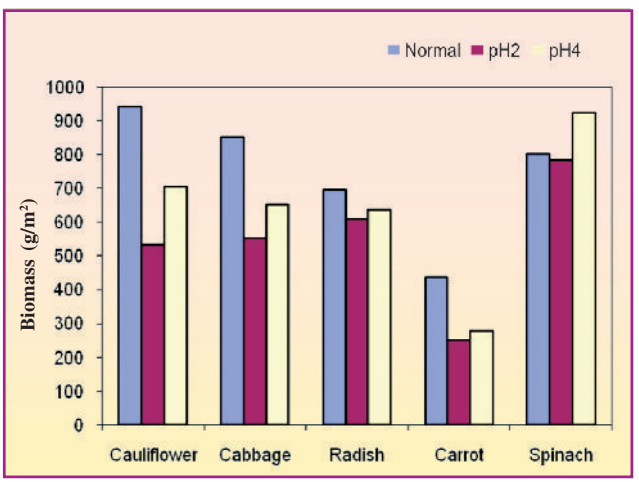
3.10.6 Impact of Air Pollutants on Indian Agriculture

Experiments on rising levels of air pollutants and increasing CO_2 on the growth and productivity of crops showed that an AOT 40 (accumulated over threshold of 40 ppb) of 12.3 ppmv hr led to a 15% decline in rice yield. Activities of antioxidant enzymes, viz., peroxidase, catalase and superoxide dismutase increased, whereas rubisco enzyme activity decreased under elevated ozone concentrations in rice. In chickpea grown under sub-ambient ozone concentration (<10 ppm O_3), the yield increased by 16% as compared to that in ambient levels. Elevated ozone exposure (Ambient + 25-35 ppb) resulted in a decline in net photosynthetic rate and leaf area index at the vegetative and flowering stages in mustard leading to a significant decline in seed yield. The oil content in mustard declined by 14% under elevated ozone as compared to that under control.

Impact of different antioxidants [ascorbic acid (AA), quercetin, (Q) and tagetus (T)] on the virulence potential of pest causing spot blotch disease (*Bipolaris sorokiniana*) was studied under laboratory conditions and on host (wheat crop). AA was the most efficient in retarding the growth of *Bipolaris sorokiniana*, followed by T and Q, respectively.

3.10.7 Effect of Simulated Acid Rain on Productivity of Vegetable Crops

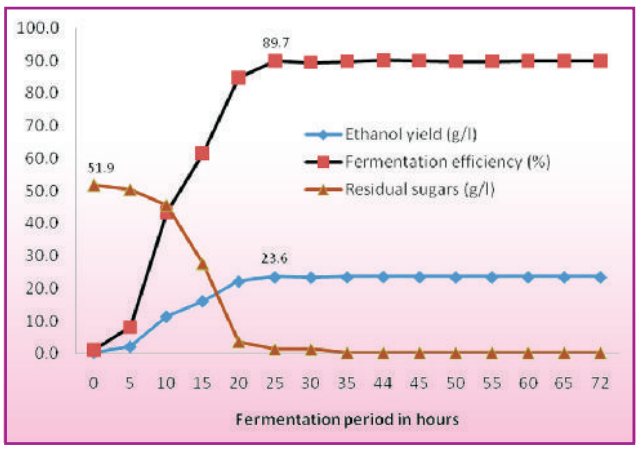
Different vegetable crops, viz., cauliflower, cabbage, potato, radish, carrot and spinach, and wheat varieties, viz., HD 2329 and PBW 343 were grown in pots and sprayed twice with pH 2 and 4 (H_2SO_4) acid solutions during the vegetative growth phase to examine the growth, yield and phytotoxicity response of different crop species to simulated acid rain. The results indicate that growth and yield of almost all the tested crop species declined markedly by acid rain of pH 2 and pH 4 solution, but the effect of pH 4 was marginal as compared to that of pH 2. Among the vegetable crops, carrot, cabbage, cauliflower and potato showed higher degree of sensitivity to acid rain compared to radish and spinach.



Effect of simulated acid rains on yield of different crops

3.10.8 Ethanol from Agri-residues

A cellulosic crop residue (100 g/l) was hydrolyzed by cellulase enzymes from *T. reesei* (20 FPUg/g substrate) at pH 4.8 and 50°C for 60 h. The reducing sugar concentration reached 51.7 g/l after 48 hours of hydrolysis, and prolonged hydrolysis time beyond 48 h helped little in increasing the yield. The reducing sugar rich cellulosic hydrolysate obtained from hydrolysis of corn stover was utilized as the fermentation medium for ethanol fermentation. Kinetic parameters of fermentation indicated that *Pichia stipitis* NCIM 3499 could readily ferment sugars in hydrolysate to ethanol. Within 25 h, 51.9 g /l reducing sugar was fermented to 23.6 g/l ethanol, equivalent to 89.7% of the theoretical yield (based on the theoretical yield of 0.51 g ethanol/g glucose).



Fermentation kinetics of cellulosic hydrolysate at lab-scale bioreactor by the use of *Pichia stipitis* NCIM 3499

3.10.9 Optimization of Parameters for Production of Thermophilic Alkaline Cellulases by Bacteria

Two potential thermophilic and cellulolytic bacteria designated as *B. licheniformis* WBS1 (Accession No. GU590782) and *Bacillus* sp. WBS3 (Accession No. GU590784) were isolated from Bakreshwar hot spring (23° 49' 48''N and 87° 19' 12''E) in Birbhum district of West Bengal, India. The effect of temperature on the carboxy methyl cellualse (CMCase) activity and FPAse activity was determined at various temperatures ranging from 55 to 75°C. *Bacillus licheniformis* WBS1 and *Bacillus* sp. WBS3 produced the maximum CMCase activity of 0.12 IU/ml and 0.08 IU/ml at 65^0C and 60^0C, respectively. On the other hand, both the organisms produced FPAse activity of 0.42 IU/ml and 0.35 IU/ml, respectively at 65^0C only. In terms of buffer pH effect, pH 8.0 was the optimal for CMCase and FPAse, and both the activities declined with further increase in pH. These cellulose enzymes have the potential for use in the production of bio-energy and in textile as well as pulp and paper industry.

4. CROP PROTECTION

Pests and diseases exert a heavy toll on crops, which necessitates the adoption of sustainable crop protection strategies to optimize production. Efforts have been made to develop rapid and reliable diagnostic assays for early detection of pests/pathogens and to identify novel molecules and biocontrol strategies for their management. The transgenic approaches for disease management have also been explored.

4.1 PLANT PATHOLOGY

4.1.1 Genetic Diversity

***Rhizoctonia solani*.** Genetic diversity of *R. solani* isolates (89) originating from leguminous crops from various agro-ecological regions and belonging to different morphological and anastomosis groups (AGs) was assessed using 12 universal rice primers (URPs) and ITS (700bp) regions. Though the isolates were highly variable and clustered into different groups, yet each group included isolates originating from various agro-ecological regions, hosts and AGs.

***Fusarium oxysporum* f. sp. *ciceris*.** Genetic diversity of *F. oxysporum* f. sp. *ciceris* isolates (53) originating from 13 chickpea growing regions was determined on the basis of translation elongation factor (tef, 372bp) region. The isolates shared more than 90% nucleotide sequence similarity with the tef sequences of *F. oxysporum* available in GenBank and were differentiated into two major clusters.

Puccinia triticina A comparison of ITS regions (650bp) of four leaf rust races (77-5, 104-2, 12-2 and 12-5) revealed that race 77-5 had 84% nucleotide sequence similarity with the already available sequences of leaf rust in NCBI.

4.1.2 Race Profiling

Virulence typing of rust pathogens prevailing in southern India. Samples analysed for identifying the pathotypes prevailing in Wellington area of Nilgiri hills in Tamil Nadu showed the dominance of brown rust race 77-5 (121R63-1), followed by 77A (109R31), 77-8 (253R31), 17(61R24) and 77-7 (121R127). Two pathotypes of black rust, 40A(62G29) and 40-1(62G29-1) prevailed in equal proportions. The virulence spectrum of two new pathotypes of leaf rust resembled race 77-5 (121R63-1). Nurseries planted at Shimla, Delhi, Indore and Wellington did not show the presence of Ug 99.

***Fusarium oxysporum* f. sp. *ciceris*.** Virulence profile of *F. oxysporum* f.sp. *ciceris* (chickpea wilt, 66 isolates) studied on a new set of 10 different cultivars of chickpea showed differential responses. The isolates were categorized into eight groups which may be considered as new races or pathotypes from India.

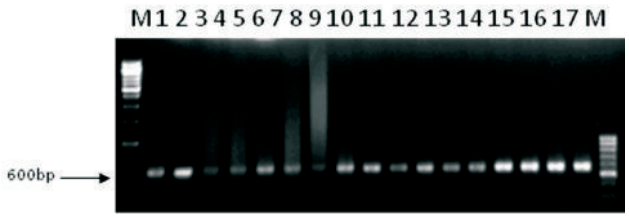
Race typing of *F. oxysporum* f. sp. *ciceris* originating from different locations

Race	Differential cultivars	Location
1	C 104 & GPF 2	Andhra Pradesh & Punjab
2	C 104 & KWR 108	Chhattisgarh, Jharkhand & Madhya Pradesh
3	BG 212 & GPF 2	Gujarat, Karnataka, Madhya Pradesh & Uttar Pradesh
4	JG 74	Madhya Pradesh & Uttar Pradesh
5	BG 212 & KWR 108	Uttar Pradesh, Delhi & Maharashtra
6	WR 315 & GPF 2	Rajasthan
7	WR 315 & KWR 108	Haryana, Punjab & Rajasthan
8	GPF 2 & DCP 92-3	Rajasthan

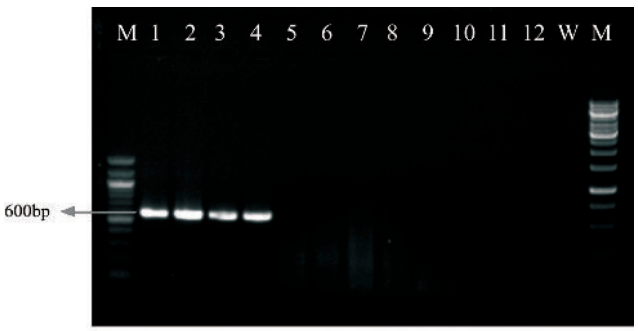
***Magnaporthe oryzae*.** Fifteen isolates of rice blast pathogen, *Magnaporthe oryzae*, collected from Basmati growing regions, when tested on a set of 24 monogenic rice blast differentials, revealed that Mawana isolate (UP) was the most virulent, i.e., compatible with 20 *R*-genes followed by New Delhi and Nagina isolates, which were virulent on 18 and 16 *R*-genes, respectively.

4.1.3 Molecular Diagnosis

Bipolaris sorokiniana. A Sequence characterized amplified region (SCAR) marker (RABSF1/RABSR2) developed for species specific diagnostics was validated for selectivity and sensitivity in detecting *B. sorokiniana*. The detection limit of PCR was 50 pg DNA, which had enabled the detection even in pre-symptomatic wheat leaves. The marker was also able to detect the pathogen in infected field samples and infested soil. Southern blot analysis confirmed the specific diagnostics.

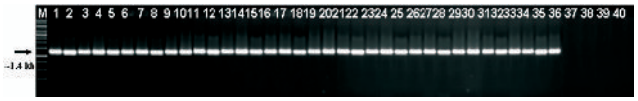


PCR amplification of different isolates of *Bipolaris sorokiniana* by the use of RABSF1/ RABSR2 primers. Lanes (from left to right): M (1kb marker); 1-17 (different isolates of *B. sorokiniana*); and M (100bp marker)



Agarose gel showing specificity of primer set RABSF1/RABSR2 to *Bipolaris sorokiniana*. Lanes (from left to right): M (100bp molecular marker, Biolab); 1-4 (DNA template of *B. sorokiniana* isolates); 5-11 (other species of *Bipolaris*); 12 (healthy wheat leaf DNA); W (sterile water); and M (1 kb molecular marker, Fermentas)

***Fusarium oxysporum* f. sp. *ciceris*.** Two sets of (SCAR) markers (SC-FOC1F: CCTCGCCAGCCTTGTACTTGCG; SC-FOCIR: CGGTACCGGATGGCCC TGCAA and SC-FOC2F: ATGGCTCAGTGAGGCGTCCGGA; SC-FOC2R: GTGTGGGGGATAGAGCATTG) developed from the sequences of the fragments amplified by RAPD primers OPA 11 and OPA 07 were found specific to *F. oxysporum* f. sp. *ciceris* causing chickpea wilt and produced an amplicon of 1.4 kb and 1.3 kb, respectively. The markers were validated against 36 isolates collected from different locations of India.

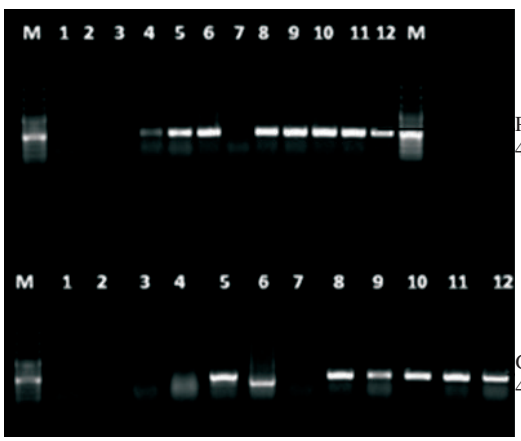


PCR amplication products of genomic DNA of *F. oxysporum* f. sp. *ciceris* isolates by the use of *Foc* specific SCAR markers SC-FOC1F and SC-FOC1R. Lanes 1-36(*Foc* isolates); lane 37(*F. oxysporum* f. sp. *lycopersici*); lane 38 (*F. udum*); lane 39(*Rhizoctonia solani*); lane 40 (*R. bataticola*); and M (1kb DNA ladder)

***Fusarium* spp.** Based on ITS sequence comparison (550 bp), 19 *Fusarium* spp. isolates associated with bakanae disease of rice were identified as *Fusarium moniliforme*, *F. fujikuroi* and *F. proliferatum.*

Ralstonia solanacearum. A PCR based detection technique was developed for bacterial wilt pathogen (*Ralstonia solanacearum),* using primer sets, Hrp_rs2F and Hrp_rs2R. The primer sets amplified 323bp fragment of hrpB gene regions. The sensitivity limit of the technique was 2.0×10^2 cfu /ml of *R. solanacearum*.

***Pomegranate bacterial blight pathogen*.** A PCR based detection technique was developed for pomegranate blight bacterium from infected tissue using two primer sets, Gyr 5 & Gyr 6 and Pag 3 & Pag 4 derived from Gyrase B gene and 16SrRNA region, respectevely. The primer sets Gyr 5 & Gyr 6 amplified 491 bp product of Gyrase B gene regions, while Pag 3 & Pag 4 amplified 430 bp of the 16SrRNA region. The sensitivity of the technique was as low as 10^2 cells per g of leaf tissue.

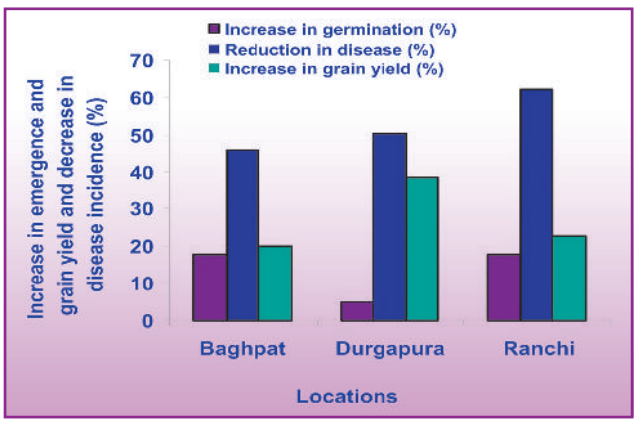


Specific amplification of pomegranate blight bacterium by the use of primers Pag3 and Pag4 and Gyr5 and Gyr6. M (marker 100bp ladder); 1(uninoculated healthy leaf); 2-5(leaf inoculated with Solapur isolate L2 with 1, 10, 50, 100 cells per gram of leaf tissue); 6(positive control-DNA of isolate L2); 7(negative control); 8-11(leaf inoculated with Delhi isolate L5); and 12(positive control-DNA of isolate L5)

SEM based detection of Ustilaginoidea virens. Scanning electron microscopic studies on surface morphology of spores of different isolates of *U. virens* revealed differences in surface ornamentations, which could be used to differentiate the strains.

4.1.4 Biocontrol

Validation of Trichoderma based bioformulation. Seed treatment with Pusa 5SD @ 4 g/kg increased the seed germination (4.9-17.8%) and the grain yield (20.0-38.5%) and decreased the disease (wilt/root rot) incidence (45.8-62%) in chickpea in farmers' fields in Baghpat (UP), ARS, Durgapura (Rajasthan) and BAU, Ranchi (Jharkhand).



Effect of seed treatment with Pusa 5 SD (*T. harzianum*) on seed germination, disease incidence and grain yield of chickpea

Validation of Chaetomium based bioformulation. A formulated product from *C. globosum* (Pusa Cg2WP), found effective against late blight of potato during 2009-10, was tested again during 2010-11 at CPRI Regional Station, Modipuram. Three sprays of the bioformulation were found effective in controlling the disease up to 30% and increasing the yield up to 10 per cent.

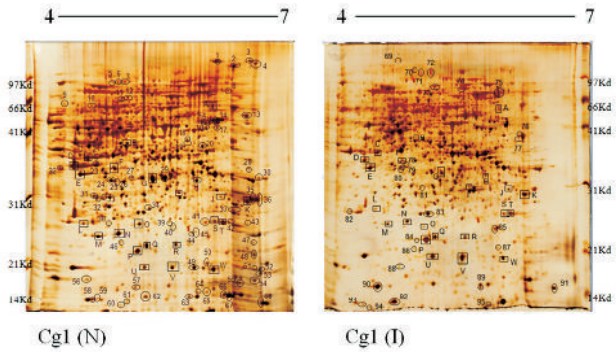
Testing of *Chaetomium globosum* based formulation (Pusa Cg2WP) against late blight of potato under field conditions

Treatments*	Blight Cg2 WP (0.2%)(%)	Reduction in severity (%)	Yield t/ha
T_1	12.5 (60)**	78.26 (29.41)	41.95
T_2	20.0 (45)	65.21 (47.05)	40.54
T_3	57.5 (85)	-	38.22

*T_1: Spray before, at and after the onset of late blight (at 8 days interval); T_2: Dithane M-45; 0.25% (3 sprays); T_3: Control

** Values in parentheses are disease severity at maturity.

Proteomics studies in Chaetomium globosum. Total cell protein profile of mycoparasitic strain of *C. globosum* under normal and induced conditions obtained through 2D-gel electrophoresis showed 60 protein spots in normal condition and; 27 spots in induced condition. Twenty-three proteins were differentially expressed under both the conditions. Some of the proteins selected from all the three categories were characterised through MALDI-TOF and LCMS analyses, of which 50% matched with *C. globosum* protein available in the data base having mapkinase and other activities.



2D-gel electrophoresis of total proteins extracted from *C. globosum* strain Cg 1 normal proteins (N) and induced proteins (I). Spots 1-68: present only under normal conditions; spots 69-65: present only under induced conditions; and spots A-W: differentially expressed and present in both N and I but showing different levels of expression

4.1.5 Evaluation of Genotypes for Resistance

Wheat. Of 125 wheat entries screened against Karnal bunt disease, 54 showed disease severity ranging from 0.44% to 35.29%; 71 entries remained free from infection. Field evaluation of wheat entries against leaf rust pathotypes, which included PPSN (541 entries), PDSN (648 entries) and IPPSN (1558 entries) showed more than 1000 resistant entries. Through multilocation evaluation of 545 advance wheat entries of IARI (under PDSN), 38 lines were identified as highly tolerant to yellow rust, brown rust and black rust. Entries, viz., HW 4201, WTT 252, DL 1314, DL 1315, DL 1317, GP S5, GP S41, CL 3138, CL 3143, CL 3144, CL 3163 and DL 2050 were free from all the three rusts across the test locations. Of 297 wheat genotypes developed by IARI, ten entries were resistant to all three rusts at seedling and adult stages.

Twenty-six of 108 entries in AVT 2nd year, and 47 of 140 entries in AVT Ist year showed least infection of yellow rust at adult plant stage. Some of the IARI entries included in AVT 2nd year, viz., HD 2967, HD 3016, HI 563, HI 8691 (d), HI 8627 (d) and HW 5207 possessed a high degree of adult plant resistance to yellow rust pathotype 78S84.

Out of 316 *durum* wheat genotypes showing field resistance to stem rust at Regional Station, Indore,165 showed resistance to both the pathotypes in seedlings as well as in adult-plants when tested in glasshouse (seedling stage) and in isolated nurseries in the field (adult-plant stage) with two stem rust pathotypes 40A and 117-6.

A total of 110 *durum* wheat genotypes showing field resistance to both the pathotypes of stem and leaf rusts when tested with eight *durum*-specific leaf rust pathotypes, viz., 11, 12-2, 12-5, 104-2, 104-3, 106, 162-2, and 162-3, showed diversity for resistance. Forty-two genotypes showed resistance to all the eight leaf rust pathotypes, while 26 were resistant to all except to the pathotype 12-5.

***Maize*.** Of 265 elite maize genotypes evaluated against maydis leaf blight (MLB, *Bipolaris maydis*) and banded leaf sheath blight (BLSB, *Rhizoctonia solani*), 80 entries exhibited resistance reaction against MLB disease, 22 entries against BLSB, and 10 entries, namely, DMR 1249, DMR 1250, DMR 1268, DMR 1275, DMR 1298, DMR 1315, DMR 1316, DMR 1382, DMR 1402 and DMR 1423 against both the diseases.

Of 200 inbreds from the Directorate of Maize Research (DMR) evaluated against MLB and BLSB, 27 entries showed resistance reaction against MLB and 32 against BLSB disease. Only 7 entries, viz., HKI 1352-5-8-9, CLQRCYQ-47-B, PFSR-R3, PFSR-R9, PFSR-S3, PFSR-S3 and CM 117-3-4-1-2-3-1 were resistant to both the diseases. Of 57 entries developed by IARI breeders, only16 entries showed resistance reaction against MLB disease. Two entries, viz., DL-200347-2 and DL-200408-2 were resistant to BLSB as well as MLB diseases. Under the ICAR-CIMMYT collaborative programme (CSISA project), of 372 inbreds and 102 hybrids evaluated against BLSB, 23 inbreds and 9 hybrids showed resistance reaction.

***Rice*.** Two rice varieties, Swarna and Aditya, were identified as resistant against sheath blight among 265 entries from the Directorate of Rice Research, Hyderabad.

***Legumes*.** In chickpea, five genotypes, namely, BG 2086, G 3001, BG 3003, IPC 05-28 and IPC 04-98 were resistant against *Fusarium* wilt, while only one genotype GLK 26153 was resistant and 7 genotypes GL 26054, GLK 24092, GLK 24096, PbC 1, GL 24021, GL 23094 and GG 1390 were moderately resistant to *Ascochyta* blight. Nine urdbean (P 702, P 713, P 1052, P 1053, P 1055, P 1056, P 1059, P 1061 and P 2051) and two mungbean (P 124 & P 125) entries showed multiple disease resistance.

***Papaya*.** Screening of papaya cultivars for *Papaya ring spot virus* (PRSV) resistance was undertaken. Four Pune selections, viz., PS 1, PS 2, PS 3 and PS 5 were identified as PRSV tolerant under Pune conditions. Three selections, i.e., PS 1, PS 2 and PS 3 were also evaluated in terms of horticultural traits. One of the local collections showing PRSV tolerance till harvest was named Local Selection 1 (LS 1). Maximum fruit yield (47 kg/plant) was obtained from PS 1 followed by PS 2 and PS 3 (37 kg/plant).

4.1.6 Epidemiology and Disease Management

***Action and biosafety of nano-pesticides*.** ID_{50} value of nano-hexaconazole ranged from 0.001 to 0.1ppm when tested against 21 *R. solani* isolates. Maximum inhibition of radial growth of *R. solani* was recorded in nano-hexaconazole (71.1%) at 0.1 ppm as compared to that in commercial hexaconazole (41.8%) at 0.1ppm. Highest inhibition of conidial germination of *Erysiphe cichoracearum* was recorded in nano-sulphur (64%) followed by that in sulphur 80 WP (26%), 'AR' sulphur (25%) and Canadian sulphur (22%).

Pomegranate bacterial blight. A detached leaf assay technique was developed to test the pathogenicity of bacterium isolated from bacterial blight affected pomegranate tissue.

Tomato wilt. *Ralstonia solanacearum* population originating from tomato, brinjal, capsicum, chilli, and potato from Himachal Pradesh, Jammu & Kashmir, Uttarakhand, Jharkhand, Orissa and West Bengal was predominantly identified as Biovar 3. Occurrence of Biovar 4 was also observed in tomato and brinjal.

4.1.7 Viral and Phytoplasmal Diagnosis

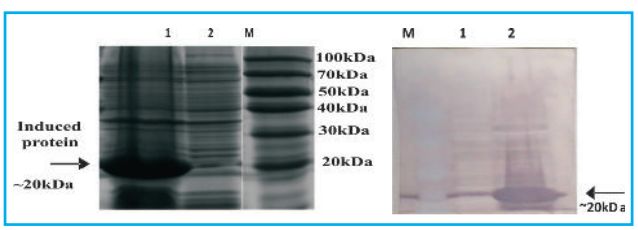
***Toria phyllody*.** Toria phyllody (TP) was transmitted either by grafting or from dodder to toria and other nine rapeseed/mustard species. Transmission of TP phytoplasma

to periwinkle (*Catharanthus roseus*) was successful only through dodder and no transmission was observed in tomato (*Lycopersicon esculentum*) and brinjal (*Solanum melongena*). TP phytoplasma was detected in *Laodelpax striatellus*, a plant hopper found abundantly in toria field, which indicated that this plant hopper might be a potential vector for TP phytoplasma.

A rapid and simplified nitrocellulose membrane (NCM) based real time PCR detection protocol for 16SrIX group phytoplasma infecting toria and periwinkle was developed. Threshold cycle (C_T) values ranged from 29.90 to 30.60 in toria and from 26.01 to 27.22 in periwinkle plants.

Garlic virus X. Allexivirus *(Garlic virus X)* in garlic cultivar G282 was identified based on coat protein (CP) gene. The CP gene was 732 nt long (HQ822272) potentially encoding a protein of 244 amino acids.

Broad spectrum antibodies for potyviruses. The conserved region of coat protein (CP) of *Papaya ring spot virus (PRSV)* (~528bp) was mobilized into protein expression vector pET-28a at specific restriction sites. The expressed recombinant protein (~20kDa) was purified and used for production of polyclonal antibodies for the detection of *Bean yellow mosaic virus, Zucchini yellow mosaic virus* and PRSV affecting agricultural and horticultural crops.



Expression of recombinant coat protein of Potyvirus (PRSV) Lane 1 (after induction); lane 2 (before induction); and M (protein marker)

Western blot of expressed coat protein Potyvirus (PRSV). Lane 1 (before induction); lane 2 (after induction); and M (protein marker)

4.1.8 Viral Genomics

Potato virus Y (PVY). The complete genome of a PVY isolate (Del 66) serologically similar to O strain and biologically similar to N strain, was sequenced. The genome was 9674 nucleotide long and was most closely related to a US strain (DQ008213).

Potato virus X (PVX). PVX was isolated from naturally infected potato plants from an experimental field of IARI and transmitted to *Nicotiana benthamiana* and *Gomphrena globosa*, which produced the symptoms of mosaic and local lesion, respectively. The complete genome of PVX was 6435 nt long and contained five ORFs (RdRp, TGB1, TGB2, TGB3 and CP). The Indian isolate was closely related to the Asian strains with 95.1-97.1% sequence identity, whereas it was highly divergent from the American strains sharing only 77.2% sequence identity. This is the first report of complete genome sequence of PVX occurring in India.

Symptoms of Potato *virus X* on *Solanum tuberosum* (A), *Nicotiana benthamiana* (B), and *Gomphrena globosa* (C), PVX virion (D)

Cucumber mosaic virus (CMV). Complete genome of RNA2 segment of CMV (Delhi isolate) was 3042 nt long (GU111228) and contained two open reading frames (ORFs) encoding the 2a protein (RNA polymerase) required for viral replication, and 2b protein, an RNAi suppressor. A comparative sequence analysis revealed that RNA2 of CMV-ND isolate shared 88.2-99.1% nucleotide sequence identity with other CMV subgroup 1B isolates.

4.1.9 Transgenic Resistance

Artificial micro RNA induced resistance against leaf curl. Artificial micro RNA based construct amiRAV1 exhibited transformation efficiencies of 68% and 62% in tobacco and tomato (Pusa Early Dwarf), respectively. Sixty-three per cent of amiRAV1 derived tomato transformants showed no symptoms, suggesting that the transgenic plants were resistant. The amiRAV1 construct transformed tobacco plants were also resistant (66%) to virus infection, while the vector-alone transformed (control) plants showed typical leaf curl symptoms.

Role of pathogenicity determinants (microRNA) in pathogenesis. Micro RNA profiling of leaf curl affected tomato seedlings was carried out. Two developmental pathways controlling leaf and root development and one defense pathway through auxin and jasmonic acid signaling were studied at different intervals of infection.

Rhizoctonia solani. To develop RNAi based management strategy for sheath blight of rice, β-tubulin gene (1642bp) was amplified from *R. solani* isolate RS4 using primers 5′ ACCAGATTGGTGCCAAGTTC3′ & 5′ TTCGTCGCGAGTAGTTAGA3′ and sequenced by cloning in pGEMT easy vector (HQ908656).

4.2 ENTOMOLOGY

4.2.1 Insect Pest Management

4.2.1.1 Cereals

Among the insecticides, viz., buprofezin + acephate (20%+50%) @ 595 g a.i./ha, buprofezin 25 SC @ 200 g a.i./ha, acephate 95SG @ 562 g a.i./ha and monocrotophos 36 WSC @ 500 g a.i./ha evaluated against the insect pests of rice during *kharif* 2010, only acephate 95 SG treated crop significantly lowered the infestation by rice leaf folder. Buprofezin was most effective against planthoppers. All the insecticide treatments yielded significantly more than untreated control. Buprofezin recorded the highest yield followed by acephate, buprofezin + acephate and monocrotophos.

Studies on the impact of climate change on brown plant hopper (BPH) dynamics and crop-pest interactions revealed that developmental period from egg hatching to adult longevity decreased from 46.8 to 18.40 days with an increase in temperature from 19 to 31 °C. However, the corresponding duration of development was found to be higher at 33±1 °C than at 31±1 °C. A mechanistic population simulation model developed was validated with BPH field infestation data at New Delhi and Aduthurai, Tamil Nadu (R^2= 0.958, RMSE = 1.87%).

The BPH population dynamics model was coupled to Info Crop-rice model. The validated model was used to simulate the impact of 0.5, 1, 1.5 °C rise in average temperature with 410ppm CO_2, and 2, 2.5 and 3 °C rise in temperature with 450ppm CO_2 on BPH population as well crop-pest interactions compared to that in current ambient conditions both at New Delhi and Aduthurai. The projected climate change scenario indicated that by 2020, BPH population would not be influenced much at New Delhi during *kharif*. It would decline only by 3.5% in 2020 but by 2050 there would be 9.3-14.0% decrease. On the other hand, BPH population would decline marginally (<1%) by 2020 at Aduthurai during *rabi* and to an extent of 2.1-3.5% only even by 2050. The simulations revealed decline in rice yield under climate change even without pest stress.

Twenty-five sorghum genotypes evaluated for resistance to stem borer *Chilo partellus* and associated morphological traits revealed that seedling vigour was significantly and negatively associated with dead heart formation (r = -0.55), shoot length was significantly and positively associated with leaf damage rating (r = 0.50), numbers of *C. partellus* recovered were significantly and positively associated with pigmentation score, leaf glossiness, number of exit holes, shoot length, tunnelling length, and number of tunnels. Sorghum genotypes ICSV 25022, ICSV 25066, ICSV 700, ICSV 708, ICSV 717, IS 2123, IS 4757, IS 5470, and IS 2205 were moderately resistant to *C. partellus*.

Efficacy of insecticides against leaf folder and planthoppers on Pusa Basmati 1

Treatment	Active ingredient (a.i/ha)	Folded leaves (%)	Planthoppers/10 hills			Yield (kg/ha)
		25 DAT	37 DAT	52 DAT	57 DAT	
Buprofezin+Acephate (20% + 50%)	595 g	7.47(15.80)*	29.12(5.38)	141.5(11.89)	22.65(4.59)	3471
Buprofezin 25 SC	200 g	8.70(17.10)	27.5(5.24)	151.25(12.89)	14.25(3.70)	3640
Acephate 95 SG	562 g	6.16(14.36)	26.0(5.10)	111.0(10.54)	19.75(4.4)	3529
Monocrotophos 36 WSC	500 g	7.02(15.30)	29.75(5.45)	118.75(10.9)	27.5(5.24)	3360
Untreated control	Water spray	9.39(17.84)	26.75(5.17)	151.75(12.32)	54.0(7.35)	2781
CD(P < 0.05)	3.05	NS	NS	1.54	521.6	

* Figures in parenthesis are transformed values

4.2.1.2 Cotton

Field trials were conducted to evaluate different levels of refugia (non-Bt cotton) in Bt cotton hybrid MRC 7017 belonging to Bollgard II during the *kharif* season of 2010. Bt cotton was infested significantly by whitefly amongst all other sucking pests. The shoot damage due to *Earias* spp. was high (15.7%) in non-Bt cotton whereas Bt cotton was completely free in 81-day old crop. Although the incidence of bollworms was less, the damage to seed cotton (in terms of *kapas* weight) was 55.6% in Bt cotton and 37.4% in non-Bt cotton in the first picking of 153-day old crop, 24.4% in Bt cotton and 29.7% in non-Bt cotton in the second picking of 195-day old crop, 15.5% in Bt cotton and 25.0% in non-Bt cotton in the third picking of 246-day old crop, and 13.5% in Bt cotton and 29.5% in non-Bt cotton in the fourth picking of 268-day old crop. The non-Bt cotton and Bt cotton yielded seed cotton of 20.9 t/ha and 31.2 t/ha, respectively.

4.2.1.3 Vegetables

Cauliflower variety PSBK 1 was border-cropped with sunflower variety KBSH 1 to study the effect of change in microclimate on natural enemies and incidence of insect pests, viz., aphids, *Lipaphis erysimi* and Diamondback moth (DBM), *Plutella xylostella*. This border cropping was effective in managing the aphid population owing to the increased activity of *Coccinella* beetles (2.67/plant) on border crop and their higher number in the main crop (1.53/ 5 plants) as compared to 0.61/ 5 plants in the sole crop.

In a field experiment, five intercropping systems with two sprays each of Neembaan (3 ml/l) and spinosad (75 g a.i./ha) evaluated against insect pests of cabbage showed that DBM population/plant was minimum in cabbage intercropped with marigold (3.41) followed by cabbage intercropped with coriander (3.48) and onion (3.75) as against 6.42 in sole crop. Further reduction in population of DBM was observed in intercropping with onion (2.45) and coriander (2.64) supported by two sprays, each with Neembaan and spinosad.

Among different synthetic and botanical pesticides evaluated against insect-pests of capsicum, imidacloprid 200 SL and acephate 75 SP were found superior to other synthetic and botanical pesticides against the aphid *Myzus persicae* but higher vegetable yield was obtained with acephate 75 SP.

Management of sucking pests in capsicum under protected cultivation

Treatment	*Per cent aphid infestation		Vegetable yield (t ha^{-1})
	Plants	Twigs	
Acephate 75 SP (1.0 g/l)	16.1 (16.13)	20.90 (21.43)	36.12
Imidacloprid 200 SL (0.5 ml/l)	6.2 (11.36)	1.00 (5.67)	35.64
Control	100.00 (90.00)	100.00 (90.00)	5.96
CD P=0.05	13.45	30.54	5.98

*Figures in the parentheses are arc sin values

4.2.2 Storage Entomology

Relative toxicity of microwave heat treatment studied against all the four stages, viz., egg, larvae, pupae and adult of pulse beetle, *Callosobruchus maculatus* showed that mortality at all stages was dose dependent, and based on LD_{50} values, pupal stage (2350.618 J/g) was most susceptible followed by early larval stage. Adult stage was the least susceptible. All the life stages except adults showed complete kill in 120 seconds.

4.2.3 Biological Control

Age-specific cohort life table analysis of *Phenacoccus solenopsis* revealed that the maximum female fecundity was 140.69 female nymphs/female/week during the 5th age interval (28-35 days). The gross reproductive rate (GRR) was 242.07 females/female/generation while the net reproductive rate (R_0) was 123.41 females/female/ generation. Mean generation time (T), the intrinsic rate of natural increase (r_m) and finite rate of increase (r_m) were 28.34 days, 0.17 females/female/day and 1.18 females/ female/day, respectively. The mortality rate was relatively higher for the first instar crawlers, which declined sharply in subsequent instars. The life cycle duration was 26.25 ± 0.5 days at 27±2 °C and 65±5% RH. The average fecundity was 351 ± 44.73 young ones with an average oviposition period of 11.75 ± 0.96 days.

Biology of four important coccinellid predators, viz., *Hyperaspis maindroni*, *Cryptolaemus montrouzieri*, *Nephus regularis* and *Scymnus coccivora* associated with exotic mealy bug, *P. solenopsis* infesting cotton and other crops studied under laboratory conditions of 27 ± 2 °C

and 65 ± 5% RH showed that the developmental time (including adult longevity) of *C. montrouzieri* was significantly longer (97.80 ± 1.32 days) than that of the rest of the three species, and females generally had longer developmental durations. In all the four species of coccinellids, females started egg laying during the 2nd week of their adult life with peak egg laying occurring between 3rd and 6th weeks.

Among the insecticides tested for their impact on larval parasitoid, *Bracon brevicornis,* carbosulfan, bifenthrin, indoxacarb and λ cyhalothrin were found more toxic than other insecticides.

Efficacy of different insecticides against *Bracon brevicornis*

Name of the insecticide	LC_{50} (ppm)	Fiducial limit	
		Min	Max
Imidacloprid	95	0.004	0.0178
Acetamiprid	41	0.0030	0.0056
Thiamethoxam	92	0.0144	0.0257
Bifenthrin	5	0.0003	0.0007
Carbosulfan	1	0.0001	0.0002
λ cyhalothrin	2	0.0001	0.0002
Indoxacarb	6	0.0004	0.0010
Pymetrozine	1056	0.0610	0.1828
Buprofezin	374	0.0284	0.0494

Further bifenthrin showed more toxicity to the adults of *Coccinella septempunctata* compared to thiamethoxam and imidacloprid. However, the grubs of the same coccinellids were 10 times more susceptible to imidacloprid than their adults.

4.2.4 Insect Physiology

Studies on the inheritance of Cry1Ac resistance were undertaken using DNA based specific molecular marker to detect the presence of mutants in the field population of *H. armigera*. The amplification showed that the susceptible parent had a 588 base pair (bp) fragment. The seventh generation of isofemale line developed from susceptible strain and used for crossing experiments was homozygous (SS). The individuals collected from Bt cotton fields in Bharuch specifically had a 553 bp fragment. In addition to this, some individuals (12%) were found to have a 717 bp fragment before the selection in laboratory. Hence, two alleles, r9 (carrying 553 bp) and r10 (carrying 717 bp) of BtR gene, were identified in the resistant BH-R strain.

Sixty-one larvae from the backcross progeny and 55 larvae from the F_2 progeny were chosen randomly for cadherin genotyping. As expected in the backcross, nearly 57.4% individuals (35 out of 61) were carrying the resistant alleles (either r9r9 or r9r10) and nearly 42.6% (26 out of 61) were heterozygous (either r9S or r10S). The c^2 test of the goodness of fit between the observations and predictions under the assumption of monofactorial inheritance did not significantly differ from the expected 1:1 ratio (c^2 = 1.328, df = 1, at P = 0.05).

Similarly, in F_2 of the reciprocal cross, individuals segregated in the ratio of 18:21:16 (RR:RS:SS), where one-fourth individuals carried the resistant specific alleles (r9r10 or r9r9), one-half carried heterozygous alleles (r9S or r10S) and the remaining one-fourth, susceptible specific alleles (SS). The c^2 test of the goodness of fit did not significantly differ from the expected 1:2:1 ratio (c^2 = 3.209, df = 2, at P = 0.05).

Different biological developmental parameters of *Leucinodes orbonalis* on artificial diet and brinjal fruit.

Diet (day)	Larval period (day)	Pupal period (%)	Pupation (%)	Adult emergence	Total Life cycle [egg-Adult] (day)
Diet-1	15.78 ± 0.11	6.33 ± 0.13	35	67	25-27
Diet-2	16.78 ± 0.03	7.83 ± 0.36	30	77	26-29
Diet-3	14.74 ± 0.23	8.16 ± 0.34	33	89	24-26
Diet-4	15.26 ± 0.23	11.0 ± 0.32	31	89	28-30
Diet-5	15.86 ± 0.1	6.83 ± 0.21	54	75	24-26
Natural (Brinjal)	14.0 ± 1.00	7.00 ± 0.11	57	64	23-25

Five artificial diets were developed and evaluated for mass rearing of brinjal shoot and fruit borer *Leucinodes orbonalis*. The evaluation of diets was carried out along with natural host fruits as larval food, to determine the best diet on the basis of biological developmental parameters such as larval and pupal period, pupation (pupae/larvae ratio) and adult emergence (adult/pupal ratio) percentages and fecundity as well as viability of eggs. Diet-5 was found to be the best and on par with natural host fruit, brinjal and thus can be used as a good replacement of the natural host for mass rearing of *Leucinodes*.

4.2.5 Insect Toxicology

Susceptibility of *Spodoptera litura* collected from cabbage fields of Jaipur and Sonepat, evaluated against commercial formulations of insecticides, viz., cypermethrin, indoxacarb, acephate, flubendamide, l cyhalothrin, emamectin benzoate, bifenthrin, deltamethrin, chlorantraniliprole, spinosad, and novaluron under laboratory conditions showed that Jaipur population had less susceptibility to most of the insecticides as compared to Sonepat population. Among the evaluated insecticides, emamectin benzoate was found to be the most toxic followed by indoxacarb against both the populations.

Laboratory studies on the relative susceptibility of 7-day old mealy bug, *Phenacoccus solenopsis* against different insecticides by leaf residue method indicated this species to be more susceptible to buprofezin (LC_{50} 50ppm) than to thiamethoxam (LC_{50} 246 ppm) and imidacloprid (LC_{50} 332ppm).

A laboratory formulated wettable powder of *Bacillus thuringiensis* var. *kurstaki* evaluated against the third instar larvae of *S. litura* under laboratory conditions exhibited LC_{50} value as 480ppm as against 550ppm of the registered commercial product. A self-suspending water dispersible tablet formulation of *B. thuringiensis* var. *kurstaki* prepared using low cost ingredients and evaluated under laboratory conditions against the third instar larvae of *S. litura* performed better than commercial wettable powder formulation with LC_{50} values of 2.599×10^{-8} and 3.326×10^{-8}, respectively.

4.3 NEMATOLOGY

4.3.1 Biodiversity

Identification and documentation of nematode biodiversity in Himachal Pradesh and Wellington, (Tamil Nadu) was done. Root-knot nematode, *Meloidogyne incognita* was predominant on vegetables, and *Helicotylenchus* and *Hoplolaimus* on wheat. *Scutellonema brachyurus* was documented from Wellington. Potato cyst nematodes (*Globodera rostochiensis* and *G. pallida*) were detected on CPRI research farms at Kurfi. Farm areas of IARI regional stations at Amartara, Tutikandy and Wellington were found to be free from potato cyst nematodes.

A survey of the potato growing areas around Delhi and Hapur (Uttar Pradesh) revealed the presence of only ectoparasitic nematodes, viz., *Tylenchorhynchus, Helicotylenchus* and *Hoplolaimus.* The presence of root-knot nematodes, *Tylenchorhynchus* spp. and *Hoplolaimus* spp. were seen on tuberose grown in U.P. The occurrence of *Meloidogyne graminicola* on rice in Andaman Islands was reported for the first time.

4.3.2 Entomopathogenic Nematode

Interspecific interactions among entomopathogenic nematodes (EPNs), *Steinernema thermophilum*, *S. glaseri* and *Heterorhabditis bacteriophora* with 4th instar larvae of greater wax moth (*Galleria mellonella*) showed the dominance of *S. glaseri* at 27 ^{o}C, and *S. thermophilum* at 35 ^{o}C. Evaluation of the compatibility of *S. thermophilum* with four different dozes of twelve insecticidal formulations revealed that, except three, namely, Hostathion (triazophos), Dursban (chlorpyrifos) and Thiodan (endosulfan), all other formulations were compatible with *S. thermophilum.*

A comparison of the pathogenicity of fresh and rehydrated IJs of *H. indica* in causing mortality of *G. mellonella* showed that the mortality was generally higher due to the fresh IJs than due to the rehydrated IJs at the same time interval and inoculum dose. The rehydrated IJs of *H. indica* retained their virulence potential and were as infective as the fresh IJs to impart mortality to the 4th instar larvae of *G. mellonella*.

4.3.3 Nematode Management

4.3.3.1 Integrated management

A population of *Pasteuria* (HcP) isolated from the pigeonpea cyst nematode *Heterodera cajani*, adhered equally well to the cuticle of potato cyst nematode *Globodera pallida*, but exhibited altered orientation of attachment and difference in germination and infection. Scanning electron microscopy revealed three new observations, (i) a *Pasteuria*

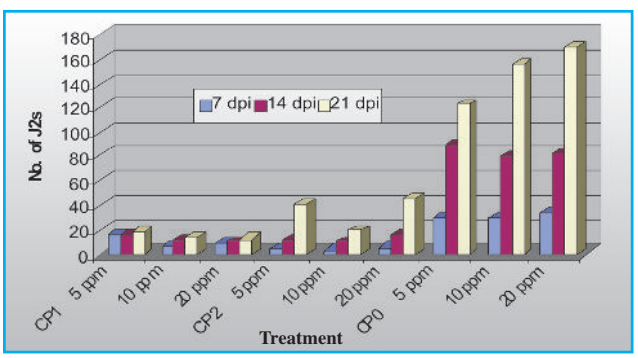
isolate from one genus (*Heterodera*) can adhere to and infect another genus (*Globodera*); (ii) *Pasteuria* spores can adhere to the cuticle in an inverted orientation and subsequently germinate and infect the nematode; and (iii) there were different proportions of the spores germinating and infecting females between the different genera suggesting germination is also a specificity determinant. A 1,430 base pair fragment of the 16S rRNA gene sequence of HcP showed 98.6% relatedness to the orthologous gene in *P. nishizawae*, a strain from *H. glycines*, suggesting phylogenic similarity. An isolate of an actinomycete (*Streptomyces lavendulae* MTCC 706) was found to cause significant juvenile mortality, hatch inhibition and reduced juvenile invasion of root-knot nematode in tomato cv Pusa Ruby.

Soil application of phosphothionate with neem oil gives longer protection against *Heterodera zeae* compared to application of nematicide alone.

Management of reniform nematode in brinjal cv. PPL with carbofuran, phorate, triazophos and caldan revealed that triazophos registered minimal increase in nematode population. Fruit yield was improved by 50% in carbofuran and phorate in comparison to control.

Integrated management of root knot nematode in tomato in protected conditions with different combinations of treatment showed that Metham sodium with neem cake enriched with *Trichoderma harzianum*, was most promising in reducing the nematode damage. Bio-fumigation of root knot infested soil with leaves of *Brassica juncea* (Pusa Jagannath and MC27) for 30 days resulted in significant decline of root knot juveniles under laboratory and field conditions.

The penetration of second stage juveniles of *M. incognita* in tomato roots was significantly reduced with the application of nanoformulations (PEG-600 and PEG-1000) of carborfuran (CP1 and CP2) resulting in improved plant growth. Nursery treated with carbofuran @ 3.3 g/m^2 was effective in reducing the *M. graminicola* population. An increase in yield of 0.53 t/ha over that of untreated control was observed with the application of carbofuran.



Effect of nano-formulations of carbofuran 3G on penetration and development of J2s of *M. incognita* infecting tomato

The studies on host preference using attraction bioassays technique in Pluronic gel indicated that *M. incognita* preferred tomato roots to rice while *M. graminicola* was attracted more towards rice. Plant volatiles like small lipophilic molecules isolated from hydroponically cultured tomato and rice through solid phase extraction might have affected nematode movement patterns.

4.3.3.2 Management through transgenic approach

Gene constructs expressing double standard RNA of five genes, viz., flp14, flp 18, cysteine protease and two oesophageal genes of *Meloidogyne incognita* have been used for transforming brinjal and tobacco for imparting resistance to *Meloidogyne incognita*. These genes were found effective in reducing the nematode infection and development when tested through *in vitro* RNAi evaluation through oral feeding. Further, brinjal cv Pusa purple long has been transformed with modified rice crystatin gene, which has been found to reduce nematode infection by 80%. The T_0 plants in phytotron have been confirmed for the presence of transgene by PCR.

Putative transgenic tobacco and brinjal plants in phytotron. A: T_0 tobacco with *flp18* gene of *M. incognita*; and B: T_0 brinjal expressing modified rice cystatin gene for controlling *M. incognita*

4.4 AGRICULTURAL CHEMICALS

4.4.1 Chemo and Bio-prospecting for Agrochemicals

4.4.1.1 Microwave assisted synthesis and antifungal evaluation of diaryl cyclohexenones

Fourteen chalcones were prepared using microwave irradiation (MWI) of acetophenones and substituted benzaldehydes. Further, 3,5-diaryl-6-carbethoxy-2-cyclohexen-1-one derivatives were prepared through base

catalyzed cyclocondensation of above chalcones with ethylacetoacetate by using MWI and silica as support. The synthesized compounds were characterized using ^{1}H NMR and IR, and screened for their antifungal activity *in vitro* against *Sclerotium rolfsii* and *Rhizoctonia solani*. The most potent compounds against *R. solani* were 1-(4-fluorophenyl)-3-phenyl-propenone (LC_{50} –2.36 mg/l) and 1,3-diphenyl-propenone (LC_{50}–2.49 mg/l). 3-(4-fluoro-phenyl)-5-(3-nitro-phenyl)-6-carbethoxy-2-cyclohexen-1-one was most active (LC_{50} –285 mg/l) against *S. rolfsii*.

4.4.1.2 Chemical profiling of bioactive constituents of *Eupatorium adenophorum* Spreng

Six cadinene derivatives along with stigmasterol were isolated and characterized from essential oil of *Eupatorium adenophoru*m Spreng by various chromatographic and spectroscopic techniques (TLC, HPLC, LC-MS, ^{1}H-NMR and ^{13}C-NMR). These cadinene derivatives were identified as: (i) cadinan-3-ene-2,7-dione, (ii) 7-hydroxycadinan-3-ene-2-one, (iii) 5,6-dihydroxycadinan-3-ene-2,7-dione, (iv) cadinan-3,6-diene-2,7-dione, (v) 2-acetyl-cadinan-3,6-diene-7-one, and (vi) 7-hydroxy-7,13-epidioxycadinan-3,6 diene-2-one.

4.4.1.3 Pest control agents based on essential oils

The essential oils of *Eupatorium adenophoru*m showed antifungal and anti-nemic activity. Maximum activity was observed against *Rhizoctonia solani* (ED_{50} 116.45 mg/l), followed by *Sclerotium rolfsii* (ED_{50} 151.65 mg/l) and *Fusarium oxysporum* (ED_{50} 186.84 mg/l). The essential oil was moderately active against root knot nematode *Melodogyne incognita* (LC_{50} 176.85 mg/l).

4.4.1.4 Fungicidal activity of *Paecilomyces lilacinus* isolates

Methanol and hexane extracts of *Paecilomyces lilacinus,* a fungus, showed fungicidal activity against *Rhizoctonia solani*, *Sclerotium rolfsii*, *Pythium aphanidermatum*, *R. bataticola* and *Fusarium oxysporum*. The methanol extract showed higher fungicidal activity against all the test fungi, the highest being recorded against *F. oxysporum* (ED_{50}=124 µg/ml).

4.4.1.5 Antifungal/aphicidal activity of karanjin/ its semi-synthetic derivatives

Activity of karanjin, a bioactive constituent of *Pongamia glabra* was enhanced by conversion of karanjin into karanjic acid esters. Decanoyl ester of karanjic acid was most effective (ED_{50} 42.2ppm) against *M. phaseolina*. Nonanoyl and octanoyl ester with respective ED_{50} of 41.7 ppm and 40.9ppm were effective against *F. oxysporum* and *S. rolfsii*. Although the activity was less than that of the commercial fungicide Bavistin (ED_{50} 10.43-21.55 ppm), the performance was significant owing to their natural origin. Karanjin and its semi-synthetic derivatives also exhibited moderate aphicidal activity against the mustard aphid *Lipaphis erysimi* (LC_{50} 0.042- 0.048 %).

4.4.1.6 Development of karanj based EC formulations

Emulsifiable concentrate (EC) of karanj oil, karanjin, and octanoyl/nonanoyl/decanoyl ester of karanjic acid prepared by employing suitable diluents and surfactants showed that isobutyl methyl ketone (IBMK) + Cyclohexanone + Creslox 3440 combination was most suitable for preparing EC formulation which can be utilized for eco-friendly pest management.

4.4.1.7 Fungicidal activity of substituted aryl carboxylic acids

Out of twenty-eight substituted aryl carboxylic acids evaluated for fungicidal activity, acids having 2-CH_3 substitution (ED_{50}=126 µg/ml) were effective against *R. solani*; 3,5-$(NO_2)_2$, 2-OH (ED_{50}=198 µg/ml) against *S. rolfsii*; 3-CH_3 (ED_{50}=146 µg/ml) against *P. aphanidermatum*; and 2-SH against *R. bataticola* (ED_{50}=82 µg/ml) and *F. oxysporum* (ED_{50}=43 µg/ml) exhibited the highest fungicidal activity.

4.4.2 Food Safety and Risk Assessment of Crop Protection Products, and Their Residue Management

4.4.2.1 Persistence of fipronil, combination mix of cypermethrin+chlorpyriphos and deltamethrin +triazophos on cabbage

Persistence of fipronil (Regent 5% SC) @ 50 and 100 g a.i./ha, combination mix of cypermethrin+chlorpyriphos (Action EC 5 & 50% @ 800 and 1600 ml/ha) and deltamethrin+triazophos (Anaconda EC 1 & 35% @ 1000 and 2000 ml/ha) was studied in cabbage. Initial deposits varied from 0.147 to 292 µg/g for fipronil, 0.20 to 0.53 µg/g for cypermethrin, 0.604 to 0.850 µg/g for chlorpyriphos,

0.015 to 0.026 µg/g for deltamethrin and 0.254 to 0.413 µg/g for triazophos. The residues in cabbage persisted for 8-12 days. The half-life values were 1.9-2.1, 1.4-1.5, 1.5-1.9, 1.5-1.6 and 2.5-3.0 days for fipronil, cypermethrin, chlorpyriphos, deltamethrin and triazophos, respectively. Based on maximum residue limit (MRL) and dietary risk assessment, safe waiting period of 3-4 days was suggested. Amongst the three products, combination mix of cypermethrin+chlorpyriphos was found to be the safest as residues of cypermethrin and chlorpyriphos on 0 days itself were found to be below MRL level.

4.4.2.2 Persistence of combination mix (Cypermethrin + Chlorpyriphos) on cauliflower and chili

Cauliflower (variety Pusa Snowball Katrain 1) was sprayed with commercial combination mixture of chlorpyriphos and cypermethrin (Action-505) @ 800 and 1600 ml/ha at curd formation stage, and chilli (variety Soldier-MH-1, F-I) with Nagraj 505 EC (5 % cypermethrin + 50% chlorpyriphos) @ 800 and 1600 ml/ha (40 and 80 g a.i./ha for cypermethrin and 400 and 800 g a.i./ha for chlorpyriphos) at 50% fruit formation stage. Residue analysis revealed that chlorpyriphos and cypermethrin persisted beyond 12 days on cabbage, and half-life of cypermethrin was found to be 1.7-1.8 days and that of chlorpyriphos 1.2-1.5 days. On chili, residues of cypermethrin and chlorpyrifos persisted for 1 and 3 days, respectively. A waiting period of 3 days can be suggested.

4.4.2.3 Microbial degradation of alachlor

Microbial degradation of herbicide alachlor was studied by a fungal culture (*Rhizopus* sp.) isolated from alachlor fortified laboratory acclimatized soil. Studies in mineral broth and soil indicated that alachlor degraded faster with the fungal isolate and could be used in bioremediation of alachlor from soil.

4.4.2.4 Sorption-desorption of sulfonylurea herbicides

Adsorption-desorption of metsulfuron-methyl and sulfosulfuron was studied. Freundlich equation described the sorption of metsulfuron-methyl, and sulfosulfuron in soils with Kf values ranging between 0.21 and 1.88 for metsulfuron-methyl and 0.37 and 1.17 for sulfosulfuron. Adsorption isotherms were L-type as slope (1/n) values were <1 suggesting that the herbicide sorption in soils was concentration dependent, and the sorption decreased with the increase in the initial concentration of the herbicide in the solution. The Freundlich adsorption constant Kf for metsulfuron-methyl showed good positive correlation with silt content (r=0.998) and negative correlation with the soil pH (r= -0.964). However, sorption of sulfosulfuron did not correlate with any of the soil parameter. Desorption of both the herbicides was concentration dependent and, in general, sulfosulfuron showed higher desorption than metsulfuron-methyl.

4.4.2.5 Persistence of fipronil in soil

Effect of moisture and light on the persistence of fipronil in IARI soil was studied. Dissipation was found to be fastest under submerged (3.2-10.9 days) condition followed by that under field capacity (27.6-36.7 days) and dry (51.0-79.2 days) moisture regimes which could be attributed to partial anaerobic conditions. In all the moisture regimes, two metabolites, i.e., sulfone and sulfide were detected. Sulfide, a reduction product, was the major degradation product detected under submerged condition. Half-life values of fipronil at 1.0 and 10.0 µg/g level varied from 3.2 to 51.0 days and 10.8 to 78.2 days with an average of 27.3 days and 42.3 days, respectively. Dissipation was slower under dark ($T_{1/2}$ 10.9 days) as compared to that under light conditions ($T_{1/2}$ 5.1-6.1 days). Major metabolite formed under sunlight and UV-light was desulfinyl, a photoproduct of degradation of fipronil.

4.4.2.6 Decontamination of pesticides

Studies were carried out to improve the efficiency of water treatment process by the addition of small amount of clay (3-4 mg) during the process. Amongst the different clays tried, nano montmorillonite clay surface modified with octadecyl amine and aminopropyl triethoxy silane removed 90-100% of pesticides (DDT, endosulfan, aldrin and lindane and their metabolites) from water.

4.4.3 Innovations in Agricultural Formulations and Application Technology for Safety and Efficacy

4.4.3.1 Bioefficacy of controlled release formulations of carbofuran and imidacloprid

The controlled release (CR) formulations of carbofuran and imidacloprid provided better (or equal) control of the pests (*Aphis gossypii* and *Amrasca biguttula biguttula)* compared to commercial formulations. Carboxymethyl cellulose-based formulation provided superior control of both

the pests. The Imida-CMC, which showed the lowest population of leafhopper (10.5 leafhopper/100 cluster), provided the best control of the pest amongst all the treatments after 35 days of application. The residues of carbofuran and imidacloprid in potato tuber and soils were non-detectable at the time of harvest in any one of the treatments.

4.4.3.2 Release kinetics of β-cyfluthrin from its encapsulated formulations in water

Controlled release (CR) formulations of β-cyfluthrin, a non-systemic, broad spectrum contact insecticide, were prepared using laboratory synthesized polyethylene glycol (PEG) based amphiphilic copolymers. Release of β-cyfluthrin was faster from the commercial formulation (25SC) than from the developed CR formulations. The rate of release of encapsulated β-cyfluthrin from nanomicellar aggregates could be reduced by increasing the molecular weight of PEG. The release was diffusion controlled with a half-release time ($t_{1/2}$) of 3.9 to 7.9 days in water from different formulations, and the period of optimum availability (POA) of β-cyfluthrin ranged from 1.4 to 20.5 days. The results suggested that the application rate of β-cyfluthrin can be optimized to achieve insect control at the desired level and period.

4.5 WEED MANAGEMENT

4.5.1 Effect of Tillage and Weed Management on Productivity of Soybean–Wheat Cropping System

Soybean was grown in fixed plots under conventional tillage (CT) or zero tillage (ZT) on flat or raised-bed. Pendimethalin was applied pre-emergence @ 0.75 kg/ha followed either by hand weeding or post-emergence application of imazethapyr @ 0.075 g/ha at 25 days of growth. Wheat residue mulch + imazethapyr, applied post-emergence, was also included. In the same layout, wheat was grown after the harvest of soybean. After two cycles of cotton-wheat system (2008-09, 2009-10), in the same plots, the performance of soybean in 2010 was equally good under zero and conventional tillage practices. There was no difference in the performance of flat and bed-planted crops under both the tillage practices, although weed growth was significantly more under zero-till conditions. Results indicated that hand weeding can be replaced with imazethapyr application at 25 days of growth.

4.5.2 Efficient Management of Weeds in Maize

Tank-mix and sequential applications of pendimethalin with imazethapyr or chlorimuron-ethyl controlled the broad-leaved weeds completely, and caused significant reductions in the populations of grass weeds and *Cyperus rotundus*. Atrazine (1.0 kg/ha) +mustard residue mulch (5 t/ha) gave significantly higher maize yield. Total chlorophyll content and leaf soluble proteins were reduced because of tank-mix application of pendimethalin with imazethapyr or chlorimuron-ethyl, but the increase in the activity of ascorbate peroxidase (scavenging enzyme) indicated a possible defence mechanism operating in maize to scavenge the ill-effects.

Weed growth and yield performance of soybean under varying tillage and residue management practices during 2010

Treatment	Weed count at 60 DAS (no./m²)	Weed dry weight at 60 DAS (g/m²)	Seed yield (t/ha)	Stover yield (t/ha)
Tillage / crop establishment				
CT-flat	55.1	55.9	1.48	3.02
CT-bed	52.6	34.6	1.44	2.98
ZT-flat	84.5	125.2	1.50	2.60
ZT-bed	61.1	105.4	1.46	2.69
CD (0.05)	5.8	12.5	NS	0.35
Weed management				
Unweeded	113.1	205.5	1.17	2.09
Pendimethalin + hand weeding	44.1	25.7	1.60	2.99
Pendimethalin + imazethapyr	46.2	33.7	1.57	3.22
Wheat residue + imazethapyr	49.9	56.4	1.53	3.00
CD (0.05)	4.9	10.8	0.25	0.30

Weed population and grain yield of maize across different treatments

Treatment	Broad leaved weed (no./m²)	*Cyperus rotundus* (no./m²)	Grass weed (no./m²)	Maize grain yield (t/ha)
Unweeded control	53.3	96.0	68.0	2.24
Atrazine (0.75 kg/ha) + pendimethalin (0.75 kg/ha) (tank mix pre-em)	16.0	101.3	20.0	3.66
Atrazine (1.0 kg/ha) + hand weeding at 30 DAS	24.0	86.7	8.0	3.81
Atrazine (1.0 kg/ha) +mustard residue mulch @ 5 t/ha	20.0	110.7	33.3	4.11
Pendimethalin (0.75 kg/ha) + imazethapyr (0.050 kg/ha) (tank mix pre-em)	0.0	57.3	0.0	3.72
KNO_3 (6%) + pendimethalin (0.75 kg/ha) + imazethapyr (0.050 kg/ha) (tank mix pre-plant incorporation)	1.3	68.0	0.0	3.60
Pendimethalin (0.75 kg/ha) + chlorimuron (0.006 kg/ha) (tank mix pre-em)	1.3	53.3	0.0	3.36
Pendimethalin (0.75 kg/ha) PE followed by imazethapyr (0.050 kg/ha) post-em with sand	10.7	130.7	0.0	3.69
Pendimethalin (0.75 kg/ha) PE followed by chlorimuron (0.006 kg/ha) post-em with sand	22.7	77.3	0.0	1.59
Brown manuring [*Sesbania* @ 5 kg/ha+ 2,4-D (0.75 kg/ha) at 25 DAS]	10.7	25.3	40.0	3.16
Brown manuring [*Sesbania* @ 10 kg/ha+ 2,4-D (0.75 kg/ha) at 25 DAS]	8.0	25.3	45.3	3.04
Weed-free check	0.0	0.0	0.0	4.27
LSD (P=0.05)	17.6	28.3	14.5	0.47

4.5.3 Sequential Applications of Herbicides for Efficient Weed Management in Wheat

Post-emergence application of clodinafop-propargyl (0.06 kg/ha) followed by (fb) metsulfuron-methyl (0.0065 kg/ha) gave efficient broad-spectrum weed control and enhanced wheat yield. Adoption of dormancy breaker (6% KNO_3) further caused slight reduction in weed growth, but the difference was not significant.

Weed control in Wheat field through clodinafop-propargyl (0.06 kg/ha) followed by metsulfuron-methyl (0.006 kg/ha) or carfentrazone (0.03 kg/ha) post-em

Weed growth and wheat yield as affected by sequential post-emergence applications of herbicides

Treatment	Grass weed dry wt. (g/m²)	Broad-leaved dry wt. (g/m²)	Wheat yield (t/ha)
Unweeded control	25.8	20.3	3.58
Clodinafop-propargyl (0.06 kg/ha) fb metsulfuron-methyl (0.0065 kg/ha) as post-em	0	0	5.03
Pendimethalin (0.75 kg/ha) + carfentrazone (0.03 kg/ha) (tank-mix) as pre-em	11.4	3.5	4.67
Clodinafop-propargyl (0.06 kg/ha) fb carfentrazone (0.03 kg/ha) as post-em	0	0	4.90
Pinoxaden (0.05 kg/ha) fb carfentrazone (0.03 kg/ha) as post-em	0	0	4.83
Isoproturon (0.75 kg/ha) as post-em	13.2	3.7	4.71
Weed-free check	0	0	4.94
LSD (P = 0.05)			0.25

4.5.4 Characterization of *Phalaris minor* Biotypes towards Cross-resistance Across Low-dose Wheat Herbicides

Twenty *Phalaris minor* biotypes including a susceptible one, collected from Punjab and Haryana were tested for their resistance to clodinafop-propargyl, sulfosulfuron and pinoxaden in controlled growth chamber studies. Of these biotypes, 14 biotypes were highly resistant to clodinafop showing a resistance factor more than 40. Five biotypes were moderately resistant showing a resistance factor of 5. All 19 biotypes were found highly resistant to isoproturon. Eight biotypes showed resistance to sulfosulfuron, while 9 biotypes were resistant to pinoxaden.

Cross-resistance of *Phalaris minor* bio-types to clodinafop-propargyl as characterized by GR_{50} value and resistance factor

Phalaris minor biotypes	GR value	Regression equation	Resistance factor
PN (Punjab) 26, PN 30; HR (Haryana) 29, HR 30, HR 32, HR 33, HR 34, HR 35, HR 39, HR 40, HR 41, HR 43, HR 83, HR 128 (14)	725.6 ±2.86	Y =2.33X -1.67	41.46
PN 11, PN 81, PN 89, HR 94, HR 119 (5)	90.1 ±1.95	Y = 3.44X -1.74	5.15

4.5.5 Impact of Planting Time and Weed Management on Productivity of Potato

The effect of dates of sowing and weed control measures on the productivity of potato tubers was studied in a field heavily infested with *Melilotus indica, Malva perviflora, Chenopodium album*, *Chenopodium murale*, and *Rumex dentatus*. Late planting (15th Nov.) of potato faced more competition from weeds as compared to that seen against timely planting (5th Nov.). Weed-free condition gave the highest tuber yield (30 t/ha), followed by pre-emergence application of atrazine (0.5 kg/ha) and metribuzin (0.5 kg/ha). However, early post-emergence applications of isoproturon (1.0 kg/ha) and paraquat (0.5 kg/ha) could not provide satisfactory season-long weed free condition.

Effect of planting dates and weed control measures on productivity of potato

Treatment	Weed population at 60 days	Tuber yield (t/ha)
5th November	63. 3	24.4
15th November	83.6	23.1
LSD (P= 0.05)	9.0	0.8
Paraquat @ 0.50 kg /ha at 15 DAP	101.2	20.8
Pendimethalin @ 1.0 kg/ha pre-em	81.2	24.2
Metribuzin @ 0.50 kg /ha pre-em	68.7	27.8
Atrazine @ 0.5 kg/ha pre-em	61.2	28.2
Isoproturon @ 1.0 kg/ha at 15 DAP	94.3	21.2
Farmers practice	37.7	27.2
Weedy check	133.3	10.7
Weed free	0.0	30.0
LSD (P= 0.05)	9.6	2.5

4.5.6 Evaluation of New Weedicides for Weed Management in Direct Seeded and Transplanted Rice

The efficacy and selectivity of different new herbicides were evaluated in aerobic (direct seeded) and transplanted rice having predominant weeds such as *Echinochloa crusgalli*, *Echinochloa colona*, *Leptochloa chinensis*, *Dinebra retroflexus*, *Eclipta abla*, *Ammania baccifera*, *Marsilea quadriflolia*, *Cyperus rotundus*, *Cyperus difformis* and *Cyperus iria.* Weed density was comparatively less in transplanted rice as compared to that in directly sown rice. Weed-free condition recorded the highest grain yield (4.57 t/ha) owing to better weed control. Pre-emergence sequential application of pretilachlor (1000 g/ha) followed by bispyribac sodium (20 g/ha at 30 DAS/DATP) proved to be best in controlling the complex weed flora.

Effect of planting methods and weed control measures on productivity of rice

Treatment	Weed population (no./m^2)	Panicles / m^2	Panicle length (cm)	Grain yield (t/ha)
Planting method				
Direct seeding	54.9	258.2	28.3	3.83
Transplanting	44.2	266.0	29.2	4.01
LSD (P= 0.05)	0.3	3.4	1.6	0.04
Weed control measure				
Bispyribac sodium @ 25 g /ha at 15 DAS	52.0	255.8	27.8	3.76
Bispyribac sodium @ 30 g /ha at 15 DAS	48.0	261.7	28.7	3.94
Bispyribac sodium @ 25 g /ha at 25 DAS	45.2	263.3	29.3	4.04
Bispyribac sodium @ 30 g /ha at 25 DAS	42.3	265.8	29.5	4.17
Pretilachlor @1000g /ha PE	66.2	262.5	28.7	3.83
Pretilachlor @1000g /ha PE fb bispybac @ 20g /ha at 30 DAS	32.3	268.3	30.5	4.42
Weedy check	110.7	245.2	24.5	2.63
Weed free	0.00	273.3	31.0	4.57
LSD (P= 0.05)	8.8	16.4	1.5	0.29

5. BASIC AND STRATEGIC RESEARCH*

The basic and strategic research conducted at IARI during 2010-2011 focused on isolation of genes and promoters, development of markers and transgenics for various traits, marker assisted selection breeding, the physiological basis of crop yield under normal and abiotic stress environments and global climate change scenario, phenotyping for biotic and abiotic stress tolerance, molecular characterization of genetic resources, utilization of static magnetic field and γ-radiation for improving crop performance, influence of crop management practices on soil physical properties, and the application of remote sensing and GIS for characterization of soil and crop.

5.1 PLANT BIOTECHNOLOGY

5.1.1 Isolation of Plant Genes and Promoters

5.1.1.1 Isolation and characterization of nematode-responsive root-specific promoter

Genome-wide expression analysis was carried out using the *Arabidopsis* gene expression data sets for root knot nematode (RKN) infection to identify nematode-responsive root specific genes. Individual and cross analysis of three datasets led to the identification of a few nematode-responsive and root-specific genes with log-ratio values > 2.5. The promoter region of nematode-responsive gene was cloned upstream to *GUS* reporter in the pORE vector and transformed into *Arabidopsis* plants by *Agrobacterium* mediated transformation. Transgenic *Arabidopsis* plants exhibited nematode-responsive root-specific *GUS* expression. Hence, this promoter will be useful in driving expression of useful genes, specifically in roots.

5.1.1.2 Isolation of a boll-specific gene from cotton

Promoters that highly and consistently express throughout the boll developmental stages are needed to express insecticidal protein genes for the Bt-technology. A gene encoding a putative senescence protein (PSP) was identified by using SSH. A sequence of 1826 bp was obtained from alignment of EST, 5' RACE and genome walking. The *PSP* gene codes for 191 amino acids and shows homology to a senescence protein from *Medicago trunculata*. Analysis of its promoter sequence revealed some unique features such as a repeat of 123 bp and CpG islands and several known regulatory elements. The *PSP* promoter sequence was cloned into pCAMBIA1302 replacing the 35S promoter to drive the *mGFP* expression. The promoter will be validated by stable transformation in tobacco and transient expression in cotton.

5.1.1.3 Identification of genes specifically expressed during adventive embryo differentiation in citrus

To identify candidate genes involved in polyembryony in citrus, SSH libraries of citrus ovules at adventive embryo initiation and development were constructed. A total of 1820 SSH clones were sequenced and about 1100 new ESTs were identified and submitted to the NCBI database. The differentially expressed genes were verified through reverse northern, microarray analysis and real time PCR. A heat shock factor gene and a calmodulin-binding protein genes were found to be differentially expressed in ovules of mono- and poly-embryonic varieties during the critical stages of embryo development.

5.1.2 Development and Characterization of Transgenic Crops

5.1.2.1 *Bt*-gene stacking in brinjal

Transgenics pyramided with multiple insecticidal genes are expected to delay the development of Bt toxin-resistance in insects. To achieve this in brinjal, earlier *cry1F* was transformed into homozygous female parent of Pusa Hybrid 6. During the year, ubiquitin promoter::*cry2Aa* was transformed into the male parent of Pusa Hybrid 6 and the transgenics were confirmed by immunostrip test, PCR, RT-PCR and qRT-PCR. The single copy *cry2Aa* transgenic line

** Includes the work done in collaboration with NRC on Plant Biotechnology, New Delhi.*

will be crossed with homozygous female parent expressing *cry1F* transgene to achieve gene pyramiding in brinjal.

5.1.2.2 Genetic engineering for aphid resistance

Previous studies have demonstrated that mustard transgenics constitutively expressing *Mentha* (E)-β farnesene synthase (E-βFS) gene repel aphids. However, the quantity of a (E)-β farnesene (E-βF) emission was much lower to employ it as a crop protection technology. Farnesyl diphosphate synthase (FPS) converts isopentenyl pyrophosphate (IPP) to farnesyl diphosphate (FDP), which is the precursor of E-βF. To elevate the cytoplasmic pool of FDP, *Arabidopsis FPS2* gene was constitutively overexpressed by using *CaMV35S* promoter in transgenic *Arabidopsis*. The transgenic *Arabidopsis* lines showed higher level of *FPS2* transcripts as compared to the wild type plants. The volatiles from transgenic plants were used for insect bioassay to study their effect on *Myzus persicae*. The colonized and feeding nymphs exposed to volatiles from transgenic plants exhibited agitation and dispersion. A quantitative estimation revealed that the number of aphids showing agitation ranged from 8 to14.6%.

5.1.2.3 Genetic engineering of blast resistance in rice

The *Pi-r*^{h} gene (an orthologue of *Pi-k*^{h}*)* isolated from the wild rice *Oryza rhizomatis* confers resistance to the most prevalent isolate PLP-1 of *Magnaporthe oryzae* present in the north-western Himalayan region of India. Transgenic rice expressing *Pi-r*^{h} gene showed a high degree of resistance to three different geographical isolates showing broad spectrum nature of the resistance gene. Pathogen challenge showed that the progenies of five T_1 transgenic lines were highly resistant to all the three *M. oryzae* isolates, namely, Deh-1, Hz-1 and PLP-1. Among the T_2 plants, TP:*Pi-r*^{h} 8.3.45 showed very high degree of resistance to *M. oryzae* and all the T_3 progenies of this plants showed resistance to Deh-1 isolate of *M. oryzae*.

5.1.2.4 Characterization of transgenic rice carrying *AtDREB1A* gene

Two homozygous transgenic lines of Pusa Sugandh 2 carrying *AtDREB1A* gene identified earlier were phenotyped for their response to drought and cold. qRT-PCR analysis revealed that 3-fold higher expression of *DREB1A* under stress as compared to that of control in one of the events of transgenic rice. Drought stress imposed on T_3 plants of these two homozygous transgenic events revealed significant level of tolerance in one of the events as compared to that in the wild type plant. After 10 days, 100% recovery was observed for this event. The transgenic plants with tolerance response had higher relative leaf water content as compared to that in the non-transgenic control. The transgenic line with high drought tolerance also showed high membrane stability under cold stress and high recovery capacity during vegetative stage.

5.1.2.5 Transgenic tomato engineered with abiotic stress tolerance

Tomato cv. Pusa Ruby was engineered with 4 different genes (*Osmotin*, *DHAL2*, *CODA* and *DHSP*) individually. These plants were confirmed by PCR amplification of *NPT II* as well as respective transgenes and phenotyped for tolerance to salinity and moisture-deficit stress in a glass house of the National Phytotron Facility. Confirmed transgenic lines (44 lines) were selfed for generation advancement and progeny testing.

5.1.3 Genomics and Molecular Markers

5.1.3.1 Bioprospecting of genes for abiotic stress tolerance in rice

The National Agricultural Innovation Project (ICAR) funded network project on "Bioprospecting of Genes and Allele Mining for Abiotic Stress Tolerance" in rice was initiated during the year 2009-10. In this project, a core germplasm set consisting of 7227 lines was identified, which will be characterized for mining of useful genes. Transcriptome profiling using rice Affymetrix DNA chips identified 877 differentially expressed genes with a minimum of two-fold change in flag leaves of upland rice variety Nagina 22 at booting stage under drought, of which, 57 known and 31 unknown abiotic stress responsive genes were validated through semi-quantitative RT-PCR. Whole genome transcriptome sequencing by the use of Next-generation sequencing (NGS) Illumina Solexa Genome Analyzer identified 8,634 differentially expressed genes in Nagina 22 seedlings under drought and 2,274 transcripts in the salt tolerant Basmati rice variety CSR 30 under salinity stress. A total of 1,237 SNPs and 29 InDels corresponding to 967 genes that were differentially expressed between Nagina 22 and CSR 30 under stress were identified.

5.1.3.2 Characterization of drought responsive ESTs from chickpea

Earlier 6053 drought responsive ESTs were generated from 8 cDNA SSH libraries of a drought tolerant chickpea variety ICC 4958, a drought susceptible chickpea variety ICC 1882 and extreme bulks of recombinant inbred lines (RILs) derived from ICC 4958 x ICC 1882. Out of a total of 3,062 unigenes identified from the ESTs, more than 50% were shown to be associated with drought stress in chickpea. The *ACC synthase* expression was 42 folds upregulated in the drought tolerant variety ICC 4958 indicating a potential role of ethylene in drought response of chickpea.

5.1.3.3 Discovery and validation of SNPs between Basmati 370 and IRBB 60 genotypes and their use for QTL mapping

SNPs were discovered between Basmati 370 and IRBB 60 genotypes by whole genome resequencing with NGS platform of ABI SOLiD. A total of 450,883 homozygous SNPs were discovered between Basmati370 and IRBB60 with an average frequency of 3 SNPs/kb, of which 173,177 SNPs were present in rice genes with an average frequency of 7 SNPs/gene. Functional annotation of 30,058 polymorphic genes with SNPs between the two genotypes was done. One hundred sixty-three of the 384 selected SNP loci covering the whole rice genome were validated successfully. Eighty one of 163 SNP loci were converted into cost efficient CAPS markers and 44 of them were validated through CAPS assay for use in laboratories lacking high throughput facilities. The validated CAPS markers were subsequently utilized along with SSR markers for mapping QTL for grain size, using F_7 recombinant inbred lines derived from the cross Basmati 370 × IRBB 60. A total of 24 QTLs were mapped for grain size attributes, namely, grain length, breadth, length-breadth ratio and grain weight, by using single marker analysis and interval mapping. Efforts are underway to test the same material in different environments and add more polymorphic markers so as to find robust and consistent QTLs.

5.1.3.4 Characterization of rice lines with multiple bacterial blight resistance genes

A set of 100 RILs were selected based on grain length from a total of 1200 RILs derived from the cross Basmati 370 × IRBB 60. Using molecular markers linked to the BLB resistance genes *Xa4*, *xa5*, *xa13* and *Xa21,* the presence or absence of these genes was ascertained in the selected RILs. The phenotypic data of the 100 RILs were analyzed and the genome wide analysis of the four and three gene pyramided lines was done in the current year. Only two lines, RIL 44 and RIL 24 had aroma among the four-gene pyramided lines. RIL 44 also combined Basmati cooking quality traits along with superior agronomic traits. Fifty-four polymorphic markers were used for genome wide analysis of RILs having three or four resistance genes. This revealed that the extent of similarity between RILS and the Basmati parent was 24-69%. RIL 44 with four resistance genes was most similar to Basmati 370 (69%). RILs 18 and 19, which showed 92% similarity to their background genome and inherited the same three resistance genes, *xa5*, *xa13* and *Xa21* differed for four important phenotypic traits. Owing to these differences and background similarity and higher homozygosity, these two lines were crossed to recover more desirable genotypes.

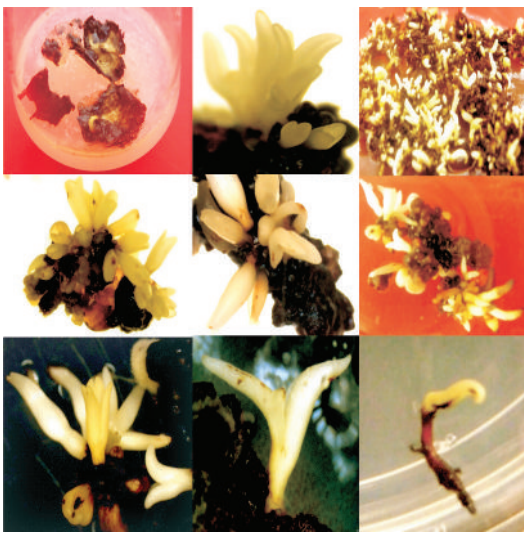
5.1.4 Biotechnological Approaches for Increasing Productivity

5.1.4.1 Development of new cytoplasmic male sterile (CMS) and fertility restorer lines of *Brassica juncea*

Earlier studies conducted by the National Research Centre on Plant Biotechnology revealed that CMS lines derived from *Moricandia arvensis, Diplotaxis berthautii, D. catholica*, etc., shared a common biochemical mechanism and restored by a common restorer in a gametophytic manner. Genetic diversity for CMS is, however, necessary for avoiding problems arising from unknown association with the traits such as quality, biotic stress susceptibility, etc. Hence, efforts are being made to harness organelle genome diversity to create new CMS and fertility restorer stocks of *B. juncea*. During the year, stable CMS and fertility restorer lines from the progeny of the somatic hybrid between *B. juncea* and *D. catholica* were isolated. The flowers of the new CMS line are normal except for the anthers which are short and pointed, and remain below the stigma at anthesis. Male sterility is stable during the entire crop season and all the *B. juncea* lines tested have been found to serve as maintainers. In fertility restored plants, the anthers are normal and exert to the level of stigma at anthesis. Fertility restoration is monogenic and sporophytic. The new CMS system appears to be particularly useful in commercial hybrid seed production as male sterile plants could be easily distinguished from fertile plants.

5.1.5 Micropropagation in Fruit Crops

Three mono-embryonic (cvs. Amrapali, Pusa Arunima, Dashehari) and two poly-embryonic (Olour and Kurukkan) genotypes were studied for callus induction and somatic embryogenesis using nucellus tissue. Poly-embryonic genotypes showed better callusing and somatic embryogenesis compared to mono-embryonic genotypes of mango. Among poly-embryonic genotypes, Kurukkan gave the high callusing (82.0%) followed by Olour (76.5%). Amongst mono-embryonic genotypes, Amrapali (48%) was found more responsive followed by Pusa Arunima (34%).



Different stages of callusing, somatic embryogenesis and plant regeneration in Kurukkan mango

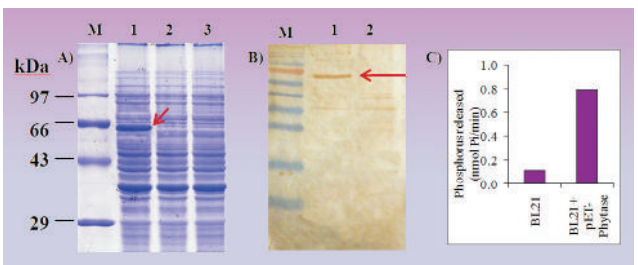
In grape, *in vitro* shoot multiplication was maximum in Pusa Navrang and Pusa Urvashi, which produced 5-7 micro-cuttings/sub-culture, while Centennial Seedless gave poor success with only 3-4 micro-cuttings/sub-culture. Similarly, a comparison of *in vitro* multiplication of four rootstock genotypes namely, SO4, Dogridge, 110R and H-144 showed that H-144 was the most responsive (7-8 micro-cuttings/ subculture). Immature embryos were rescued from inter-specific hybrid cross made between pummelo (*C. grandis* (L.) Osbeck) and sweet orange (*C. sinensis* (L.) Osbeck) cv. Mosambi. A sixty-day old ovule was not found ideal for *in vitro* culture. However, 107-day old immature seeds were found viable to regenerate through *in vitro* culture by the use of MS (full-strength) supplemented with 2.5 mg/l BAP, 0.5 mg/l NAA, 200 mg/l activated charcoal and 200 mg/l casein hydrolysate.

5.2 BIOCHEMISTRY

5.2.1 Isolation and Characterization of Phytase cDNA from *Glycine max*

Soybean contains 60-80% of total seed phosphorus (P) in the form of phytate, which limits the availability of P to humans. One of the approaches to ameliorate this problem is overexpression of phytase in seeds. Phytate content in Indian soybean varieties varied from 1.48 to 1.96%. Increase in phytase activity led to hydrolysis of phytate in cotyledons resulting in increased levels of inorganic P and total P in the stem, leaf and root tissues of the germinating seedlings. Semi-quantitative RT-PCR analysis showed expression of phytase in stem, root, cotyledon and leaf, with the highest levels of phytase transcript accumulation in cotyledons on the 10th day after germination.

A full length cDNA encoding phytase was isolated from *Glycine max* through splicing over-lap extension PCR. Sequence analysis revealed an open reading frame of 1644 bp encoding a 547 amino acid protein (~ 62 kDa) with an N-terminal secretary signal peptide of 28 amino acids. The deduced phytase amino acid sequence showed 81.9% identity to the phytase of *Lupinus albus*. Soybean phytase exhibited the conserved motifs and signature metallophosphoesterase domains characteristics of the purple acid phosphatase family. A codon optimized phytase cDNA was overexpressed in *E. coli*. Bioassay with the crude protein extracts from *E. coli* overexpressing phytase confirmed its functionality indicating its potential for use in transgenic development.



Expression analysis of soybean phytase in a prokaryotic expression host. A: SDS-PAGE analysis of soybean phytase expression in *E. coli* BL21; B: Confirmation of Phytase expression by Western analysis; and C: Enzyme activity of *E. coli* expressed soybean phytase. Lane1, induced; Lane 2, uninduced; and Lane 3, WT *E. coli*. Arrow in A & B shows HIS-phytase fusion protein

5.2.2 Off-flavour Development in Soybean

5.2.2.1 Enzyme kinetics of lipoxygenase (LOX) and off-flavour development in soybean

The catalytic parameters of LOX enzyme on PUFAs (linoleic acid and linolenic acid) substrates were studied at different pH and buffer combinations. In pH environment ranging from 6.0 to 9.0, when the enzyme protein to substrate ratio was kept constant, the pure LOX-1 enzyme preferred linolenic acid to linoleic acid as better substrate. The result validates the fact that owing to one extra *cis,cis*-1,4 pentadiene moiety in the backbone, linolenic acid (18:3) acts as a better substrate for LOX enzyme than linoleic acid (18:2). The importance of enzyme/substrate (E/S) ratio was studied using defatted soya-flour. The studies showed that LOX reaction is a substrate limiting reaction, i.e., higher the enzyme to substrate ratio, lower the specific activity. This result also suggests that defatting is a simple operation to modulate lipoxygenase mediated activity as LOX isozymes are inhibited by defatting. But this inhibition can be overcome by modulating the enzyme to substrate ratio, as lower the E/S ratio, more will be the HPOD formation.

Since the ratio of linoleic acid to linolenic acid ratio varies from 2 in *Glycine soja* (24% linolenic acid and 48% linoleic acid) to 15 (4% linolenic acid and 58% linoleic acid) in some of the *Glycine max* varieties, the effect of varied combinations of linoleic and linolenic acid on individual LOX isozymes (LOX-1, LOX-2, LOX-3) was analysed using both full fat and defatted soya flour. The maximum enzyme specific activity (ESA) rate was registered when the ratio was 2, whereas it was the lowest when the ratio was 15. This trend was found true for all the three LOX isozymes. These results suggest that when the total PUFA content remains constant, the cultivars with more linoleic to linolenic acid ratio will perform better than the cultivars of less linoleic to linolenic acid ratio, against off-flavour generation. It also suggests that linoleic to linolenic acid ratio can act as a marker for developing varieties against off-flavour development. This study validates our earlier findings on the levels of these fatty acids in the soybean mutants, which correlated with the off-flavour.

5.2.2.2 Effect of *gamma* radiation on off-flavour generation in soybean

The levels of off-flavour generation in soybean is mainly determined by its intrinsic total antioxidant capacity and LOX activity. Hence, the effect of different doses (0.5 kGy, 1.0 kGy, and 2.0 kGy) of γ-radiation treatment on the total antioxidant capacity and LOX activity of soybean genotypes differing in their seed coat color was examined. The total antioxidant potential (TAP) of these cultivars, as determined by DPPH and CUPRAC methods, was found to be enhanced with a concomitant reduction in LOX activity by 0.5 kGy dosage of γ-radiation. The TAP enhancement was more pronounced in cultivars with yellow-colored seed coat. To get more insight into the effect of γ-radiation treatment on off-flavour generation, thiobarbituric acid number (a measure of fatty acid hydroperoxides) and Carbonyl value (a measure of off-flavour causing aldehydes and ketones) were determined, which also suggested a decrease in the levels of off-flavour generation after 0.5 kGy γ-radiation treatment.

5.2.3 Abiotic Stress Tolerance

5.2.3.1 *SHN* expression, wax and ABA content in drought tolerant rice cv. Nagina 22

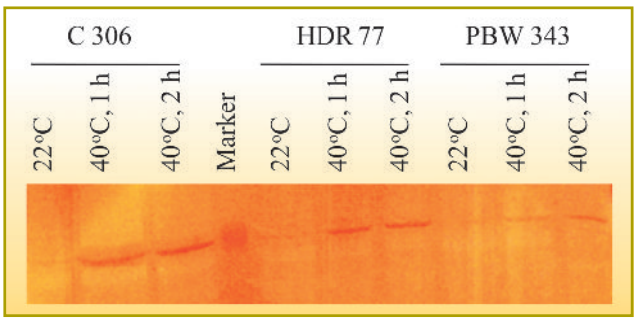
The plant stress hormone ABA levels were quantified in the leaves of drought tolerant rice cultivar Nagina 22 (N22) under normal and water deficit stress (WDS) conditions. The ABA content was more in stressed leaves as compared to that in control at all the three different developmental stages of the vegetative growth. A cDNA of WDS-inducible SHN clade AP2/ERF transcription factor gene was isolated from the leaves of rice cv. N 22 (GenBank acc # GQ369789). Since the *SHN* genes were involved in wax biosynthesis in *Arabidopsis*, epicuticular wax content was compared at varied relative water content (RWC) in leaves of *Oryza sativa* L *cv* N22. The wax content showed positive correlation with the expression levels of *SHN* in rice.

5.2.3.2 Screening of wheat cultivars for heat tolerance by TMS

Twenty-two wheat genotypes were characterized for basal as well as acquired, thermo-tolerance at the seedling stage by evaluating the thermal membrane stability (TMS) percentage. The wheat cultivars with >50% TMS were considered more thermotolerant than cultivars with <50% TMS. Based on TMS, C 306, HDR 77 and RS 909 were identified as thermotolerant and HD 2815 and Lal Bahadur as thermosusceptible for further studies.

5.2.3.3 HSP70 expression in developing grains of wheat

The HSP70 protein levels were analyzed in thermotolerant (C 306 and HDR 77) and susceptible (PBW 343) cultivars of wheat, which were subjected to heat shock treatments of 40 °C for 1 h and 40 °C for 2 h. Anti-HSP70 antibody was used for the western blotting. The accumulation of HSP70 increased with the increase in the duration of the heat shock treatment and was more in the case of thermotolerant cultivars (C 306 and HDR 77) than in the susceptible PBW 343.



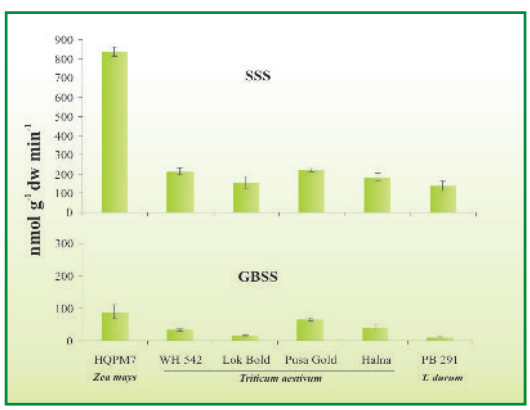
Immunoblot analysis of HSP70 expression in thermotolerant (C 306 & HDR 77) and susceptible (PBW 343) wheat cultivars

5.3 PLANT PHYSIOLOGY

5.3.1 Physiological Basis of Crop Yield

5.3.1.1 Starch synthase enzyme activity in the grains of wheat and maize

The activity of soluble starch synthase (SSS) and granule bound starch synthase (GBSS) was studied in the developing grains (20 days after anthesis) of five wheat varieties namely WH 542, Lok Bold, Pusa Gold, Halna and PB 291, and the maize variety HQPM 7 during *rabi* season. The SSS activity in maize grains was 3-4 times higher than that of wheat indicating high SSS protein concentration or catalytic rate in maize as compared to wheat. Among wheat genotypes, Lok Bold and PBW 291 had significantly lower activity of SSS. The activity of GBSS was considerably lower than the activity of SSS, confirming the role of SSS as the major enzyme for starch synthesis.



Soluble starch synthase (SSS) and granule bound starch synthase (GBSS) activity in the grains of wheat and maize varieties

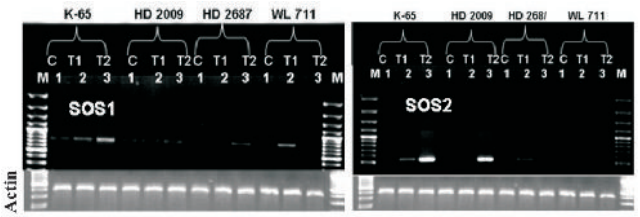
5.3.1.2 Chemical formulation(s) for improving growth and yield in chickpea

Application of urea, benzyl adenine and molybdenum significantly affected membrane stability index, chlorophyll content, and rate of photosynthesis. This resulted in better source capacity and thus better biomass production. The sink capacity was also improved as evident from the increase in the number of pods per plant and 100-seed weight resulting in high seed yield, in part, due to enhanced NR activity and photosynthetic rate. Under rainfed conditions, oliar spray of thiourea (750ppm), NAA (50ppm), IAA (50ppm), BA (40ppm), tannic acid (50ppm) and nitrobenzene (1ml/l) at 75 days after the sowing (before flowering) enhanced the yield by 15% over that of the water sprayed control treatment in chickpea through improvement of yield components such as photosynthesis, level of photosynthetic pigments, relative water content, membrane stability, crop growth rate and HI.

5.3.2 Abiotic Stress Tolerance

5.3.2.1 Conservation of SOS pathway and its role in salt tolerance of wheat

The salt overly sensitive (SOS) pathway is crucial for salt tolerance and ion homeostasis in *Arabidopsis*. The present study examined the role of SOS pathway in sodium homeostasis of wheat genotypes differing in their salt tolerance. Salinity treatment significantly reduced the potassium and calcium contents and increased the sodium content in leaf, stem and root of the six wheat genotypes studied. However, the decrease in potassium and calcium contents, and the increase in sodium content were less in tolerant genotype Kharchia 65, which also showed lower Na/K and Na/Ca ratios, and thus more favourable cellular environment. The expression of *SOS1* (plasma membrane H^+/Na^+-antiporter), *SOS2* (serine/threonine protein kinase), and *SOS3* (calcium sensor protein) increased under salinity

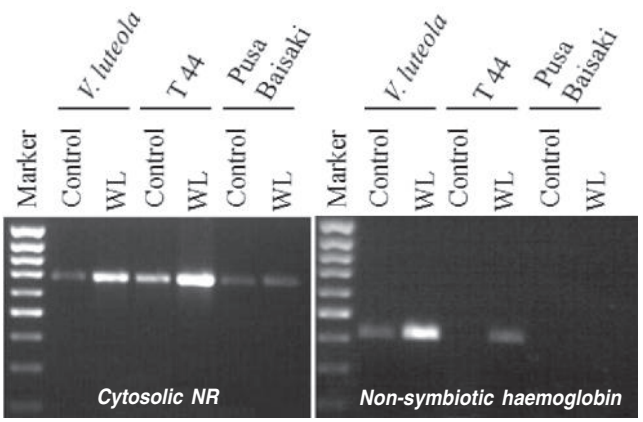


Expression of *SOS1* (A) and *SOS2* (B) in roots of wheat genotypes under salinity stress. *Actin* was used as internal control (M: marker, C: control, T1: 100 mM NaCl, T2: 200 mM NaCl)

both in root and leaf tissues. However, the increase specifically in root tissues was significantly greater in Kharchia 65. The expression of genes encoding tonoplastic proton pump *H^+-pyrophosphatase* and vacuolar *H^+/Na^+-antiporter* (*NHX1*) also increased under salinity, and the salinity induced expression was higher in Kharchia 65. SOS1 excludes Na^+ from cytosol, while NHX1 sequesters Na^+ in vacuole. An efficient SOS pathway consisting of SOS1, SOS2 and SOS3, and NHX1 in Kharchia 65 represent a Na^+-detoxification mechanism, leading to salinity tolerance.

5.3.2.2 Role of nitrate reductase, nitric oxide and non-symbiotic haemoglobin in waterlogging tolerance

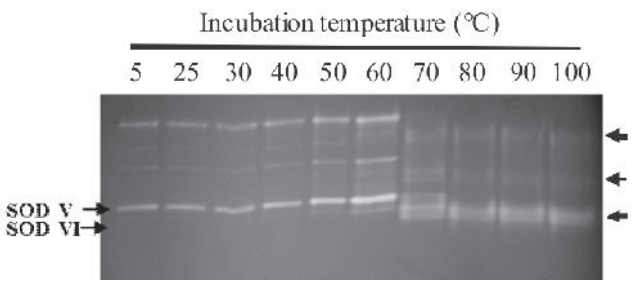
Under waterlogging/hypoxia, ATP is synthesized by substrate level phosphotylation in glycolytic pathway, which needs continuous supply of NAD. Normally this function is carried out by ethanolic fermentation which is accompanied by the accumulation of both lactic acid and ethanol that are injurious to plant cells. It is postulated that cytosolic nitrate reductase (cNR), nitric oxide (NO) and non-symbiotic haemoglobin (NS-Hb) act as an alternative to fermentation, for the oxidation of NADH and thus help continuation of glycolytic pathway. Hence, cNR, NO and NS-Hb were examined in green gram genotypes differing in waterlogging tolerance. The cNR activity and NO content increased under waterlogging, and the highest increase was observed in *Vigna luteola* (VL), a highly tolerant wild species, followed by T 44, and the lowest in waterlogging susceptible Pusa Baisakhi (PB). Consistent with the *in vitro* NR activity and NO content, waterlogging stress-induced expression levels of *cNR*, *nitric oxide synthase* (*NOS*) and *NS-Hb* genes were highest in tolerant genotype VL followed by T44. Both cytosolic NR and NOS are reported to be involved in NO synthesis. Further both cyosolic NR and NOS utilize NADH/NADPH for the synthesis of NO, and thus make the NAD available for continuation of glycolytic pathway.



RT-PCR expression analysis of *cytosolic-NR* and *non-symbiotic haemoglobin* genes as affected by 24 h water logging treatment in tolerant and susceptible *green gram* genotypes (WL= waterlogging)

5.3.2.3. *In vitro* heat stability of antioxidant defense enzymes of *Chenopodium album*

In vitro heat stability of different antioxidant enzymes in the leaves and inflorescence of heat tolerant weed *Chenopodium album* was studied in the samples harvested during December, March and April. The enzyme extracts were incubated at temperatures ranging from 25 to 100 ºC for 30 min in a water bath and assayed for enzyme activities and isozyme profiles. SOD was the most heat stable enzyme followed by APX in both leaf and inflorescence as both showed activity even after boiling treatment, and heat stable isoforms were visible on Native PAGE. Diversity in SOD and APX isoform profile was observed and some unique low molecular weight APX isoforms showed increase in activity with the increase in incubation temperature. Inflorescence contained more heat stable isoforms (up to 100 ºC) of SOD and APX than leaf. Chloroplast contained more heat stable (up to 100 ºC) APX isoforms than



Thermostability of SOD isozymes in the chloroplast isolated from inflorescence of *Chenopodium album* (Arrows indicate heat stable SOD isofrms)

mitochondria in both leaf and inflorescence. SOD, APX and POX showed activity up to 100 °C treatment owing to the presence of heat stable isoforms. Major heat stable isoforms of antioxidant enzymes were present during all the stages in leaves and inflorescence of *C. album* indicating their importance in innate thermotolerance.

5.3.2.4 Physiological basis of ascorbic acid induced drought tolerance in wheat

An experiment was conducted to study the effect of foliar spray of 100 mM ascorbic acid (AsA) at flowering stage on the physiological and biochemical changes in two contrasting wheat genotypes, namely, C 306 (drought tolerant) and HD 2687 (drought susceptible) under water-deficit stress. AsA treatment delayed the senescence, as evidenced by chlorophyll, photosynthesis and other senescence related markers in wheat. Total seed weight, 100-seed weight and harvest index were also enhanced significantly in AsA treated plants under both irrigated and water stressed conditions. However, the effect was more pronounced in the drought susceptible cultivar HD 2687 than in drought tolerant cultivar C 306.

5.3.2.5 Phenotyping for abiotic stress tolerance

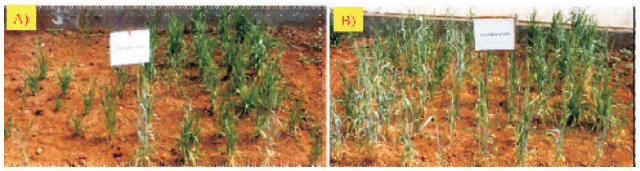
Water deficit stress tolerance in the RILs of the wheat cross WL 711 × C 306. The parents and 209 RILs of WL 711 (drought susceptible) × C 306 (drought tolerant) were subjected to post-anthesis water deficit stress by differential irrigation under field conditions. WL 711 showed higher reduction for yield and yield components as compared to C 306 under water-deficit stress. Some RILs showed transgressive segregation for yield and yield components. The response of the RIL population to water-deficit stress for biomass and grain number was similar to that of WL 711 while for 1000-grain weight and HI, it was similar to that of C 306. C 306 maintained cooler canopy as compared to WL 711 while the canopy temperature depression (CTD) of RILs varied widely in the post-anthesis period.

Drought susceptibility index (DSI) analysis of yield and yield components of the medium to late flowering RILs of the WL 711 × C 306 population during 2007-2010 at Delhi enabled the identification of eight RILs with high yield (540-673.6 g m^{-2}) and stability. These RILs maintained better water relations, cooler canopies and better membrane stability under water deficit stress conditions. The selected RILs have the combination of the desirable traits, i.e., medium to late flowering, yield higher than that of C 306, bold and amber colored grains and yield stability.

Phenotyping for drought and high temperature tolerance. Wheat association panels consisting of 294 genotypes from physiology programme and 146 lines from the international core set of CIMMYT were phenotyped for canopy temperature, relative water content and other physiological traits for their adaptability to drought and high temperature tolerance. Sufficient variability was observed for different physiological traits which can be effectively utilized for the breeding programme. International core set of wheat germplasm from CIMMYT involving Indian, Chinese, Australian, CIMMYT and other international material was subjected to differential water availability regimes with zero, one, two or five irrigations. Some of the promising lines identified with high drought tolerance were: Wyalkatchem, Drysdale, Gladius, and genotypes from populations of BAV92/SERI, Kukri/Excalibur and RILs of SOKOLL/WBLL1.

Effect of water deficit stress on phenology, yield and yield components in WL 711, C 306 and W × C RIL wheat mapping population at Delhi 2009-10

		WL 711	C 306	RILs
Grain yield (g/m^2)	Control	180.5 ± 2.2	113.5 ± 3.4	72.6 – 241.0
	Stress	107.2 ± 2.9	92.5 ± 1.7	55.2 – 158.7
Grain yield (g/m^2)	Control	32.4 ± 0.8	38.5 ± 0.5	24.0 – 45.1
	Stress	27.1 ± 1.1	40.8 ± 0.9	18.0 – 48.7
1000 grain weight (g)	Control	5512 ± 316	3101 ± 225	2201 - 7948
	Stress	3821 ± 580	2270 ± 447	1596 - 4933



Differential response of wheat genotypes to drought stress at vegetative (A) and reproductive (B) stages

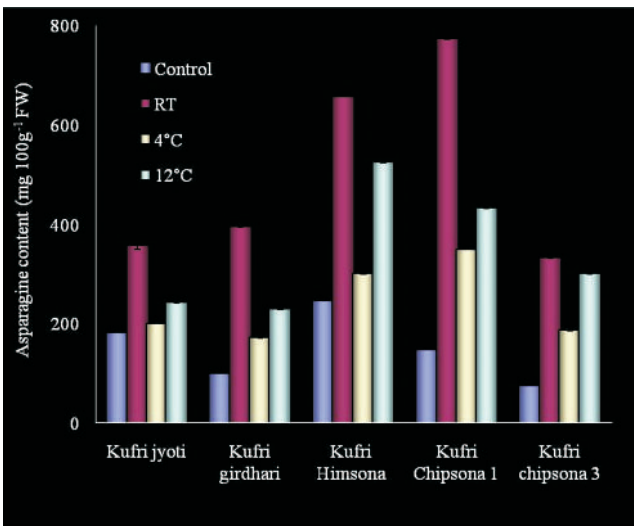
Phenotyping of lentil for abiotic stress tolerance. Forty-six genotypes of lentil were evaluated for root and shoot lengths and fresh weight of roots and shoots under drought stress. Genotypes, P51107 (ILL7620 × 88522), P51104 (ILL590 ×ILL7683), P51205 (88527 × ILL7555), P51207 (ILL10706), P51222 (ILL7723 × IL87062), P 51124 (ILL5588 × ILL99) and P 51115 showed the least reductions indicating their high tolerance to drought stress while genotypes, L4147, JL-3 and Haryana Masoor 1 showed early appearance of drought symptoms and greatest reduction in seedling traits. Several lentil genotypes were also screened for their tolerance to salinity stress and aluminium stress, and contrasting set of genotypes were identified.

Screening for high temperature tolerance in Brassica. Screening of 104 *B. juncea* genotypes for high temperature tolerance at seedling stage under controlled conditions in phytotron led to the identification of NPJ 124, EJ 22, NPJ 147 and 5011 (Pusa Agrani × Laxmi) genotypes that can tolerate 42 C for 5 hours/day up to 9 days.

5.3.3 Post-harvest Physiology

5.3.3.1 Minimizing cold induced sweetening in potato tubers

Cold-induced sweetening is caused by the accumulation of reducing sugars during cold storage of potato. These reducing sugars react with asparagines to yield acrylamide, when heated above 120 ºC under extremely low moisture content (Maillard reaction). A study was carried out to quantify the asparagine levels in three processing (Kufri Chipsona 1, Kufri Chipsona 3 and Kufri Himsona) and two non processing varieties (Kufri Jyoti and Kufri Girdhari) of potato stored at room temperature, 4 ºC and 12 ºC. Ten days after harvest, the level of asparagine was the highest in Kufri Himsona followed by that in Kufri Jyoti. Three months after storage, the minimum asparagine content was observed in the samples stored at 4 °C and the maximum under room temperature as compared to that stored at 12 °C temperature in all the varieties. In general the processing varieties were found to contain more amount of aspargine compared to that in the non-processing varieties. This suggests the need for reducing asparagine content in processing varieties to minimize acrylamide formation in potato chips and fries.



Influence of storage temperatures on asparagine content in potato tubers

5.3.3.2 Heterologous expression of ethylene insensitive receptor for delaying ripening/ senescence in tomato

Tomato transgenics expressing *CaMV35S* promoter driven ethylene receptor gene *GgERS1* from ethylene insensitive gladiolus flower were developed and confirmed by RT-PCR. The transgenic lines showed higher activity for antioxidant enzymes, SOD, CAT and MSI, and lower levels of oxidative stress in terms of TBARS and LOX compared

Development of *GgERS1* overexpressing transgenic tomato. Rooting of kanamycin resistant shoots (A: 8 weeks old shoots transfer to rooting media; B: 3-4 weeks old putative transgenic transfered to autoclaved soilrite filled pots; and C, D, E, F & G: plant development from flowering to fruit production)

to non-transformed wild type plants. These results suggest that *GgERS1* is effective in delaying ageing process in tomato.

5.3.3.3 Role of mineral nutrients in ripening of tomato fruits

A study was conducted to assess the relationship between the concentrations of different mineral nutrients (P, K, Mg, Ca, Fe, Zn, B, Cu and Mn) in the outer pericarp of tomato fruits with the ripening behaviour in contrasting varieties. Results showed that transition of tomato fruit from immature to green mature stage resulted in a net decrease in the contents of nutrients like Zn, Ca, and Mn while all other nutrients remained on a par. This indicated that tomato fruits at green mature stage may have inadequate levels of nutrients like Ca, Zn and Mn. Besides this, significant variability was also observed with respect to the contents of K, Mg, Ca, Fe, Cu and Mn at green mature stage. This variability may further contribute towards the observed differences in the ripening behaviour of different varieties.

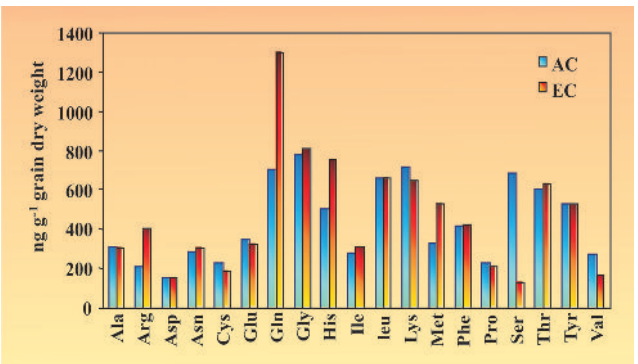
5.3.3.4 Role of ascorbic acid in delaying gladiolus flower senescence

The effect of ascorbic acid (AsA) was studied on flower senescence of gladiolus. AsA increased the vase life of flower spikes significantly over that of control and retained the fresh weight for longer duration. The expression of senescence associated genes (SAGs), viz., *GgCyP1*, *Gglox, GgERS1a* and *GgERS1b* was down-regulated while *GgDAD1* was up-regulated by AsA treatment during the flower development. The spikes kept in vase solution containing AsA also maintained higher membrane stability index while lipid peroxidation, measured as TBARS and lipoxygenase activity, was reduced as against that in control.

5.3.4 Impact of Global Climate Change on Crop Quality and Yield

5.3.4.1 Impact of elevated CO_2 on grain composition of wheat

An experiment was carried out to quantify the potential impacts of projected atmospheric CO_2 levels on the wheat grain composition relevant to processing and human nutrition. Wheat cv. PBW 343 was grown in field under free-air CO_2 enrichment (FACE). Results revealed that total grain protein concentration decreased significantly by 7.4% under elevated CO_2. High molecular weight (HMW) glutenin fraction and concentrations of some amino acids were significantly decreased under CO_2 enrichment. The reduction in amino acids ranged from 19% (serine, Ser) to 7% (proline). High-CO_2 treatment decreased the glutamine and proline (major amino acids of gluten proteins) levels by 9% and 7%, respectively. The concentration of cysteine, which is considered essential for children, was reduced by 16% in the FACE treatment. Minerals such as Mn and Cu increased while Zn, Fe and Mg decreased suggesting that adjustments of agricultural nutrient management may be required to retain current grain quality standards.



Changes in amino acid composition of wheat grains in response to CO_2 enrichment. AC = ambient CO_2; EC = elevated CO_2 (~600ppm)

5.3.4.2 Role of high temperature on reproductive physiology and yield of chickpea

Under the climate change scenario, *rabi* season temperatures are expected to increase more than *kharif* season temperatures. An experiment was conducted to quantify the effect of high temperature on the reproductive physiology, growth dynamics and yield of two commonly cultivated chickpea cultivars, viz., Pusa 1103 (*desi* type)

Effect of high temprature on plant yield in two chickpea genotypes

Genotypes	Temperature treatment	Number of pods plant^{-1}	Number of seeds plant^{-1}	Seed weight (g plant^{-1})
PUSA 1103	AT	111.83±4.17	123.17±4.42	24.26±0.95
	HT	79.33±2.36	88.33±2.75	19.02±0.65
PUSA 1105	AT	75.50±3.13	81.67±1.80	16.75±0.71
	HT	51.17±3.01	64.83±1.96	10.21±0.35
CD at 5% V x T		9.73	9.32	1.91

and Pusa 1105 (Kabuli type). High temperature (HT) grown plants flowered and pod initiated 10 days earlier than control plants (AT). Among the two genotypes, the total number of flowers and pods produced per plant were higher in *desi* type (Pusa 1103) compared to those in Kabuli type (Pusa 1105). HT stress considerably reduced the all the yield components, and the per cent reduction was less in Pusa 1103 as compared to that in Pusa 1105.

5.3.5 Use of Electromagnetic Radiation for Yield Improvement

5.3.5.1 Static magnetic field treatment for ameliorating seed ageing

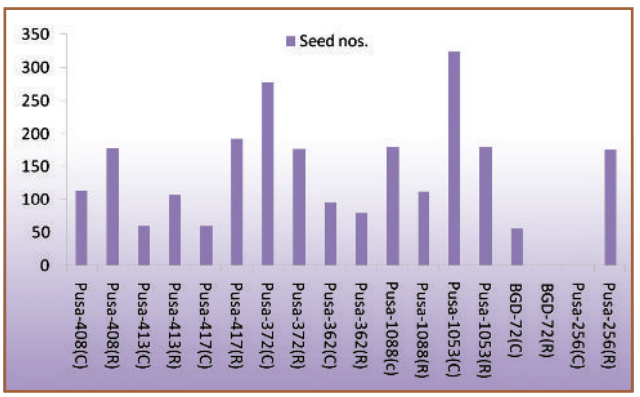
Ageing is a natural phenomenon leading to seed deterioration. The efficacy of magnetic field treatment in ameliorating the deterioration caused in naturally aged (stored for six years at 20 °C and 40% RH) in breeder's seed of garden pea (*Pisum sativum*) variety Bonneville was determined. Among the treatments, 100 mT for 1h was able to restore the vigour of aged seeds to the level of fresh seeds. The per cent increases over the unexposed aged seed were: 3.5 % for germination, 40.3 % for seedling length and 35.9 % for seedling dry weight. Vigour Index I and II improved by 45.4% and 40.9%, respectively, over those in the untreated controls. Seed leachate conductivity reduced significantly (5-13%) in magnetically treated seeds indicating improvement of seed coat membrane integrity of these seeds. Static magnetic field exposure of 100 mT for 1h can ameliorate the deterioration caused in storage and improve the germination and vigour of the seedlings and help in reclaiming the costly breeder seed.

5.3.5.2 Static magnetic field seed treatment for improving chickpea growth

Chickpea (Pusa 256) seeds were exposed to magnetic field of 100 mT for 1h and sown in a farmer's field along with control (unexposed). All seedling parameters such as shoot and root lengths, and shoot and root dry weight of the plants raised from magnetically treated seeds exhibited highly significant increase over those of the control. Shoot length increased by 34%, root length by 37%, shoot dry weight by about 80%, root dry weight by 30%, leaf area index by 38% and total chlorophyll by 22%. The number of nodules was significantly higher in the plants raised from magnetically treated seeds than in the untreated control. The root surface area increased by 63%, volume by 24% and total root length doubled in plants raised from magnetically exposed seeds. Further studies could reveal whether the enhanced root traits help extract moisture from the deeper layer.

5.3.5.3 *Gamma* irradiation to improve stress tolerance and yield

Mungbean seedlings raised from γ-irradiated seeds were subjected to 0, 25, 50 and 100 mM NaCl under lab condition. Positive effect of γ-irradiation under high salt level (50 mM) was found to be related to better maintenance of root as well as shoot attributes when compared with those of 0 mM NaCl - unirradiated mungbean. Field emergence of *bhindi* cultivars Pusa A4 and Selection-1 was studied in response to γ-irradiation at 0, 0.005, 0.05, 0.1, 0.2 0.4, 0.6 and 0.8 kGy. The γ-irradiation dose for GI50 were between ~0.55 and ~0.37 kGy. The seedling emergence improved at a low dose of 0.005 kGy, beyond which γ-radiation reduced the seedling emergence. A study on the effect of γ-radiation on the yield characteristics of chickpea genotypes revealed that cultivars, Pusa 408 and Pusa 417 gave the best response with higher pod and seed numbers and seed mass.



Effect of γ-irradiation treatment on seed number in chickpea. C = control; R = 0.025 kGy γ-irradiation

5.4 GENETICS

5.4.1 Wheat

5.4.1.1 Molecular mapping of *Rf* gene in wheat

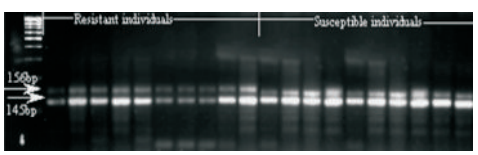
Genetic analysis of fertility restorer PWR 4099 revealed that fertility restoration of *Triticum timopheevi* cytoplasm based male sterility was controlled by a single dominant gene. Molecular mapping by the use of SSR markers showed that the linked markers, *Xwmc*503, *Xgwm*296 and *Xwmc112*

were present on 2DS at a genetic distance of 3.3cM, 5.8cM and 6.7cM respectively. The accuracy of the closest marker *Xwmc*503 in predicting fertility restoration was validated in a set of known and newly bred fertility restorers, maintainers and CMS lines. The result suggested that the *Xwmc*503 marker can be used in MAS for fertility restoration in segregating populations and also for screening wheat germplasm for their fertility restoration ability.

5.4.1.2 Rust resistance genes and markers in wheat

Leaf rust caused by *Puccinia recondita* f.sp. *tritici* Rob.ex.Desm. is an important pathogen of wheat. Transcriptomic analysis of host-pathogen interaction in leaf rust infection of wheat was carried out by challenge inoculation of resistant near isogenic line (HD 2329 + *Lr28*) and susceptible parent HD 2329 with the inoculum of race 77-5 of leaf rust. Real-time RT-PCR analysis led to the identification 10 genes of wheat that are upregulated by leaf rust infection. These genes will help illuminate the mechanisms of rust resistance and develop molecular markers.

Even though many leaf rust resistance genes have been reported, linked molecular markers have been discovered for only a few of them. Hence, a study was undertaken by IARI Regional Station, Wellington to develop a molecular marker for *Lr32* gene by using F_2 population of Agra Local × Tc+*Lr32*. Two markers, AP-PCR $SS9L_{700}$ and ISSR marker $UBC801_{800}$ were found to be associated with *Lr32* gene. About 119 F_2 population of Agra Local X Tc+*Lr32* were genotyped by using both the primers for the segregation of *Lr32* gene and it was found that the gene followed 3:1 Mendelian ratio for both of the primers. Future studies will be continued for the confirmation of these markers in other *Lr32* careers and their linkage analysis. The microsatellite marker *Xgwm131* (1BL) in cross UP 2338 × Agra Local against 40A and Xwmc679 (3BS) in the cross Kundan × Agra Local against 122 were identified as linked to the unknown stem rust resistance *Sr* genes. UP 2338 possesses resistance to Ug99 race of Africa and other races of India.



Identification of putative microsatellite marker Xgwm131 located on 1BL linked to the stem rust resistance gene in cross UP 2338 × Agra Local against 40A

Efforts are being made at IARI Regional Station (Tutikandi) Shimla to identify new genes for rust resistance in wheat. The genetic analysis of parents, F_1, F_2, and F_3 generations of a cross HS 365/Agra Local revealed the presence of a single dominant gene for rust resistance in the wheat variety HS 365, whereas another cross HPW 155/ Agra Local revealed the presence of two recessive genes in the wheat variety HPW 155 for controlling adult plant resistance against pathotype 121R63-1. Allelic tests indicated that HS 365 and HPW 155 carry different genes against pathotype 121R63-1.

5.4.2 Rice

5.4.2.1 Development of NILs for major blast resistance genes in the background of Pusa Basmati 1

Basmati rice varieties, in general, are highly susceptible to rice blast disease. More than 73 blast resistance genes have been identified so far, but all these genes are present in non-Basmati background and their transfer to Basmati background impairs the grain cooking quality characteristics of Basmati rice varieties. In order to circumvent this problem, isogenic lines carrying major blast resistance genes (*Pi1, Pikh, Pita, Pib, Piz5, Pi5* and *Pi9*) in the background of Pusa Basmati 1 were developed by using marker assisted backcross breeding. These lines, namely, Pusa 1633-1 (*Pi1*), Pusa1633-2(*Pikh*), Pusa1633-3(*Pita*), Pusa 1633-4(*Pi1*+*Pikh*), Pusa 1633-5(*Pi1*+*Pita*), Pusa 1633-6(*Pita*+*Pikh*), Pusa 1633-7(*Pi1*+*Pikh*+*Pita*), Pusa

Pusa Basmati 1 **Pusa Basmati 1633-7**

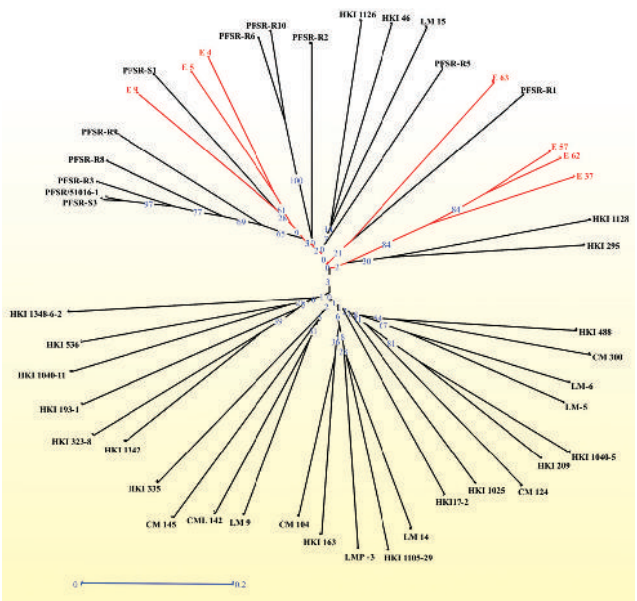
Photograph of bast susceptible Pusa Basmati 1 and blast resistant Pusa Basmati 16633-7

1634(*Piz5*), Pusa 1635(*Pib*), Pusa 1636 (*Pi5*) and Pusa 1637(*Pi9*), showed Pusa Basmati 1 genome recovery ranging from 71.5 to 93.7 % and agro-morphological; grain and cooking quality characteristics similar to those of Pusa Basmati 1 with resistance to blast disease. While these lines have the potential to be released as direct varieties after the required testing, they will serve as genetically enhanced donors for blast resistance genes in the Basmati breeding programme.

5.4.3 Maize

5.4.3.1 Analysis of molecular diversity in maize inbred lines for pink borer response

Maize inbreds were phenotyped for their resistance and tolerance to pink borer and genotyped using microsatellite markers. Sufficient diversity was observed indicating scope for exploiting the variability for breeding parental inbreds for tolerance to the pest.



Molecular diversity among maize inbred lines differing for pink borer response

5.4.4 Chickpea

5.4.4.1 Development and phenotyping of mapping populations of chickpea

Five mapping populations (2 for yield and 3 for drought tolerance) and 10000 TILLING lines in ICC 4958 were developed. Phenotyping of mapping populations for yield and drought were carried out. Phenotyping of F_8 generation of the mapping population in the cross SBD 377 × BGD 112 for seed index and seeds per plant was done and both the characters gave a polynomial distribution. The mapping population of the cross Pusa 1103 × SBD 377 was evaluated for drought related parameters, viz., relative water content and membrane stability index at pod initiation stage. A perfect polynomic distribution for membrane stability index in the RILs was observed indicating quantitative nature of inheritance for MSI.

5.4.4.2 Genetic analysis of stem growth habit

Chickpea, an indeterminate plant, produces excessive vegetative growth that acts as a competitive sink for developing pods resulting in reduced fruit set under favourable environments. Determinate chickpea is needed to break the yield barrier and stabilize yields in cool and long-season sub-tropical environments of semi-arid tropics. BGD 9971 is the first true breeding determinate chickpea genotype developed at the IARI Centre for Pulses Improvement, Dharwad. Genetics of determinate growth habit was studied in two crosses, BGD 72 × BGD 9971 and BGD 128 × BGD 9971 involving indeterminate and determinate parents. All the F_1 plants in both the crosses were indeterminate indicating the dominance of the gene(s) governing indeterminate growth habit over those for determinate growth habit in chickpea. The segregation patterns in the F_2 and F_3 of the two crosses involving indeterminate and determinate parents showed that the determinate growth habit in BGD 9971 was governed by two recessive genes. The genes for determinancy in BGD 9971 were designated as *dt1* and *dt2*. The homozygous recessive for both alleles (*dt1dt1dt2dt2*) produced a determinate phenotype. The utilization of genes identified for determinancy in the newly developed BGD 9971 will have major impact on chickpea breeding for better adaptation to cool climate, high fertility and irrigated environments.

5.4.4.3 Diversity analysis in a global collection of chickpea accessions

Diversity analysis of a world collection of 50 chickpea accessions was done using STMS markers. Polymorphic Information content (PIC) between cultivars ranged from 0.409 to 0.858. Darwin's tree constructed using the STMS marker data showed two distinct clusters with the accessions of ICARDA, Syria and the wild types forming a distinct sub-cluster quite divergent from those of Indian sub-

continent including those from ICRISAT, Hyderabad. The primary grouping appeared to follow geographic distribution. Within cluster I, the accessions of ICRISAT and IARI were grouped into a distinct sub-cluster. Within this cluster, all the Kabuli and *desi* genotypes of IARI grouped distinctively into two sub-groups. In cluster II also, the grouping has followed a definite pattern with all the cultivated types of *Cicer arietinum* L. falling in a distinct group while the wild *C. reticulatum* grouped into a single cluster with the genotype Pusa 1103 (IC 411513) falling in this group. The pedigree of this genotype involves the use of *C. reticulatum* as one of the parents and is the only chickpea variety released using a wild derivative. There is a very narrow genetic variation in *Cicer arietinum* species and the use of wild species in pre-breeding programmes greatly increases the available genetic variation. Greater genetic gains can be obtained by crossing the lines from the Indian sub-continent with those of ICARDA and the wild types, and pre-breeding would be the most suitable breeding approach to achieve this strategy.

5.4.4.4 Molecular breeding for *Fusarium* wilt

Marker assisted recurrent selection (MARS) in advance chickpea breeding lines is being carried out and 17 advance breeding lines (F_3 -2, F_2 -2, F_5 -5, F_6 -4, F_8 -4) have been selected using the markers TA 96, TA 110, and TS 82 which have been reported to be tightly linked to wilt genes.

5.4.5 *Brassicas*

5.4.5.1 Genetics of erucic acid and validation of SNPs for *FAE1.1* and *FAE1.2*

Pusa Karishma, a derivative of ZEM-1, possessing low erucic acid in the oil was taken to study erucic acid genes. Low erucic acid is controlled by two recessive genes in additive manners. Fatty acid elongase has been shown to be responsible for the elongation of oleic (C18:1) to erucic acid (C22:1). Two full length *FAE1* genes, reported in ZEM 1, were isolated and studied for the detection of already reported single nucleotide polymorphisms (SNPs) for both *FAE 1.1* and *FAE 1.2* genes. The DNA sequencing from Pusa Karishma revealed the same SNPs as reported earlier. All the four SNPs in *FAE 1.1* gene and three in *FAE1.2* gene were found in Pusa Karishma. Thus, all seven SNPs reported for low erucic have been validated in the parents and are being used in this study.

5.4.5.2 Genotyping for low glucosinolates in BC_3 population

Genotyping was done for 2100 plants in three BC_3 populations with five gene based markers. In the cross LES-1-27 × EC EC-597325, 18 plants were heterozygous for 4 or 5 primers; whereas in cross LES-39 × EC-597318, 15 plants were heterozygous for 4-5 markers, and in the cross LES-39 × EC-597325, only six plants were heterozygous for all five markers. All these plants were genotyped with SNPs for screening them for low erucic acid content also. Backcrosses with respective low erucic acid recurrent parent were attempted.

5.4.5.3 Identification of 0 & 00 genotypes

As a part of maintenance breeding and development of '0' and '00' material, biochemical analysis of 9984 single plants of breeding material, 4 released varieties and advance cultures (LET-36, LET-42 and LET-43), and 32 station trial entries was done, of which 6354 plants/bulks were having 0-2% erucic acid.

Analysis of single plant for selection of low erucic acid content

0 -2%	2 – 5%	5 – 10%	10 - 20%	>20%	Total
6354	1488	1292	406	444	9984

More than 5000 single plants of breeding material and mapping populations were screened for their glucosinolate content by using a spectrophotometer. Two-hundred and fourty-four single plants with less than 50 ppm glucosinolate in defatted cake were identified. From the segregating generations and advance material of the crosses for low erucic acid and low glucosinolates, 68 genotypes fulfilled the condition of 00, and 203 were low (<2%) in erucic acid. More than 5000 single plants selfed last year were phenotyped using GC and spectrophotometer. Eleven mapping populations for mapping genes/QTLs for white rust resistance, erucic acid and glucosinolate contents are being developed through single pod descent method.

5.4.6 Soybean

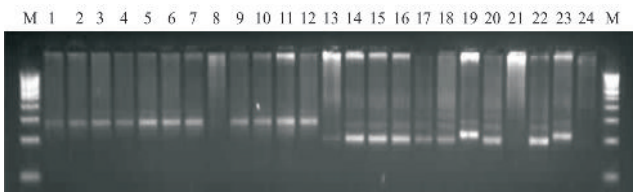
5.4.6.1 Seed storability

The variability in seed longevity of 313 lines of soybean was evaluated by storing these seeds for two years under ambient temperature and moisture conditions. Majority of the accessions (83.07%) registered < 30% germination and were classified as poor storers while 2.23% accessions,

which exhibited > 70% germination were classified as good storers. Black seed coat colour showed strong association with storability. The storability was found to be negatively correlated (-0.23) with seed size indicating that genotypes having smaller seeds were good storers. Linkage disequilibrium approach was used for identification of molecular marker capable of distinguishing soybean genotypes for storability behaviour. A set of 75 diverse accessions stored for a period of two years under ambient condition were studied. The selected germplasm lines were genotyped using 10 polymorphic SSR markers and the data were analyzed using STRUCTURE and TASSEL softwares. Results indicated the presence of association between the germination percentage and region close to SSR markers Satt600 and Satt285.

5.4.6.2 Identification of SSR markers linked to YMV resistance

Polymorphism of the markers (satt228, satt409 linked to *ti* allele) between the donor (PI542044) and the recipient (DS9712) was studied, and both the markers were found to be polymorphic. More than 200 SSR markers were tested for polymorphism between the parents to be used for background selection. More than 50% markers showed polymorphism.



Molecular profiling of YMV resistant (lanes 1-12) and susceptible (lanes 13-24) genotypes. M is Marker

5.4.6.3 Carbon isotope discrimination to identify genotypes with high WUE

Crosses were made between lines showing higher water use efficiency (PS 416, PS 1042, Pusa 9814 and PS 1024) and lines showing low water use efficiency (SL 444 and EC 472183). For association mapping, 225 lines along with 4 checks were grown in an augmented design for phenotyping. Data on 12 morphological characters were collected. Leaf samples of all the 225 lines along with their checks were evaluated for water use efficiency by using the carbon isotope discrimination technique ($\Delta^{13}C$). All 225 lines were characterized for specific leaf weight, leaf area and leaf ash content.

Variability in water use efficiency ($\Delta^{13}C$) and associated traits of soybean germplasm lines

	Minimum	Maximum
$\Delta^{13}C$	19.95	23.01
Specific leaf weight (mg cm^{-2})	1.20	13.33
Leaf area (cm^2)	54.71	138.64
Leaf Ash (mg g^{-1} dry weight)	0.073	0.139

5.4.7 Cotton

Evaluation of 299 RILs in F_6 generation developed from P 56-4 × RS 2013 in single row plots and 500 single plants in F_6 generation from 4 crosses to develop RILs for fibre quality and other important traits was carried out in cotton. Good variation was observed for yield (13.6 g to 244.8 g/plant), ginning outturn (29.8% to 42.8%), seed index (6.4 g to 12.1 g) and days to flowering (64 to 92).

5.4.8 Genetic Characterization and Diversity Analysis in Horticultural Crops

5.4.8.1 Mango

To identify the molecular markers for fruit quality, forty hybrids and their parents were analyzed using simple sequence repeat (SSR) markers. F_1 progeny population segregated by fruit quality traits were used for bulked segregant analysis. Candidate markers, namely, AKS-65180 and LMMA-14170- were found to be linked to high total carotenoid content and green peel colour, respectively, in mango. Similarly, MiSHRS-32 marker showed linkage to low titrable acidity content. These candidate markers will be useful to screen the F_1 progenies for high total carotenoids and green peel colour at nursery stage. Heritability study revealed high heritability and genetic advance for fruit weight and fruit volume, whereas extremely low genetic advance was found for titrable acidity and peel thickness in mango.

5.4.8.2 Carrot

Molecular diversity analysis was carried out among 15 genotypes of tropical carrot using 22 ISSR, 10 URP and 7 SSR primers. The mean genetic similarity among 15 genotypes was 0.60 indicating thereby that these had high genetic diversity. The genotypes, IPC 11 and IPC 122 were most divergent suggesting their suitability for hybrid breeding.

5.4.8.3 Bitter gourd

Based on morphology, cytology and molecular markers, three natural groups were recognized in the genus *Momordica*. The first group consisted of monoecious annual species (n=11), namely, *M. charantia* (var. *charantia*, var. *muricata*) and *M. balsamina*. The second group consisted of the dioecious perennial species (n=14), namely, *M. dioica*, *M. sahyadrica*, *M. subangulata* subsp. *renigera* and *M. cochinchinensis*. Morphological and cytological studies revealed that *M. cymbalaria* (n=9) had very less similarity with other *Momordica* species of Indian occurrence. Maximum genetic distance was also evident between *M. cymbalaria* (monoecious, perennial, n=9) and other *Momordica* species (monoecious annual, n=11 or dioecious perennial, n=14) of India based on RAPD and ISSR analyses.

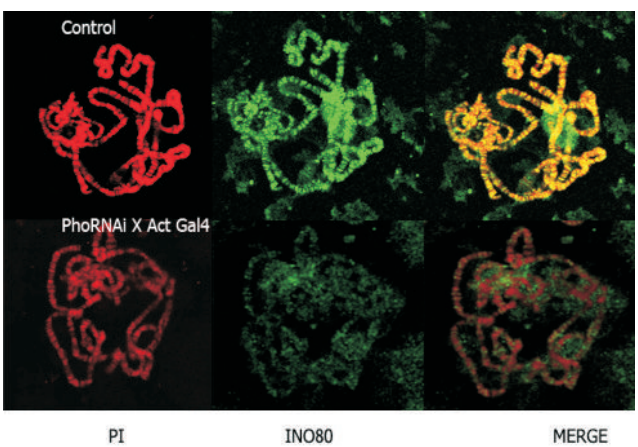
The somatic chromosome number 2n=22 in *M. balsamina* and *M. charantia*, and 2n=28 in *M. cochinchinensis* and *M. dioica* were reconfirmed while 2n=28 in *M. sahyadrica* somatic chromosome number was observed for the first time. A new chromosome count of 2n=18 was recorded in *M. cymbalaria* against its previous reports of 2n=16 or 22. In *M. subangulata* subsp. *renigera* (2n=56), a polyploidy chromosome number was observed for the first time. Pollen mother cells (PMCs) of the triploid hybrid (*M. dioica* × *M.subangulata* subsp. *renigera*) showed an average of 12.76 bivalents, 13.84 univalents and 0.88 trivalents, while *M. cochinchinensis* × *M. subangulata* subsp. *renigera* showed an average of 13.08 bivalents, 12.96 univalents and 0.96 trivalents. Hybrids involving the two diploid species (*M. dioica* × *M. cochinchinensis*) showed a mean of 9.12 bivalents and 9.76 univalent chromosomes at metaphase I suggesting that genomes of these species are only partially homologous. Segmental allopolyploid origin of teasle gourd (*M. subangulata* subsp. *renigera*) from spine gourd (*M. dioica*) and sweet gourd (*M. cochinchinensis*) was suggested based on the morphology and chromosome pairing behaviour in interspecific hybrids among them. It was also proposed that the genome of *M. dioica* could be designated as A1A1, that of *M. cochinchinensis* as A2A2, and that of *M. subangulata* subsp. *renigera* as A1A1A2A2.

5.4.8.4 Cauliflower

For molecular tagging of black rot resistance gene, about 120 primers were used for genotyping Pusa Himjyoti (susceptible genotype) BR 161 (resistant genotype) and 120 F_2 plants from the cross Pusa Himjyoti × BR 161. Of these, 7 (3 RAPD, 2 ISSR and 2 SSR) markers showed polymorphic banding pattern in bulk segregant analysis. The RAPD 04_{833} and ISSR 11_{635} markers were found to be closest at 1.6 cM distance flanking the resistance gene on lower and upper side, respectively, thus, showing their potential for marker assisted breeding for black rot resistance.

5.4.9 PHO-dependency of Ino80 for Chromatin Binding in *Drosophila melanogaster*

The consensus DNA binding sequence of Ino80 was determined as being 5′ [AC] [CA] [CA] [CG] GTCAGCC3′. This sequence was searched in 2 kb upstream regions of the ~14000 genes of *Drosophila* and it was found to be represented in homeotic genes, namely, Sex Combs Reduced (*Scr*), Antennapaedia (*Antp*), Ultrabithorax (*Ubx*) and Abdominal-B (*AbdB*). This finding supports the earlier finding that in the absence of Ino80, the *hox* genes showed altered expression. The other significant observation was that Pho binding sites were very often adjacent to Ino80 sites, raising the question of interdependency of Ino80 and Pho proteins in DNA binding. The pho gene expression was repressed by RNAi method. In the absence of pho, *Drosophila* showed the typical *pho* null phenotype of pupal death and homeosis. A study was carried out to ascertain if Ino80 would bind to chromosomes from pho RNAi larval polytene chromosomes. It was observed that in the absence of pho, Ino80 binding was highly reduced but not lost. Ino80 binding to chromocentre was not affected significantly by the absence of PHO. Ino80 protein was localized (immunologically) in oocytes and found to be concentrated in the nurse cell and follicle cell cytoplasm.



Ino80 binding on chromosomes of wild type and phoRNAi lines in *drosophila*

5.5 AGRICULTURAL PHYSICS, REMOTE SENSING AND GIS

5.5.1 Soil Physics

5.5.1.1 Soil aggregation and associated organic carbon fractions as affected by tillage in rice–wheat rotation

Soil samples were obtained from a long-term trial conducted on a silty-loam soil at Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram (Meerut) to study the effects of various combinations of conventional tillage and zero-tillage and raised-bed systems on the soil aggregation and associated organic C fractions in 0-5 cm and 5-10 cm depths in a rice–wheat rotation. Bulk and aggregate associated C increased in zero tillage systems with greater accumulation in macroaggregates. The fine (0.053–0.25 mm) intra-aggregate particulate organic C (iPOM-C) in 0.25- to 2-mm aggregates was also higher in zero tillage than in conventional tillage. A higher amount of macroaggregates along with greater accumulation of particulate organic C indicates the potential of zero tillage for improving soil C over the long-term in rice-wheat rotation.

5.5.1.2 Impact of elevated CO_2 on utilization of soil moisture and associated soil biophysical parameters in pigeonpea

The water use and root characters in pigeonpea (*Cajans cajan* L.), and fractions of active carbon pools in soils were studied under elevated CO_2 (580ppm) in open top chambers. In elevated CO_2, greater biomass led to higher water use efficiency by the crop. Root characters (0-30 cm soil depth) at 72 and 110 DAS showed significant increase in root weight, root length and root surface area under elevated CO_2. Roots with diameter <0.1 mm were significantly higher under elevated CO_2, which possibly contributed in greater soil moisture uptake. The rhizosphere soil at harvest showed no appreciable change in the soil bulk density, hydraulic conductivity and aggregation, although oxidizable-, carbohydrate-, labile- and microbial biomass-carbon pools increased significantly under elevated CO_2. The dehydrogenase and FDA hydrolysis enzymes increased substantially and were in a highly positive correlation with all C fractions indicating the role of active carbon pools in the stimulation of microbial population, leading to better biological activity in the soil near the root zone under CO_2 enrichment.

5.5.1.3 Effect of tillage and residue management on hydro-physical environment of a sandy loam soil under pigeonpea-wheat rotation

A long-term (6 years) experiment on tillage and residue management in a sandy-loam soil (Typic Haplustept) under pigeonpea–wheat cropping system at IARI farm was evaluated. Residue application significantly affected the soil bulk density (ρb) and resistance to penetration (PR), which were the lowest in conventional tillage with residue incorporation (CTRI) (ρb=1.52 Mg m^{-3}, PR=1.27 MPa). The PR (1.77 MPa) was greater in no-till and bare (NT) treatment, while residue retention (NTRM) drastically reduced both ρb (1.58 Mg m^{-3}) and PR (1.65 MPa) in NTRM treatment. A hard pan (PR between 1.72 MPa and 1.80 MPa) was detected at 0.2 m layer although marginal reduction in PR was recorded in NT and NTRM at this layer. The soil organic carbon was higher in CTRI and NTRM. Mean weight diameter was 20-50% (0-0.10 m) and 20-30% (0.10-0.20 m) higher in CTRI and NTRM than that in conventional tillage and bare (CT). Soil macro-pores were 30-40% higher in NT and NTRM, compared to those in CT or CTRI plots. Residue incorporation could significantly improve the transmission pores in conventional tillage, which might have contributed to better water retention in soils.

5.5.1.4 Effect of Pusa hydrogel application on hydrophysical properties

A laboratory experiment was conducted with 4 soil types: sandy, alluvial sandy-loam, red sandy-loam and black clay loam in PVC columns as the main treatment, and 3 levels (0, 0.5, 0.7%) of Pusa hydrogel application (0-10 cm) as sub-treatment to investigate the effect of hydrogel on soil hydraulic properties. Results revealed that water release per unit change in suction at 0-10 kPa range was higher in un-treated soil as compared to that in hydrogel-treated soil. However, the water release in the range of 10-100 kPa (available water) was significantly higher in the hydrogel treatment in all the soil types, and it became very less at soil water suction > 100 kPa. The effect of hydrogel was better in sandy type of soil than in other types, where water (corresponding to 10-100 kPa) remained available for a longer period of time.

5.5.1.5 Influence of cropping systems on soil health

The influence of seven cropping systems on the soil health was quantified through the development of soil quality indices (SQI). Four SQI's were developed based on 13 physical, chemical and biological properties of soil by

different methods of integration of scores. The maximum sensitivity of an index to changes in soil quality was exhibited by the Non Linear Weighted Index (NLWI) and was selected for evaluating and comparing the total quality of soil under seven cropping systems, viz., pearl millet-wheat-fallow, cotton-wheat-fallow, pearl millet-barley-green gram, cluster bean-broccoli-onion, green gram-mustard+*kasni*-fallow, pearl millet-wheat-cowpea and pearl millet+green gram-wheat+mustard-fallow at Hisar. The cotton-wheat-fallow and moongbean-mustard+*kasni*-fallow showed the highest index values indicating that the soil under these cropping systems was in better health than in other cropping systems. This study showed that the soil quality under pearl millet-wheat-cowpea was 29% degraded and hence should not be continued for long term as it slowly deteriorated the soil quality.

5.5.1.6 Assessment of groundwater development potential in the Yamuna river flood plain of Delhi

About 30% of the Yamuna river flood plain stretch (length 22 km; area 97 km^2) in Delhi is used for agricultural practices. Based on the IRS LISS-III satellite image of the river flood plain stretch and the ^{18}O isotope signatures of the groundwater and the river water, the influent/effluent seepages were assessed to be 70-98% along the different parts of the flood plain stretch in Delhi. The potential ground water (GW) recharge zones were delineated to be located mostly in the northern parts near Palla well field of the river stretch. Non-invasive GW recharge potential from the river discharge in the Palla region flood plain stretch was assessed to be ~ 260 MCM per year. Conservation of this potential water in the recharging zones may be helpful for flood management, ecological regime protection and water supply.

5.5.2 Remote Sensing and GIS

5.5.2.1 Intra-seasonal variations in vulnerability to agricultural drought in Rajasthan

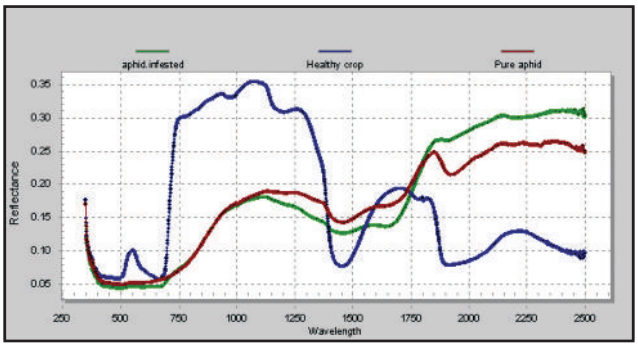
Quantification of the vulnerability to agricultural drought and its intra-seasonal variations is essential to design area specific crop contingency and mitigation plans. Drought vulnerability of an area is a function of hazard's exposure, area's sensitivity and adaptive capacity. Vulnerability to drought in *kharif* season and its intra-seasonal variability was mapped for the state of Rajasthan. Frequency and intensity of standardized precipitation index (SPI) computed by using monthly rainfall data (1951-2006) were used as indicators of hazard probability, frequency and intensity of satellite derived vegetation condition index (VCI) during 1982-2006 and soil water holding capacity were used as indicators of sensitivity, whereas percent area under irrigation was used as an indicator of adaptive capacity. The vulnerability was mapped separately for early, mid, late and whole *kharif* season. Results showed that about 11, 53, 31 and 5% of the state's net sown area had extreme, high, moderate, and low vulnerability, respectively, for whole *kharif* season. The top five districts, vulnerable to agricultural drought, are Jaisalmer, Churu, Barmer, Jalore, and Sirohi, whereas Alwar, Sriganganagar, Bundi, Dausa, and Kota have low vulnerability. Besides mapping, district-level drought vulnerability statistics were generated which showed significant correlation with human development index (HDI) and food grain productivity.

5.5.2.2 Bi-directional reflectance modeling of soybean

Understanding the bi-directional reflectance behavior of crops helps develop a methodology for retrieval of leaf and canopy parameters from remote sensing data that are very useful in regular crop growth monitoring and yield assessment. Bi-directional reflectance for soybean cv. Pusa 9814 at 400-2500 nm wavelength range was measured using spectro-radiometer with an inhouse-designed goniometer at different growth stages. The radiative transfer model PROSAIL was able to simulate well the overall spectral reflectance curve of soybean. The model underestimated the reflectance in visible region (0.4-0.8µm) but overestimated the reflectance in near-infrared and mid-infrared regions (0.8-2.4µm). Results showed that PROSAIL model simulated well the spectral reflectance of soybean crop at different view geometries and could be inverted to estimate soybean biophysical parameters of leaf area index, chlorophyll and leaf water.

5.5.2.3 Identification of aphid infestation in mustard through remote sensing

A field experiment was conducted with 3 cultivars of mustard, viz., Pusa Gold, Pusa Jaikisan and Pusa Bold sown on 19th October, 3rd November and 18th November. Spectral reflectance of the healthy, and aphid infested mustard was measured in laboratory and field. The aphid infested mustard showed very low reflectance throughout the visible region while healthy mustard showed a 10% reflectance at 550nm. In the near infra-red region, the aphid infested mustard showed consistently less reflectance than the healthy mustard while this trend reversed in shortwave infrared region (1500-2500 nm). At water absorption bands of 1390 nm and 1900 nm, the

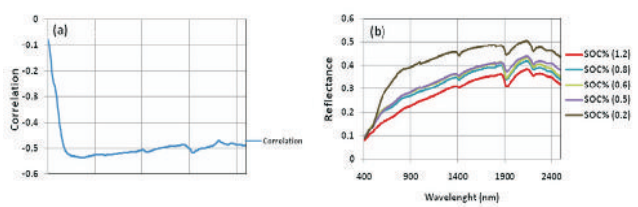


Spectral reflectance curves of aphid infested and healthy mustard, and that of pure aphid

aphid infested mustard showed higher reflectance than the healthy crop. Spectral indices, viz., NDVI, RVI, AI and SIPI showed significant correlation with aphid infestation. The study revealed that there is a scope of using hyperspectral remote sensing for the identification of aphid infestation.

5.5.2.4 Characterization of soil by the use of hyperspectral remote sensing data

A study was carried out in northern Punjab to characterize soils through hyperspectral reflectance data to generate their characteristic signature for varying physico-chemical properties. Soils of this area are covered by two soil orders, 4 soil-sub orders and 10 soil mapping units. It was found that the representative soil reflectance curves could discriminate the soil sub-groups and orders. The magnitude of reflectance in the 1400 nm for four sub-groups in the descending order is Haplustepts > Ustochrepts > Ustipsamments > Ustilfluvents. The soil organic content showed significant negative correlation with the soil reflectance in visible and near-infrared region. Spectral correlation analysis revealed that the highest correlation (-0.55) was obtained in the visible region, i.e., 620-810 nm. Hence, this region can be considered as the main remote sensing band for retrieving soil organic content.



Change of reflectance characters with soil organic carbon (SOC). (a) Correlation of reflectance at different regions of spectra with SOC (b) Change of reflectance curve with the variability in SOC

5.5.3 Agricultural Meteorology

5.5.3.1 Analysis of meteorological drought during *kharif* season at IARI

Frequency and temporal trend of meteorological drought at IARI, New Delhi station for the *kharif* seasons of the period 1951-2009 was done. For this, standardized precipitation index was calculated and analyzed at four time scales, namely, trimonthly SPI_JJA, bimonthly SPI_AS, bimonhthly SPI_SO and pentamonthly SPI_JJASO corresponding to early, mid, late and whole *kharif* seasons, respectively. The study showed that the meteorological drought had nearly the same frequency for early, mid, late and whole *kharif* seasons at Delhi and, on an average it was experiencing one drought year in 10-12 years. The early season rainfall deficit was mainly determining the whole season drought at Delhi. There were nearly equal numbers of deficit and excess rainfall years in the past 59 years and no temporal trend was seen in the magnitude of rainfall deficit in any of the seasons. This has important implications from the point of view of climate change and climate variability, suggesting that rainfall variability and magnitude have not changed significantly at Delhi.

5.5.3.2 Weather-based agro-advisory services

Weather based agro-advisories for farmers of Delhi and NCR are sent twice a week by the agro-advisory unit located in the Division of Agricultural Physics of the institute. The advisories based on medium-range weather forecast data for next five days (received twice a week, Tuesday and Friday from IMD, New Delhi) are prepared by a team consisting of expert from different disciplines. Weather information along with crop wise weather-based agro-advisories is passed on to the progressive farmers on real time basis through print, electronic media and speed-post. Bi-weekly agromet advisory bulletins are prepared in Hindi as well as in English and published in the newspapers (*Dainik Jagran* and *Haribhoomi*) and uploaded on IARI website (http://www.iari.res.in), besides sending them through e-mail to IMD for use in their website for district agro-advisory and also for preparing national agro-advisory bulletin. The bulletin is sent through e-mail to ATIC, KVK Shikohpur, Ujawa, state departments of agriculture, Agricultural Technology Management Association, NGOs and e-chopal. A web page was also developed and maintained on IARI website for issuing advisories and real time weather data along with medium range weather forecast. During 2010-11, 103 agro-advisory bulletins were prepared in Hindi as well as in English and given coverage in 26 newspapers.

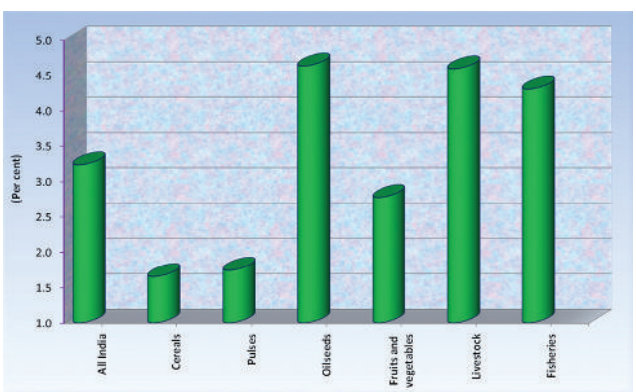
6. SOCIAL SCIENCES AND TECHNOLOGY TRANSFER

The School of Social Sciences comprising the Divisions of Agricultural Economics, and Agricultural Extension, Centre for Agricultural Technology Assessment and Transfer, Agricultural Technology Information Centre and Krishi Vigyan Kendra focussed research on the priority areas of agricultural growth, trade agreements, and investments in agriculture, cyber extension, innovative extension models, entrepreneurship development and gender empowerment. The recent trends in Indian agriculture revealed impressive growth in Gujarat .Two cyber extension centres were established in Sitapur and rural youth were trained for using ICT tools. The propensity of technology adoption and entrepreneurial initiatives had improved as a result of interventions under ATMA in M.P. Development of Model Villages was initiated in semi-urban areas of NCR for integrated development.

6.1 AGRICULTURAL ECONOMICS

6.1.1 Agricultural Growth and Non-farm Employment

A study analyzed the three recent trends in the growth experience of Indian agriculture. Firstly, coarse cereals, particularly maize, oilseeds and cotton showed rapid growth rates. The growth in maize and cotton was primarily technology driven. In oilseeds, area expansion, price incentive and better seed varieties were responsible for yield growth. The second major welcome trend was the impressive agricultural growth in some states like Gujarat where institutional reforms to expand irrigation and transfer of technology were the major contributing factors. The third major trend was the rapid growth of high value commodities like fruits, vegetables, livestock and fisheries. Price incentives because of rising demand and strong market linkages prompted farmers to diversify towards these commodities. This was accompanied by supply-side factors like improved availability of seed and other planting material. The evidence indicates that these sectors will continue to grow faster and, therefore, will compete for area with foodgrains. Thus, there is a need for raising the productivity of foodgrains so as to release area for high value commodities, and this will require better technologies and input delivery system in newer regions like eastern India.



Annual growth rates in agricultural GDP, 1999-00 to 2008-09

The experience of east Asian countries shows that higher growth can be realized in smallholder agriculture but there should be rapid transfer of people from agriculture to industrial or rural non-farm sector. In India, where employment elasticity is low in agriculture, the growth of non-farm sector becomes critical and this again depends on agricultural growth and rural infrastructure. Sectoral estimates of employment elasticity showed agriculture having extremely low elasticity (0.009) implying nearly no capacity in agriculture to employ additional labour force. This is in contrast to higher absorption capacity (0.3920) in non-agricultural sector (construction sector).

6.1.2 Inter-regional Trade Agreements in Agriculture

A study on inter-regional trade agreements in agriculture showed an increasing trend towards regionalism with a shift in trade to new partner countries in Asia, Middle East and Africa. Between 1992 and 2009, the share of India's merchandise exports to Asia, Africa and the Middle East has increased while the share of exports to Europe and north

and central America has declined. Estimates of trade intensity indices, which reflect a country's export intensity with a trading partner in relation to world exports to that partner, also show greater prominence of regional partners in trade. An examination of the trade intensity indices for India with neighboring Asian partners shows that Sri Lanka is an important partner of India in external trade. The indices for the Russian Federation show a marked decline between 2000 and 2007. The total merchandise exports from India to SAARC countries have, in absolute terms, increased by 344 per cent between 2000-01 and 2009-10. India's imports from SAARC countries have increased by 248 per cent during the same period. This implies a positive balance of trade between India and its SAARC partners. In recent years, the inter-year variability in exports and imports related to SAARC countries is also declining.

6.1.3 Agricultural Investments in the Post-Liberalization Period

A study analyzed the trends and composition of investment in Indian agriculture. The analysis showed a declining trend in growth of real public investments during the eighties and nineties in contrast to the private investments, which grew rapidly. The growth in public investment rebounded again (15.80 per cent) during the current decade, and with modest private investment (4.8 per cent), the total investments registered an impressive growth of 7.1 per cent. Despite this robust growth in recent years, the share of agriculture remained around 7 per cent in the total investment. The changing sectoral shares within agricultural investments still show the prominence of crop and livestock sectors followed by the rising share of fisheries sector (13 per cent) indicating the diversification of agricultural investment portfolio in recent years. Investments in fisheries sector are predominantly done by the private sector. In contrast to this, in forestry sector, the investments remained meager and stagnant (2 per cent), and were mostly propped up by the public sector owing to its ownership pattern. Investment priorities in agricultural sector have been centered on infrastructure creation, irrigation and flood control, and rural development. Among the states, southern and western states accounted for two thirds of the total state investment, while hilly and north eastern regions had to do with less than 10 per cent of the state investments.

Decadal growth trends in public and private capital formation in agriculture and allied sectors (1999-2000 prices)

Time period	Compound growth rate in gross capital formation (%)		
	Public	Private	Total
1980-81 to 1989-90	-3.80	2.50	-0.26
1990-91 to 1999-00	-0.22	4.11	3.05
2000-01 to 2007-08	15.80	4.80	7.08

Private sector investment in agriculture is being made by corporate bodies and farm households. An analysis of the decennial All India Debt and Investment Survey data regarding the composition of farm household investment in agriculture shows that investment in farm machinery, transport equipment and minor irrigation constitutes 70 per cent of the total farm business investment by rural households in 2002-03. Investment in land improvement, which used to be important during the eighties and the nineties (15 per cent), has declined to 6 per cent in 2002-03. The other capital expenditure, which largely includes livestock, has also been gaining importance in recent years. These changing priorities of rural households seem to be compatible with the need for more intensive use of land resources and commercialized agriculture. But this encouraging trend in private investment has been accompanied by a fall in the proportion of farm business investment in the total household investment to 22 per cent in 2002-03 from 35 per cent in 1981-82.

Private investment in agriculture is considered to be largely dependent on several enabling factors such as public sector investments, especially in infrastructure, terms of trade and availability of investible funds with the farmers. Total direct institutional credit to agriculture by all institutional sources has shown impressive growth rate especially during the current decade. The term-credit, which facilitates investment in agriculture, constitutes a sizeable proportion of private capital formation. The proportion, which was one-third during the seventies, doubled during the eighties. After a temporary decline in the share to 45 per cent in the nineties, it rose to 75 per cent of the private investment in agriculture after 2003-04. A number of innovative credit delivery instruments like kisan credit card (KCC), microfinance, etc., have been promoted to enhance the timeliness and access of credit to agriculture sector. It is observed that the flow of credit through KCC is growing at the rate of 22 per cent. However, the performance varies across the institutions with cooperatives and commercial banks playing a major role in the flow of credit through KCC. KCC helps in 40 per cent

reduction in transaction cost of borrowing loan from banks. KCC beneficiaries realized higher farm business income ranging from 5 to 60 per cent across different crop enterprises mainly because of the timely availability of good quality inputs.

6.1.4 Energy Use in Indian Agriculture

A study showed structural changes in energy consumption in Indian agriculture, with a shift from animal and human labour towards commercial energy inputs such as electricity and diesel for groundwater irrigation, and other farm machinery operations. The consumption pattern of both direct and indirect sources of commercial energy was analysed by using time series data to explain the direction and the extent of energy use in Indian agriculture. The consumption of electricity witnessed a sharp increase between 1980-81 and 1995-96 and became stagnant thereafter. It started increasing again in recent years. The consumption of diesel had a sudden spurt during 1995-2000 while the consumption of fertilizer increased consistently throughout the study period. The total commercial energy input to Indian agriculture has increased from 425.4×10^9 Mega Joules (MJ) in 1980-81 to 2592.8×10^9 Mega Joules in 2006-07. The estimated energy intensity per hectare of gross cropped area also showed an impressive rise from 2.5 thousand MJ to 13.4 thousand MJ during the same period.

The study showed that the output per unit of direct as well as indirect energy has declined over time. This further underscores that Indian agriculture has become more energy intensive. Keeping in view the declining groundwater table, mechanized farm operations and increasing nutrient deficiencies, the direct and indirect energy requirements for sustaining the current yield levels will further increase. Therefore, there is an urgent need for developing energy saving technologies of production.

6.1.5 Productivity Divide and Instability in Rice-Wheat System

A disaggregate analysis of rice growing districts in the rice-wheat system of Indo-Gangetic Plains (IGP) revealed a clear divide between the agriculturally prosperous areas and lesser developed areas. In Trans-Gangetic Plains, rice productivity is far greater than that in middle and upper-Gangetic regions. All the districts in Punjab and 61% of the districts in Haryana achieved productivity of more than 2.5 tonnes/ha. However, dismally low productivity levels at less than one tonne per hectare are more pronounced in the middle and upper-Gangetic Plains region. Though the relationship of productivity can be broadly associated with the major growth factors such as percentage of high yielding varieties (HYVs), level of fertilizer consumption and percentage of irrigated area, it is important to identify the location specific production constraints, both biotic and abiotic, and eliminate them. The distribution pattern of instability indices of productivity of rice in different districts of IGP region showed that a few districts are still unstable. Rice productivity is unstable in 4 districts of Punjab with an instability index of more than 10. Having identified the districts of IGP region based on low productivity of rice, falling productivity growth, and instability in productivity, targeted approach to improve the productivity level of rice can be followed. This would be helpful particularly in resource scarce areas where prioritization of resources for research and developmental activities should be taken up.

Productivity in rice-wheat cropping system has a correlation with irrigation water. The percentage coverage of irrigated area under rice and wheat crops in the trans-Gangetic Plains (Punjab and Haryana) is almost 100 per cent. The extent of ground water use is exorbitant in Punjab, and the percentage share of tube well irrigation in net irrigated area is 72 per cent. Seventy-five per cent of the blocks are designated as over-exploited. Water productivity in wheat cultivation is estimated to be 0.11 tonne per hr of irrigation in Haryana and 0.14 tonne per hr of irrigation in Bihar. Although, wheat crop productivity in Haryana is more than that of Bihar, water productivity is less in Haryana, which revealed the intensity of water use in Haryana. The water productivity is significantly influenced by the method of cultivation in wheat. Zero tillage has shown potentials in IGP region in terms of water saving. It is important, therefore, to promote resource conservation technologies like zero tillage in IGP region on a wider scale to maximize the productive use of water.

6.1.6 Economic Analysis and Prospects of Non-edible Oilseeds in India

Non-edible oilseeds such as *jatropha curcas* and *pongamia pinnata* are being promoted as important sources of bio-fuels and considerable efforts are on to promote the cultivation of these crops, especially jatropha, in the country.

Information collected from the farmers growing jatropha in Tamil Nadu showed that in the third year after the establishment of the plantation, the average per hectare yield realized by the producers was 1978 kg/ha. This improved to 3457 kg/ha during the fourth year and further to 4997 kg/ha in the fifth year of the plantation. The average yield for all years was 3462 kg/ha. The initial cost of setting up the plantation is high with the first year accounting for ₹ 13175 per ha. Human labour accounts for almost half of this cost. Planting material is the second item on which high expenses are incurred. The costs declined in the second year to ₹ 5777 per ha. The expenditure in this year is related largely to the establishment of the plantation with FYM, irrigation, replacement cost of dead saplings, and human labour. Cost C2 was estimated at ₹ 24825 per ha during the first year and ₹ 16411 in the second year making the total establishment cost of ₹ 41236 per ha. Cost C2 declines from the third year onwards to ₹ 19697 per ha on an average. On per kg basis, the cost of production of *Jatropha curcas* seeds works out to ₹ 6.79 on the basis of Cost C2. The private companies that are promoting *Jatropha curcas* cultivation in the region have an arrangement to buy seed from farmer- producers at a rate of ₹ 7 per kg. This was raised slightly to ₹ 10 per kg by the companies in 2008-09. The price does not seem to be attractive given the per kg cost of production of ₹ 6.79. This, coupled with poor procurement facilities, is the major factor that deters the farmers from taking up *Jatropha curcas* cultivation. Lack of high yielding varieties, high requirement of labour and high labour wages, and uncertainty in prices and procurement were found to be the other important deterrents to the adoption of *jatropha* cultivation.

6.2 AGRICULTURAL EXTENSION

6.2.1 Cyber Extension Model for Agricultural Development

Two cyber extension centres were established in Neelgaon and Chaudiya Manpara villages of Sitapur district in Uttar Pradesh. Three rural youths in each of the 2 villages were trained to use information communication technology (ICT) tools to facilitate the farmers of the villages to access information. For capacity building of farmers (120) and post office personnel (20), a two-day training programme was organised at the Krishi Vigyan Kendra, Ambarpur, Sitapur on improved production technologies. Short message service (SMS) based agro-advisory services were also started for dissemination of improved crop production technology.

It was observed that most of the KVK and state agricultural department officials (81.82%) were using the internet for information.

Pattarn of internet usage by farmers (N=49)

Type of information sought	Frequency	percentage
New technological information	40	81.63
Farm related problems	36	73.46
General agricultural information	49	100.00
Market related information	32	65.30
Weather information	20	40.81
Input and commodity prices	49	100.00
Educational information	09	18.36
Information regarding government schemes	11	22.45

It was found that all the officials of KVKs, state agricultural departments and post office had mobile phones, while 71.67 per cent of the farmers had mobile phones.

High yielding seeds of different crop varieties were supplied to farmers through post offices to disseminate information on high yielding varieties of IARI and encourage the farmers to adopt them for cultivation. During *rabi* 2010, high yielding seeds of the wheat varieties HD 2985 and HD 2987 and the mustard variety Pusa Jaikisan were supplied to 130 farmers (20 villages) covered under seven post offices in two blocks of Sitapur district. The performance of these varieties was found to be better than that of the prevailing varieties. The yield data and feedback on paddy (PRH 10, Pusa Basmati 1 and Pusa Sugandh 5), pigeonpea (Pusa 992 and Pusa 2001) and *bajra* (Pusa 383 and Pusa 443) supplied to 129 farmers in *kharif* 2010 through post offices revealed that the farmers preferred PRH 10 to other varieties for yield, taste, etc. Basmati type of rice was preferred less because of non-availability of specified milling facility. Short duration pigeonpea was not accepted by the farmers. For summer season, seeds of bottle gourd (25 kg), pumpkin (5 kg) and okra (105 kg) were supplied to 135 farmers in the catchment of seven selected post offices. In order to develop a structural mechanism between postal department and IARI for effective dissemination of farm information, sensitization meetings with postal officials were held. The supply of seeds through post offices was perceived positively by the farmers.

A cyber extension centre in Sitapur (U.P.)

A training programme organized on improved wheat and mustard production technologies for farmers and post office staff

6.2.2 Extension Models and Strategies for Sustainable Livelihoods

A study on the effectiveness of the Agricultural Technology Management Agency (ATMA) conducted in Hoshangabad and Dhar districts of MP revealed that a majority of the beneficiary farmers (87 per cent) were satisfied with the quality of information and advisory services. However, measured on a 5-point continuum of "can do all" to "cannot do at all" with a respective weightage of 5 to 1, the field extension professionals showed a mean score of 1.41 expressing skill gaps in: (i) use of participatory rural appraisal (PRA) tools, (ii) preparation of Comprehensive District Agricultural Plan (C-DAP) and Strategic Research and Extension Plan (SREP), (iii) organization of farmers' field school, (iv) entrepreneurship development, (v) use of ICT-enabled information dissemination tools, and (vi) presentation of radio and TV talks. The propensity for technology adoption and entrepreneurial initiatives had improved as a result of interventions under ATMA.

A case analysis of two producer companies, namely, Samarth Kisan Producer Co. Pvt. Ltd. of Sajhapur, Ujjain and Luv and Kush Producer Company of Gairatganj, Raisen of Madhya Pradesh revealed socio-economic benefits for the farmers that include: availability of quality seeds, seed change, assured and subsidized quality seed material and farm inputs, additional gain of ₹ 100/- to ₹ 200/- per 100 kg of produce, assured procurement and market for produce.

The first public-private partnership (PPP) model in agricultural extension between the department of Agriculture, MP and Dhanuka Agritech Ltd. led to effective technology dissemination especially in "Soil Testing and Advisory and Seed Treatment" in Hoshangabad District of MP. Another PPP between ATMA, MP and Dawat Foods led to 5-time increase in the area under paddy in Hoshangabad district, 90% of which was under Pusa Basmati 1121. These arrangements not only enhanced the yield significantly but also facilitated mutual gains for the Department of Agriculture and Dhanuka Agritech Ltd. A case analysis of public-private partnership based sericulture by tribal women of Gujarwada village of Babai block of Hoshangabad district in MP revealed a novel institutional arrangement for empowerment and livelihood security of rural poor. As against a mere 3 months' employment per year at the rate of ₹ 50/- to ₹ 60/- per day, these women have round-the-year assured gainful employment for themselves as well as for the members of their family with an average monthly income of about ₹ 5000/-. The PPP in sericulture between the Government of Orissa and self help group (SHG) women in Sundergarh district also led to an additional income of ₹ 6000/- per month for the tribal women.

A Case analysis of MAHA ANAR (Pomegranate) Cooperative Society revealed that a majority of the beneficiary farmers (92 per cent) had a high level of knowledge about pomegranate production technology and earned ₹ 75,000- ₹ 1,00,000/- per acre more than that earned by non-beneficiary farmers who sold their produce in local market through (Krishi Utpanna Bajar Samiti).

An analysis of the Farmer-Scientist Forum (Krishak Vigyan Manch), an innovative extension model of SAUs

in Maharashtra, with a case study of Dr. Punjabrao Deshmukh KrishiVidyapeeth Akola showed enhancement in technical knowledge among the farmers with 50% of them being in the category of medium level of knowledge and 23.33% of them being in the category of high level of knowledge.

The potential of the extension model led by Primary Agricultural Credit Societies and Self Help Groups (PACS-SHG) and backed by the recently launched "Sanchar-Shakti" scheme for empowering ICT related livelihood skills for all SHGs in rural India was explored with a survey study in Kurukshetra district, Haryana. Since almost all the farmers frequently visit PACS, the level of satisfaction of farmers with PACS services was high (mean score of 3.53 on a scale of 1 to 5). The demands for better seeds, information and agricultural implements could be effectively used for enhancing the accessibility of farmers to quality seeds and other agricultural inputs and information. The extensive outreach of these rural institutions in the villages throughout India can strengthen knowledge sharing and promote gender equity.

6.2.3 Constraints in Adoption of Improved Technologies and Identification of Yield Gaps in Selected Pulses and Cereals

During *kharif* 2010, sixty profitability demonstrations (1 demonstration = 0.40 ha) of paddy were conducted in farmers' fields at four locations. The demonstration yield of paddy varieties, Pusa Basmati 1121 and Pusa 1460 was very encouraging compared to that of the local check. However, the yield gap-I and the yield gap-II varied from 700-1000 kg/ha and 500-1300 kg/ha, respectively. Pusa 1121 was preferred to Pusa 1460 because of the farmer's high returns per unit area.

Bumper crop of paddy variety Pusa 1121 in Mumtajpur village (Haryana)

6.2.4 Enhancing Entrepreneurship among Rural Youth

Forty potential agricultural entrepreneurs from four NCR villages – Partapur, Ghaziabad, UP; Badarpur Said, Faridabad, Haryana; Kansala, Rohtak, Haryana; and Hasangarh, Rohtak, Haryana were given entrepreneurship development training. A few youth have taken the intiative to start their enterprises. Motivational inputs are being provided and handholding is being done besides linking them with other agencies.

6.2.5 Capacity Building of Self Help Groups (SHGs) for Gender Empowerment

The effectiveness of SHGs in improving livelihood and gender empowerment was assessed by a case study of Kesala Poultry Sahkarita Maryadit at Sukhtawa village in Madhya Pradesh. Mapping of the motivational profile of SHG women participating in the programme indicated the need for personal achievement oriented influence (*n*PSA), followed by need for personal-cum-social achievement (*n*PSA), and hope in majority of the cases.

***Kharif* paddy demonstrations**

Location	Variety	No. of demonstrations (1demo=0.40 ha)	Yield (kg/ha)			Yield gap-I (kg/ha) C-A	Yield gap-II (kg/ha) A-B
			Demo. (A)	Farmer (B)	Res. station (C)		
Tentigaon, Mathura (UP)	P-1121	15	4000	3500	4000	000	500
Mumtajpur, Pataudi, Haryana	P-1121	20	4800	3500	4000	-800	1300
Kallugarhi, UP	P-1121	15	3000	3000	4000	1000	000
Kastala Kasmabad, UP	P-1460	10	4300	3500	5000	700	800

In a survey of 100 self help group members from Sundergarh district in Orissa, market was perceived by SHG women as the main factor for enterprise success. This shows the recognition of the importance of marketing factors by SHG women. Other factors like family,bank, and official and personal traits were also important for enterprise success. Very favourable response towards self help groups was expressed by 38 per cent of women. Seventy-nine per cent of SHG women had medium level of political empowerment as demonstrated by their participation in local elections, *panchayat* meetings, etc., whereas 63 per cent had medium level of social empowerment.

Training for capacity building were organized for the members of women self help groups in Mewat region of Haryana, with empharis on gender sensitization, farm based enterprises (value addition and food preservation) and non-farm based enterprises for income generation. A framework was designed for the preparation of capacity building module for motivational development.

6.2.6 On-farm Testing (OFT) of IARI Technologies in NCR Region

Two villages, namely, Partapur in Ghaziabad district UP and Badarpur Said in Faridabad district (Haryana) were selected for laying out on-farm trials (OFTs) of wheat cultivation. With the help of PRA techniques like social map, resource map, seasonality analysis, and crop calendars, the area under wheat crop, different varieties grown and the major problems encountered in wheat production were assessed and brought to the research system. The following technologies were found relevant to overcome the constraints and laid out for testing:

1. Varietal performance: Timely sown (HD 2733, HD 2967, HD 2894, and farmer's variety), and late sown (WR 544, HD 2285, HD 3016 and, farmer's variety)
2. Weed management: Clodinofop (60 g/ha) +metsulfuron (4 g/ha); sulfosulfuron (30 g/ha); and farmer's practice)
3. Site-specific nutrient management: Recommended doses of fertilizers (RDF), recommendations on the basis of soil test (SSNM), and farmer's fertilizer practice (FFP)

The technological interventions were laid out in the fields of selected farmers, who were willing to participate in the research process. The data collected during and at the end of the cropping seasons showed significant difference in the vegetative and productive growth of the crop. The yields of the varieties, HD 2967 (timely sown) and WR 544 (late sown) were the highest. The nutrient application, on the basis of soil tests, yielded significantly in terms of grain yield as well as straw yield. Weed management through Clodinofop (60 g/ha) + metsulfuron (4 g/ha) proved to be promising in terms of spike length, number of grains per spike and effective number of tillers/m^2.

6.2.7 Visioning, Policy Analysis and Gender

Impact assessment of mustard variety Pusa Bold (Year 2010-11). The impact of IARI mustard variety Pusa Bold released in 1985 was assessed. This variety is bold seeded and preferred by farmers. The productivity of Pusa Bold is 2.0-2.2 t/ha, which matches with the yields of other IARI varieties. Approximately 15 per cent of the total mustard area in Rajasthan, 4 per cent of the total mustard area in Uttar Pradesh and nearly 30 per cent of the total mustard area in MP is cultivated with Pusa Bold. The production of Pusa Bold from these three important states was 6.86 lakh tonnes valued at ₹ 1715 crores. The incremental gain of Pusa Bold over the yields of other Pusa mustard varieties was approximately 0.2t/ha. The cost of cultivation of all the mustard varieties was nearly the same and, hence, the farmers' demand was high for the seeds of Pusa Bold.

6.2.8 Scientific Productivity of IARI Scientists

Garret Score ranking of eleven factors identified by Q-sort technique indicated that the major factors that influenced the scientific productivity, as perceived by IARI scientists, were autonomy, research facilities and creativity. These factors need to be considered for promoting scientific excellence.

6.3 TECHNOLOGY ASSESSMENT AND TRANSFER

6.3.1 Assessment and Promotion of Agricultural Technologies

The project on "Assessment and Promotion of Agricultural Technologies and Developing Market led Extension Modals" was reoriented to develop model villages in peri-urban areas of NCR for integrated development. Four villages, namely, Badarpur Said (Faridabad district), Pabesara (Sonipat district) and Kumbawas (Gurgaon district), of Haryana and Partapur (Ghaziabad district) of Uttar Pradesh were identified for dissemination of need based and situation-specific technologies. A socio-economic and bio-physical appraisal of the identified

Assessment of improved varieties during *rabi* 2010-11

Location	Crop	Variety	Yield (t/ha)	Local yield (t/ha)	Increase in yield (%)
Pabesra, Sonepat, (Haryana)	Wheat	HD 2932	5.40	4.75	13.70
		HD 2987	6.05		27.40
		HD 2733	6.20		30.50
		HD 2894	5.33		12.20
Partapur, Ghaziabad (UP)	Wheat	HD 2987	5.25	3.95	32.91
		HD 2733	6.21		57.26
		WR 544	5.06		28.10
		HD 2894	4.88		23.64
		HD 2851	5.17		30.98
		HD 2932	5.02		27.03
	Lentil	K. 75	1.98	1.43	38.32
Dhani Kumbhawas, Gurgaon (Haryana)	Wheat	HD 2851	5.35	4.76 (PBW-343)	10.00
		HD 2899	5.42		13.50
		HD 2932	5.70		18.40
Badarpur Said, Faridabad (Haryana)	Wheat	HD 2932	5.60	4.73 (PBW 502)	15.50
		HD 2733	5.00		05.40
		HD 2894	5.00		05.40
		HD 2967	4.50		-
	Mustard	P.Jagannath	2.28	1.93 (Krishna)	12.70
		Pusa Vijay	2.39		16.00
	Gram	BGD 72	2.28	1.93	12.70

villages in participatory mode was conducted. Problems as experienced by the farmers were prioritized and the potential interventions planned. A Few technological interventions were implemented during *rabi* 2010-11.

6.3.2 Dissemination of Improved Technologies for Higher Productivity and Profitability in Agriculture

The National Extension Programme was further strengthened in collaboration with 17 ICAR institutes/SAUs for faster diffusion of IARI varieties and production technologies to a large number of farmers in different parts of the country. This programme was found to be effective in dissemination of IARI technologies in far off locations. During *kharif* 2010, six hundred forty-three (643) demonstrations of 13 crops were conducted in different states.

Results (*Kharif* 2010): Paddy

1. In Barielly region U.P.), PRH 10 yielded 5.7 t/h with a higher B:C ratio of 2.38:1. PRH 10, Pusa 44 and Pusa 1401 yielded 5.6 to 6.0 t/ha in Varanasi, UP.

Demonstrations at different locations during *kharif* 2010

Crop	Variety	No. of demos.	States
Paddy	PB 1, P 1121, P 2511, PRH 10, P 1401	445	UP, Jharkhand, MP, HP, and Haryana
Bajra	Pusa 443	14	Rajasthan and UP
Moong	Pusa Vishal	59	Karnataka, Rajasthan, Maharashtra, UP, HP and Haryana
Arhar	Pusa 991, Pusa 2001	35	Karnataka, Jharkhand, Maharashtra, UP, HP
Sorghum	PC-9, PC-6	35	Rajasthan, Karnataka, UP, Haryana, HP
Brinjal	Pusa Uttam	45	Karnataka
Cabbage	Golden acre		UP
Cowpea	Pusa Sukomal		Karnataka
Bottle gourd	Pusa Naveen		Karnataka, UP, Jharkhand, HP, Haryana
Palak	Pusa Harit		Karnataka and Haryana
Bhindi	A-4		UP
Ashgourd	Pusa Ujjwal		Haryana
Marigold	PNG	10	UP

2. PRH 10 gave 6.0 t/ha and 73.57% yield increase with a B:C ratio of 2.89:1at Chhapra, Bihar.
3. PRH 10 recorded higher average yield of 6.8 t/ha (49.9%) compared to the average yield of 4.5 t/ha of the local check variety, Savitri. B:C ratio (2.73) was the highest for the variety, Pusa 1121 (4.8 t/ha).
4. At IVRI, Bareilly, Pusa Basmati 1121 had more demand in the market. Farmers sold this variety @ ₹ 20/kg immediately after harvesting.
5. At Bareilly the performance of PB 1 was better (4.1t/ha) and was popular among the farmers. This variety gave higher return (₹ 51000/-ha). Farmers sold this variety @ ₹ 20/kg. PB 1401 was found susceptible to bacterial leaf blight at this location.
6. PNR 519 gave 17% more yield, high B:C ratio (2.24) and was of shorter duration (20-30 days less) in West Bengal.
7. Jaldi Dhan 13 was preferred for *rabi* paddy cultivation under less water availability in West Bengal.

Pulses

1. *Moong* variety, Pusa Vishal yielded 30% higher than that of the local check in Kangra district of Himachal Pradesh with a B:C ratio 2.21:1.
2. Pusa Vishal gave 81% more yield than that of the local variety with a B:C ratio 2.63:1 in Bharatpur region (Rajasthan).
3. In Varanasi district of UP, Pusa Vishal out yielded the local check by 0.8 to 1.2 t/ha (with 25 to 66.67% increase).
4. The best trait of Pusa Vishal was observed to be its early maturity. It was found to have good potential for adoption at Palampur.
5. Pusa Vishal gave an average yield of 0.7 t/ha as against 0.5 t/ha by the local check variety at MPUAT, Udaipur.
6. Pigeonpea (P 992) gave an average yield of 1.6 t/ha in Etah district of UP. The yield advantage over that of the local check was 26.57% with a B: C ratio of 5.76.

Vegetables

1. Cowpea (Pusa Sukomal) yielded 12.0 t/ha with an advantage of 33.4% over the local check in Banglore region of Karnataka. The B:C ratio was 2.66:1.
2. Bottle gourd (Pusa Naveen) gave an average yield of 20 t/ha in Bharatpur district of Rajasthan with a B:C ratio of 3.44:1
3. Pusa Naveen was also demonstrated in 32 farmers' fields at Banaras Hindu University, Varanasi centre. Fruits were attractive of medium to small size. Plants had less problem of gummosis.
4. *Palak* (Pusa Harit) yielded 20 t/ha with 60% increase in yield, and enhanced B:C ratio (2.8), and 6 to 8 cuts could be taken at Chhapra, Bihar.
5. *Bhindi* (A-4) yielded 14 t/ha with 75% increase in yield and B:C ratio of 3.22 at Chhapra, Bihar.

Grains and pods of the mungbean variety Pusa Vishal demonstrated at Mirzapur

Demonstration conducted at BHU Varanasi centre

Fodder sorghum (PC 6) gave an average yield of 3.4 t/ha as fodder with a yield advantage of 27.22%. However, the B:C ratio was 1.28, the same as for the local check in Dharwad region of Karnataka.

Maize variety Vivek QPM 9 yielded 4.2 t/ha with 52.89% increase in yield and a higher B:C ratio of 2.97 in Shillong.

Bajra (P 605) yielded 1.8 t/ha (36.02% increase) with a B:C ratio of 2.30:1 at Alwar, Rajasthan. This variety was preferred for its higher yield without any specific problem associated with it.

Rabi 2010-11: Results

Wheat

1. HD 2932 with an average yield of 4.0 t/ha outyielded all other varieties including the local checks (Lok 1, GW 322, GW 366) demonstrated at JNKVV, Jabalpur.
2. HI-1500 encountered the problem of lodging at Jabalpur.
3. As there is a niche area of late sown wheat of about one lakh hectare, the varieties, HD 2932 and WR 544 are suitable for Jabalpur.
4. WR 544 yielded up to 4.3 t/ha compared to HD 2733 (3.7 t/ha) in Lucknow, UP.
5. The variety HD 2894 gave a yield of 2.5 t/ha and had tillering higher than that of the local check Raj 3077 (1.8 t/ha). The variety HD 2932 gave a yield of 2.4 t/ha. This variety had lower incidence of insect and pest infestations at Udaipur.

A wheat variety HS 507 resistant to yellow rust demonstrated at Palampur (HP)

6. At IVRI, Izatnagar, the late sown varieties, WR 544 and HD 2643 gave significantly higher yield (3.6 and 3.7 t/ha, respectively) than the local check (3.5 t/ha). Significant increase in the yield over that of the local check (4.6 t/ha) was observed in the demonstrated varieties, HD 2851 (17.78%), HD 2733 (24.89%) and HD 2894 (30.13%).
7. Under transplanted condition in the Bilaspur region (HP), HS 277 gave good tillering as well as yield (6.2 t/ha).
8. HS 277 yielded (5.2 t/ha) higher than DBW 17, PBW 550, HD 2894 and HD 2824 in Mathura region of UP.
9. HI 1544 and HI 8663 yielded 3.5-5.0 t/ha in the Wardha district of Maharashtra.
10. HD 2985 gave an average yield of 3.1 t/ha at Navasari, which was up to 27.7% higher than that of the local check.
11. HD 2733 gave an average yield of 5.0 t/ha at IIVR locations and 4.8 t/ha at BHU location. Karnal bunt was seen in HD 2985 at Ugapur village under BHU, Varanasi centre.

Mustard

1. The average yield of Pusa Jagannath was 1.1 t/ha compared to that of the local check, Pusa Bold (1.0 t/ha) and Varuna (0.5 t/ha) at JNKVV, Jabalpur.
2. Crop performance of Pusa Bold (1.9 t/ha) and Pusa Jaikisan (1.8 t/ha) was better than that of the local varieties at IIVR and BHU centres.
3. BGD 72 (gram) gave a yield of 1.5 t/ha in Varanasi region of UP.
4. Mustard (Pusa Jaikisan) yielded 2.6 t/ha, which was more than that of Pusa Bold, Pusa Agrani and JD 6 in the Mathura region of UP. However, Pusa Agrani proved to be a bonus crop in between *kharif* and late *rabi* crops.
5. In Rahuri, Maharshtra, farmers preferred Pusa Jagannath (1.4 t/ha) to Pusa Jai Kisan (1.1 t/ha).

Lentil

Lentil variety K-75 gave about 0.8 t/ha, while L 4076 gave an average yield of 1.1 t/ha. Lentil (L 4076) was preferred by the farmers for its bold and attractive grain and yield (1.5 t/ha) in Varanasi, UP.

Pea

Farmers of Palampur district reported bigger pods in pea variety Pusa Pragati compared to that in the popular variety Punjab 89. The pods of Pusa Pragati were also completely filled.

6.3.3 Participatory Seed Production of Improved Varieties of IARI

The seed production programme for *kharif* 2010 was taken up at different locations. Seed of 32.0 tonnes of Pusa 1401, 28.9 tones of Pusa 44, and 0.7 tonnes of PRH 10 and 0.2 tonnes of bottle gaurd (Pusa Naveen) were produced at Nekpur village, Bulandshahr district. A total of 78.0 tonnes of seed of paddy was also produced at Rakhra, Patiala, Punjab. During *rabi* 2010-11, a total of 48.0 tonnes of seed of wheat variety HD 2987 was produced at Rakhra, Patiala, Punjab.

6.3.4 Technology Dissemination for Integrated Farming System

Under an NAIP project in operation in four districts of Rajasthan, namely, Udaipur, Banswara, Dungarpur and Sirohi, the following interventions were carried out.

- During *kharif* 2010, thirty-nine demonstrations of rice varieties, Pusa 1460, Pusa 2511, Pusa 1160 and PRH 10 were laid in different villages of Banswara district. Except PRH 10, other varieties were affected by drought. PRH 10 gave an average yield of 2.5 t/ha.
- During *rabi*-2010-2011, demonstrations of high yielding wheat varieties, namely, DBW 17, WR 544, HD 2864, HD 2329, HD 2332, WR 544 and HD 2894; mustard varieties, namely, Pusa Tarak, Pusa Jaikisan and NCDR 02; and vegetable crops like onion (Pusa Red), tomato (P. Rohini), *palak* (P. allgreen) and *methi* (P. Early Brunching); and marigold were undertaken in the project area. At Dungarpur, Rajasthan, the yield of wheat variety, DBW 17 was 44.59% higher than that of the local variety Raj 3077. The other demonstrated varieties also gave higher yields compared to those of the local checks, viz., HD 2894 (43.89%), WR 544 (36.49%), HD 2329 (35.14%) and HD 2932 (26.32%).

6.3.5 Front Line Demonstrations

6.3.5.1 Wheat (in collaboration with DWR)

During *rabi* 2010-11, thirty-five FLDs on wheat in selected villages of Aligarh and Bulandshahr districts in UP were conducted on newly released varieties of wheat, DBW 17 and PBW 550 with zero tillage and use of bio-fertilizers (Azotobacter + PSB).

6.3.5.2 Maize (in collaboration with DMR)

During 2010, maize varieties, 30V 92, 32T 25 and 30R 77 were demonstrated for grain as well as green cobs in separate demonstrations (179 for grain and 51 for green cobs) in Aligarh, Ghaziabad, Bulandshahr, G.B.Nagar and Mathura districts in UP. The average grain yields of these varieties in the demonstrations were 4.1 t/ha (30V 92), 4.4 t/ha (32T 25) and 4.6 t/ha (30R 77) against the state average yield of 1.4 t/ha. The green cob yields of maize varieties, 30V 92, 32T 25 and 30R 77 were 10.6 t/ha, 11.1 t/ha and 11.2 t/ha respectively, in the demonstration plots. The grain quality of 30R 77 was reported to be the best in respect of colour as well as taste. All these hybrids remain green even after plucking of the cobs and can be used as green fodder for animals.

Frontline demonstrations on newly released wheat varieties during *rabi* 2010-11

Technology	Variety	No. of Demos.	Area (ha)	Yield (t/ha)		% increase in yield
				Test	Check	
Newly released varieties	DBW 17	15	6.60	4.78	4.26	12.38
	PBW 550	4	2.40	4.56	5.05	-9.64
Use of biofertilizers (Azotobacter+PSB+Micorrhyza	DBW 17	6	3.00	4.91	4.45	10.42
Zero tillage	DBW 17	6	2.40	4.79	4.55	5.43
	PBW 550	4	1.60	4.95	4.67	6.10
Total		**35**	**16.00**			

6.3.6 Innovative Transfer of Technology Model: Partnership between IARI and Non-Government Organisations for Effective Transfer of Agricultural Technologies to the Farmers

Twenty-seven NGOs of repute from 17 states of the country were involved since *rabi* 2009-10 to assess and disseminate IARI technologies in their operational areas. During 2010, nine hundred twenty-six (926) demonstrations of 16 crops were demonstrated at different locations of NGO partners.

Kharif 2010

- Paddy: PRH 10 was found resistant to Tungro virus, which is prevalent in Tamil Nadu and Kerala region. This variety gave an average yield of 7.3 t/ha in Gorakhpur region.
- *Bhindi*: Pusa A4 gave an average yield of 12.5 t/ha in Gorakhpur region. However, in Jhalawar region, it gave an average yield of 6.7 t/ha against 6.0 t/ha given by the local check with a B:C ratio of 3.44:1.
- Pigeonpea: Pusa 992 gave an average yield of 1.8 t/ha against the yield of (1.4 t/ha) given by the local variety.
- *Bajra*: Pusa 605 performed well (1.8 t/ha) in Alwar region.
- Brinjal: Farmers observed that 20% of the brinjal crop was affected by thrips, and aphids and shoot borer in Pusa Uttam in Jhalawar region.

Rabi 2010-11

- In Gorakhpur district, the wheat variety HD 2733 gave a yield of 4.0 t/ha with a advantage of 47.13% over that of the local check, followed by HD 2985 with a yield 3.3 t/ha.
- In Dola, UP, the wheat variety HD 2894 (5.4 t/ha) outperformed HD 2851 (5.1 t/ha) and the local check PBW 343 (4.0 t/ha). The B:C ratios for the above IARI varieties were 3.25 and 3.01, respectively.
- In Aligarh, HD 2932 (4.9 t/ha) gave 33.22% yield advantage over that of the local check (3.5 t/ha).
- Mustard (Pusa Vijay) was badly affected by white rust and aphids at Jammu. However, at Gorakhpur, Pusa Jagannath (2.8 t/ha) gave 37% more yield compared to that of the local variety (2.1 t/ha).
- The gram variety BGD 72 gave an average yield of 2.9 t/ha at Gorakhpur, which was 30% higher than that obtained with farmers own seed (1.3 t/ha).
- The lentil variety L 4076 gave an average yield of 1.7 t/ha, which was 31% more than that of the local check with a B:C ratio of 3.85.

Demonstrations of various crops in collaboration with NGOs

Crop	Variety	No. of Demos.	States
Paddy	PNR 546, P 2511, JD 13, VL Dhan, P 1121, PRH 10, PB 1, P 1401, P 44, P 1460 and PNR 381.	723	WB, Meghalaya, J&K, Punjab, Karnataka, UK, MP, UP, Rajasthan, Haryana, Maharashtra, and Kerala.
Maize	Vivek QPM 9, HM 4,		Meghalay, MP, UP
Moong	Pusa Vishal	84	UP, MP, TN, J&K, Raj., HP, Karnataka, Maharashtra and HR
Arhar	Pusa 992, Pusa 991, Pusa 2001	36	Rajasthan, HP, MP, UP, Haryana, Maharashtra
Sorghum	PC-6	16	MP, Rajasthan, UP and Haryana
Bajra	Pusa 383	14	Rajasthan and Haryana
Bhindi	P.A 4	53	Haryana UP, MP, J&K, Rajasthan, HP, Karnataka, Kerala
Brinjal	Pusa Uttam		Rajasthan, Karnataka, TN, UP, Kerala
Bottle gourd	Pusa Naveen		UP, MP, HP, Karnataka, TN, UK, Haryana, Kerala
Cauliflower	Pusa Snowball		HP
Amaranthus	PLC		Kerala
Carrot	Nantes		HP
Cabbage	Pusa Acre		HP, Kerala
Broccoli	KTS-1		HP
Palak	Pusa Harit		HP, UP
Tomato	Pusa Roma		HP

6.3.7 *Pusa Krishi Vigyan Mela*

The annual *krishi vigyan mela* of the Institute on the theme "Farm Technologies for Enhanced Productivity and Income" was organised from March 3 to 5, 2011. Farm technologies developed by the Institute for enhanced productivity and income were displayed in a thematic *pandal*. Different project directorates, divisions, centres and units of the Institute demonstrated their technologies in their respective stalls. A total of 200 stalls including 34 of IARI, 5 of state agricultural universities, 28 of ICAR Institutes, 4 of KVKs, 70 of private companies and NGOs, and 12 of public sector undertakings were put up at the *mela* site to demonstrate their technologies/products for display or sale. Twenty-two progressive farmers from the Extension Operational Areas of the Institute also put up their stalls for display and sale of their farm produce. More than 1,00,000 visitors from different parts of the country including farm men, farm women, students, extension workers, entrepreneurs and others visited the *mela*. One technical session was organized each day to provide farmers-scientist-industry interface. A workshop was also organised to deliberate on women empowerment through technology, education and health awareness. More than 5000 farm women and farm men from different parts of the country participated in this workshop. Another attractive feature of the *mela* was the "Innovative Farmers' Meet", which was held on 5th March. During the meet, 18 innovative farmers from different parts of the country shared their experiences in seed production, organic farming, farm machinery, livestock development, etc., and were honoured. Seeds of high yielding varieties of different crops worth rupees 30 lackh were sold through Pusa Seed Sale Counter during the *mela* period. Revenue to the extent of ₹ 11,23,500/- was generated from the *mela* through stall bookings, advertisements in *mela* souvenir; including ₹ 2 lakh as the financial assistance from the Ministry of Agriculture.

Hon'ble Union Minister of State for Agriculture and Food Processing Industries, Government of India, Shri Harish Rawat (centre) inaugurating the *krishi vigyan mela* on March 3, 2011 at IARI

The chief guest Shri Harish Rawat, Hon'ble Minister of State for Agriculture and Food Processing Industries, Government of India inaugurated the *mela* on March 3, 2011. At the valedictory function, 27 progressive farm men/ farm women from different states of the country were honoured for their excellent innovations in agricultural production. The chief guest addressed the farmers and gave away prizes and certificates to various participating organizations and farmers.

Hon'ble Union Minister of State for Agriculture and Food Processing Industries, Government of India, Shri Harish Rawat releasing the publications at *krishi vigyan mela*

6.3.8 Off-campus Exhibitions

The staff the Centre for Agricultural Technology Assessment and Transfer (CATAT) and the Agricultural Technology Information Centre (ATIC) organised/ participated in twelve national/international agricultural exhibitions for display/sale of IARI technologies, products, services and publications.

6.3.9 Trainings for Farmers and Extension Workers

In all, 35 on-campus training programmes were organised by CATAT and ATIC for agricultural officials and

progressive farmers of different states. These programmes were attended by 885 participants from Uttar Pradesh, Uttarakhand, Bihar, Assam, Rajasthan and NCR of Delhi. The major areas covered were improved agricultural and horticultural technology, scientific management of crops, livestock and fishery enterprises, organic farming, skill development of farmers and entrepreneurs, reclamation of alkaline soils, major, micro and trace elements for good crop production, protected farming, climate change and its impact, WTO in the context of agriculture, post harvest technology and marketing for sustainable agriculture, hi-tech horticulture, adoption of good agricultural practices (GAP) for major crops and vegetables, etc. These programmes were sponsored by SIRD (Assam), Delhi Development Department, NABARD, ATMA (Haryana), BAMETI (Bihar), ATMA (Jhalawar, Rajasthan), ATMA (Narendernagar, Uttarakhand) and ATMA (Mujjhaffarnagar, UP).

6.3.10 Agricultural Technology Information Centre

The Agricultural Technology Information Centre (ATIC) is effectively providing products, services, technologies and information to different stakeholders through a 'Single Window Delivery System'. Besides the farm advisory services provided at the ATIC, the farmers are given farm advice through Pusa Helpline (011-25841670), Pusa Agri Com 1800-11- 8989, exhibitions, farm literature and letters. The 2nd level of Kisan Call Centre (1800-180-1551) was established at the ATIC for providing remedial measures to problems and answers to queries of farmers of Delhi state. Live demonstrations of paddy [Pusa Basmati 1121, Pusa Sungadha 6 (P-1401), Improved PB 1(Pusa 1460), and Pusa Sungadha 5 (Pusa 2511)], *moong* (Pusa Vishal and Pusa Ratna), *bajra* (Pusa 383, and Pusa 605), *dhaincha* as green manure crop for organic farming in *kharif* , mustard (Pusa Vijay, Pusa 21 and NPJ 112), wheat (HD 2967, HD 2894, HD 2733 & Pusa Gold (WR 544) of IARI, and DBW 17 of DWR, Karnal in *rabi* 20010-11), gram (BG 1053) and lentil (L 4076, i.e, Pusa Shivalik) were demonstrated in a crop cafeteria for the benefit of the visitors. High density of orchards fruit trees planted with lemon (Kagzi Kalan), mango (Amrapali), guava (Lucknow 49, Allahabadi Safeda and Lalit), *ber* (Banarasi Karaka and Gola) and *aonla* (NA 7, NA 10, Lakshmi 52 and, Chakaiya); winter vegetables like *bathua* (Pusa Bathua No. 1), *methi* (Pusa Early Bunching), *sarson saag* (Pusa Saag 1), *palak* (All Green), pea (Arkel and Pusa Pragati) chilliy (Pusa Jwala), capsicum (California wonder), tomato (Pusa Ruby), radish (Pusa Chetki), cauliflower (PSBK 1), cabbage (Golden Acre), carrot (Pusa Rudhira and Pusa Kesar), coriander, onion (Pusa Red) and brinjal (Pusa Uttam); cucurbitaceous crops like bottle gourd (Pusa Naveen), sponge gourd (Pusa Sneha), bitter gourd (Pusa Domausami), okra(Pusa A-4), and amaranthus (Pusa Lal Cholai) were grown for demonstration. For awareness of farmers about medicinal plants, small plots of aloevera, *ashwagandha*, *satavar*, coleus, *giloe*, lemon grass and java citronella, etc., were demonstrated. Information and advisory needs of the visitors are being catered through information museum, plant clinic, farm library and exhibits of agricultural implements, seed samples and bio-fertilizers.

About 18,365 farmers/entrepreneurs, development department officials, students, NGO representatives, etc., from 24 states of India visited the ATIC and its stalls in various exhibitions during the year for farm advisory, diagnostic services, purchase of technological inputs/ products and trainings. Purpose-wise maximum number of farmers visited the ATIC to purchase/enquire about seeds/ varieties (9065). Other purposes including seeking of information on horticultural and medicinal plants (5221), plant protection (1256), agro-based enterprises (1045), farm literature (3546), dairy (503), and agricultural implements (643) besides other matters (1170). A total of 3340 persons visited the ATIC stalls state-wise, out of the total number of farmers, who visited the ATIC, U.P. (33%) ranked first followed by Haryana (24%), Delhi (23%), and Rajasthan (20%). Besides, 2480 farmers/entrepreneurs from 16 states were able to get information on various aspects of agriculture through Pusa Agricom (a toll free Help Number 1800-11-8989) Pusa Help-line (011-25841670) and Kisan Call Centre 1800-180-1551(2nd level). The total calls received were 4131. Purpose-wise the calls were related to seed availability (2875), followed by production technology (1105), plant protection (905), agro-based enterprises (545), literature (512), biofertilizer (275) and others (580). Seeds and publications worth about Rs. 1414034.00 and Rs. 50805.00, respectively, were sold by the ATIC during the period.

Two bulletins, *Rabi Fasalon Ki Kheti* and, Technological Options for Higher Income & Profit, and four issues of farm magazine Prasar Doot were published by the Centre during the reporting period. Twelve pamphlets

(reprints) on cereals, pulses, vegetables and fruit crops were distributed free to visiting farmers. Besides, 76 farmers approximately got farm advisory services through letters/e-mails during the period. The ATIC also participated in 4 exhibitions and 3 farmers' days where IARI products, and technologies were displayed and sold. Visitors took a lot of interest in IARI products and technologies.

The demands for IARI products, technologies and services are increasing day by day in the market. Besides farmers, the industry has shown a lot of interest in IARI research products. The ATIC is providing a mechanism for direct feedback from the technology users to the technology generators. The feedback strengthened the ATIC activities and provided a ground for need based technologies. The ATIC has also developed functional linkages with various agencies working for the farming community to effectively cater to the information needs of different stakeholders.

6.3.11 Krishi Vigyan Kendra, Shikohpur, Gurgaon (Haryana)

6.3.11.1 Front line demonstration programme

During the period, (*rabi* 2009-10 and *kharif* 2010), 115 demonstrations covering 59 ha on oilseeds, pulses and cereal crops were organized in farmers' fields in 7 villages of 4 blocks of Gurgaon district.

The average yields obtained were: 1819 kg/ha (mustard), 1878 kg/ha (gram), 6895 kg/ha (pea), 4810 kg/ha (barley), 1943 kg/ha (*arhar*), 511 kg/ha (*moong*), 3626 kg/ha (*bajra*) and 4065 kg/ha paddy. The comparative results revealed that the average yield of mustard, gram, pea, barley, *arhar*, *moong*, *bajra* and paddy increased by 12.60 per cent, 8.86 per cent, 8.37 per cent, 2.40 per cent, 12.57 per cent, 11.92 per cent, 7.80 per cent and 16.80 per cent, respectively, over that of the farmer's existing practices. During *rabi* 2009-10, the KVK organized 23 demonstrations on wheat and barley (covering 9.00 ha)

Results of FLDs organized in farmers' fields during *rabi* 2010-11 under KVK scheme

Crop	Varieties	No. of demos.	Area (ha)	Yield (kg/ha)		Percentage increase
				Demo	Local	
Mustard	Pusa Jgannath	25	20.00	1819	1615 (Pusa bold)	12.60
Gram	Pusa 1103	10	4.00	1878	1725(P 372)	8.86
Barley	BH 393	10	4.00	4810	4700 (BL-426)	2.40
Pea	Azad P-1	05	1.00	6895	6362(Jawahar-P)	8.37
	Total	**50**	**29.00**			

Results of FLD organized in farmers' fields during *kharif* 2010 under KVK scheme

Crop	Varieties	No. of demos.	Area (ha)	Yield (kg/ha)		Percentage increase
				Demo	Local	
Arhar	Pusa 992	12	4.00	1943	1726	12.57
Moong	Pusa Vishal	10	2.00	511	First time introduction	
Paddy	Pusa 1121	15	9.60	3895	3480 (PB 1)	11.92
	Pusa 1460	13	8.00	4065	Do	16.81
	Total	**28**	**17.60**			
Pearl millet	JK 36	03	1.60	3556	3361 (JK 26)	5.80
	PA9444	04	1.60	3626	Do	7.80
	Dhanya	04	1.60	3362	Do	-
	Total	**11**	**4.80**			
Sesamum	G2	04	1.60	511	403 (HR-Til No.1	26.80
Total *kharif*		**65**	**30.00**			
Total under KVK scheme		**115**	**59.00**			

sponsored by the Directorate of Wheat Research (DWR), Karnal and 71 demonstrations on wheat, mustard and paddy (covering 30.50 ha) in farmers' fields under the National Extension Programme.

6.3.11.2 Trainings for different target groups

The major objectives of on-campus & off-campus trainings are to generate opportunities for income and employment, to provide technical knowhow to the practicing farm men and farm women and to update the knowledge of in-service personnel. In all, 98 trainings were conducted for farm men, farm women, field extension functionaries and rural youths. During the period, 16 vocational training courses on the subjects, viz., bee keeping (2) dairy farming (2) dress designing & tailoring (2), nursery management (2), motor winding (1), protective cultivation of vegetable crops (1), vemi compost technology (1), preservation of seasonal fruits & vegetables (3), and plant protection and pest control service (2) were organized benefitting, in all, 321 youth (156 male & 165 female). During the period, 72 day long training programmes for the practicing farm men and farm women were organized in different disciplines to update their knowledge about production and protection technologies of oilseeds, pulses, vegetables and cereal crops and other allied areas. Through these trainings, 1272 farmers (1091 male & 181 female) were benefited.

6.3.11.3 On-farm testing

On-farm testing is done to test the developed technologies, which might be helpful to solve the most important and widespread problems of farmers in a defined area with their farming system perspective, active participation and management. The major objective of the programme is to provide tailor-made recommendations to the farmers by testing the location-specific technologies to solve their field problems. During the period, 37 on-farm trials 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 Gurgoan district, and at the KVK campus.

Agricultural extension activities and farm advisory services

Extension activities	Number
Field days	11
Ratri chaupals	2
Women in Agriculture Day	1
World Food Day	1
Animal Health Day-cum-Clinical Camp	1
Method demonstrations	34
Group meetings/discussions	8
Camps/campaigns	6
Lectures by subject matter specialists (SMSs) in meetings/trainings of line departments	34
TV/Radio programmes	15
Press releases of KVK activities	12
Field visits of scientists/SMSs to the farmers fields	156
Visits of farmers to KVK for scientific/farm advice	410
Farm advisory services to farmers on telephone	1020
Popular articles	5
Exhibitions	3
Diagnostic surveys	2
Farmers-scientists interaction	4
Exposure visits of farmers	4
Dogs vaccinated against rabies	414
Animals treated during animal health camp	172

Krishi Vigyan Patrika, a quarterly newsletter (in Hindi) of the KVK, continued to provide the latest technologies to the farmers at proper times at their doorsteps. It provides relevant technical know-how on production technologies of field crops, fruits, and vegetables, and information on home

A bumper crop of gram (Pusa 1103) demonstrated in Shikohpur village under on-farm testing for podborer management

Participants of the vocational training course on "Motor Winding" organized by the KVK in collaboration with the Division Agricultural Engineering at IARI

A field day on mustard

and dairy management. During the period, 5820 (4580 male and 1240 female) members of different farming communities were benefited through these programmes. Among the beneficiaries, 76.5% belonged to OBC, 11% to SC and 12.5% to other categories.

6.3.12 IARI Regional Station, Indore

Sixty-one demonstrations (FLDs) of 15 wheat varieties were conducted in 22 hectare area in the tribal regions of Dhar, Indore, and Khargone, and remote areas of Ujjain and Dewas districts of M.P. The average increase in yield was 40% in these demonstrations. Around 110 officials and extension workers from the State Department of Agriculture and NGOs were trained in wheat seed production technology.

Trainings (including campus and farmers' field trainings) were imparted to around 2400 farmers from different states in the Central Zone on "Wheat and Wheat Seed Production Technology".

6.3.13 IARI, Regional Station, Wellington

Front line demonstrations were conducted for successful introduction of wheat as an alternate viable crop in the Southern Hills Zone for improving the farm income of resource poor farmers in non-traditional wheat areas. The varieties promoted were CoW (W)1, HW 5207, CoW 2 and HD 2833.

6.3.14 IARI Regional Station, Karnal

Under the Seed Village Programme, special emphasis was given to resource poor farmers, specially farm women around Karnal region. Eleven trainings were organized under this programme for 76 farmers on various aspects of quality seed production. Seed production through Seed Village Programme was undertaken on 15.2 ha area for farmer-to-farmer horizontal spread of seeds of paddy (cv. PB 1121) and wheat (cv. HD 2894) in five villages of Karnal district.

6.3.15 IARI Regional Station, Pusa (Bihar)

In order to reduce the yield gap between the lab and the land, 10 frontline demonstrations were laid out during the year in Samastipur and Muzaffarpur districts. The demonstrations conducted were on the use of bio-fertilizers, *Azotobactor* and PSB (3), zero tillage technology (2) and new improved wheat varieties (5). The performance of different demonstrations conducted on one hectare area each was very encouraging. The wheat varieties grown were K 307 and CBW 38. The farmers were impressed with the performance of CBW 38, and they stored and produced the seeds to be distributed to other farmers in the next season. Field days were organized and extension literature was distributed among the farmers.

6.3.16 IARI Outreach Programme

With a view to popularizing IARI wheat varieties among the farmers, eight demonstrations of four timely sown varieties (HD 2733, HD 2824, CBW 38 and PBW 343), and four late sown varieties (HP 1744, WR 544, HD 2985, and PBW 373) were laid out in Samastipur, Vaishali and Muzaffarpur districts of Bihar under the IARI Outreach Programme on "Strengthening of Wheat Programme in Eastern India",. In addition, 25 demonstrations of wheat varieties were also laid out in the villages around the KVK,

Pratapgarh; the KVK, Kaushambi; the KVK, Ghazipur; and the KVK, Sonbhadra in eastern Uttar Pradesh, and in the villages around Koderma and Hazaribagh in Jharkhand. The response of farmers was very encouraging.

6.3.17 Farmer Participatory Research

Under the bioversity-ICAR project on "Climate Change Adaptation and Visualization through Establishing Farmer Based Experimentation Networks in Indo-Gangetic Plains of India", ten farmer participatory research trials (with 3 replications) were conducted to evaluate the performance of 12 wheat varieties of different zones in the context of climate change. Farmers participated enthusiastically in the on-farm research experiments, which resulted in mutual knowledge and experience sharing. Four field days and two workshops were organised to discuss and deliberate on the relevance of farmer-based experimentation for climate change adaptation and visualization. Farmers participated actively in choosing the wheat varieties based on performance.

6.3.18 Farmers' Workshop

A farmers' workshop was organized at Kasbe Ahar village in Samastipur district on March 26, 2011 where farmers interacted with the scientists in understanding the climate change adaptation and visualization and in choosing wheat varieties based on their observations and discussion in the workshop.

6.3.19 IARI Regional Station Katrain

Data were collected from the farmers of Kullu district, and field demonstration work was continued for technology dissemination. Seeds were distributed to the farmers for forty-one field demonstrations of different vegetables in *kharif* 2011.

6.3.20 Transfer of Technology

Data were collected from 100 farmers through pre-tested interview schedule/questionnaire. Seventy field demonstrations were conducted during 2010-11 with satisfactory results. Varietal trials of AICRP on French bean were conducted for 9 varieties along with the check.

Different varieties of vegetables were exhibited in the Kullu Dussehra, where the farmers were imparted technical knowledge about improved vegetable cultivation practices. Demonstrations of different vegetables were conducted in the farmers' fields with the preliminary satisfactory results.

7. EMPOWERMENT OF WOMEN AND MAINSTREAMING OF GENDER ISSUES

Realizing that empowerment of women is the key to raising levels of nutrition, enhancing the production and distribution of food and agicultural products and improving the living conditions of rural population, IARI focussed on capacity development of women farmers. The KVK, Shikohpur organized vocational trainings for women on income generation and farm advisory services. Trainings were also organized for the Self Help Groups in Mewat region of Hayana.

7.1 EMPOWERMENT OF WOMEN IN AGRICULTURE

Rural women are playing a significant role not only in homestead activities but also in agricultural development and allied fields. Women have proven that they can be good entrepreneurs and development managers in any kind of activities. The KVK, Shikohpur is playing a vital role in empowering rural women of Gurgaon district by organizing various need-based self-employment and income generating activities and other extension programmes for creating awareness about scientific farming and disseminating technologies in a wide area.

The important programmes and activities organized for rural women during the period are as under:

- Vocational training courses for self employment and income generation
- Trainings in villages for updating the farm knowledge/skills
- Method demonstration for skill development
- Visits of rural women to agricultural fairs and exhibitions
- Celebration of women in agriculture day

Activity-wise participation of rural women

Name of activity	No.of activities	No.of beneficiaries
A. Vocational trainings		
• Dress designing & tailoring	02	58
• Dairy management	01	30
• Preparation of fruits & vegetables	03	59
• Nursery management of horticultural crops	01	15
Total	**07**	**162**
B. Agricultural extension & farm advisory service		
• Celebration of women's day as agriculture day	01	160
• Method demonstrations	07	85
• Day-long trainings in villages	08	145
• Women's visit to agricultural fairs	01	60
Total	**17**	**450**
Grand Total	**24**	**612**

Out of 612 participants, 62 (10.13%) belonged to SC, 410 (67%) belonged to OBC and 140 (22.87%) belonged to other castes.

7.2 IMPACT OF CAPACITY BUILDING AND AGRICULTURAL EXTENSION ACTIVITIES

- After getting vocational trainings, the rural women were able to save/earn ₹ 3000-3500/- per month by stitching the garments for their family members and other needy neighbours.
- Some of the rural women started their own training centres and provided training to needy girls/women on tailoring in their own village and earned Rs. 200/- per month from each trainee.
- Through active participation in village trainings and in extension activities, the rural women were able to do the farm work, including dairy farming, with the application of improved technologies earning more profit.
- Some SHGs comprising rural women, after being trained in preservation of fruits & vegetables, were

doing value addition activities by making different types of pickle, *murabba*, squash, etc., and established their own successful business or marketed their own products.

- The most distinct impact of women empowerment activities in the area was the creation of a sense of security and self reliance among rural women, which increase their active participation in rural development, and improved their socio-economic status in family and village.

7.3 WOMEN'S PARTICIPATION IN SEED PRODUCTION

Rural women actively engaged in agriculture showed their abilities to be good managers. Sixty-six farm women from Monak and Pundri villages of Karnal district, Haryana were selected under the seed village scheme, and were given trainings on quality seed production of the wheat variety, DBW-17. Through active participation in the trainings, their level of understanding of seed production had improved.

Training of women SHG members of Mewat district (Haryana) for value addition to *aonla* and tomato

8. POST-GRADUATE EDUCATION AND INFORMATION SYSTEM

The Indian Agricultural Research Institute, since its inception in 1905, has played a flagship role in the field of agricultural research, education and human resource development. A formal course leading to a two year diploma, 'Associateship of IARI' in various fields of agriculture was started in 1923, which was awarded to 903 graduates up to 1957. During 1958, IARI was granted the "deemed university" status by University Grants Commission and thus became the fore-runner of the agricultural university system in India. Keeping the tradition of the glorious past, the PG School endeavours to scale newer heights in agricultural research, education and extension through upgradation of course curriculum and by adopting new methods of teaching.

8.1 POST-GRADUATE EDUCATION

8.1.1 Admission during the Academic Session 2010-11

The Post Graduate School of IARI 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 Indian Council of Agricultural Research, the foreign students are admitted through DARE, Ministry of Agriculture.

During the academic year 2010-11, two hundred sixty seven students were selected for admission to various M.Sc. and Ph.D. courses as per details given below.

Category	M.Sc.	Ph.D.	Total
Open Competition	112	144	256
Foreign Students*	9	2	11
Total	121	146	267

*Foreign students admitted were from Iran, Egypt, Namibia and Vietnam.

The total number of students on roll were 736 (229 M.Sc. and 507 Ph.D.) including 52 international students (11 M.Sc. and 41 Ph.D.) from 13 foreign countries, namely, Afghanistan, Bangladesh, Egypt, Ethiopia, Iran, Libya, Namibia, Nepal, Rwanda, Sudan, Sri Lanka, Syria and Vietnam.

8.1.2 Convocation 2011

The 49th Convocation of the Post Graduate School of IARI was held on February 05, 2011. Dr. Montek Singh Ahluwalia, Deputy Chairman, Planning Commission, Government of India was the chief guest on this occasion. In his Convocation Address, the chief guest, Dr. Ahluwalia highlighted the significant contributions made by IARI in the field of research, human resource development and extension. He stated that the greatest challenge before us was to produce more food to remove poverty and urged the IARI scientists to accept that challenge. He emphasized the need for improving agricultural productivity, income distribution and shifting some proportion of farmers to other vocations.

Dr. H.S. Gupta, Director, IARI presented the significant research achievements of the Institute during the year 2010. Dr. H.S. Gaur, Dean & Joint Director (Education), IARI highlighted the significant achievements made by the Institute in the field of education and human resource development. The chief guest released twelve IARI seed/plant varieties, which included four varieties of mango, three varieties each of wheat and mustard, one variety each of pearl millet and moong. The chief guest also released the IARI publications, (i) Post Graduate Research and Human Resource Development at IARI 1996-2009, (ii) Post-

A Ph.D. student receiving his degree certificate from Dr. Montek Singh Ahluwalia, Deputy Chairman, Planning Commission, Government of India at the convocation. Also seen in the picture is Dr. H.S. Gupta, Director, IARI (centre)

Dr. Montek Singh Ahluwalia, Deputy Chairman, Planning Commission, Government of India receiving the Degree of Doctor of Science *(Honoris Causa)* from Dr. H.S. Gupta, Director, IARI (left) at the convocation

graduate School Calendar, and (iii) Pusa AgriScience - Journal of IARI Post-graduate School, Volume 33.

At this convocation, 99 M.Sc. and 73 Ph.D. students were awarded degrees, which included 13 international students. Mr. Susheel Kumar (Plant Pathology) and Dr. Manoj Kumar (Soil Science & Agricultural Chemistry) were awarded the Best Student of the Year 2010 Awards for M.Sc. and Ph.D., respectively. In addition, five recipients each of Ph.D. and M.Sc., degrees were awarded the IARI Merit Medals for their outstanding academic performance. The significant research achievements of the students were in the fields of climate change; molecular characterization of *Citrus tristeza* virus; host recognition by root-knot nematodes; rural employment guarantee programme; and genetic diversity analysis.

Dr. Montek Singh Ahluwalia was awarded the Degree of Doctor of Science *(Honoris Causa)* for his internationally acclaimed contribution to economics.

Two faculty members, namely, Dr. S.C. Datta, Principal Scientist (Soil Science & Agricultural Chemistry) and Dr. (Ms.) Alka Singh, Principal Scientist (Agricultural Economics) received the Best Teacher Awards for their achievements in academics during 2010.

Dr. R.K. Jain, Head, Division of Plant Pathology, IARI was awarded the 11th Shri Hari Krishna Shastri Memorial Award for the year 2010 for his outstanding research contributions to plant pathology. Dr. T.K. Behera, Senior Scientist, Division of Vegetable Science, IARI was awarded the 21st Hooker Award for the biennium 2008-2009 for his outstanding research contributions on 'First time development of gynoecious x monoecious hybrids in bitter gourd, leading to early fruiting and better productivity'.

41st Lal Bahadur Shastri Memorial Lecture

The 41st Lal Bahadur Shastri Memorial Lecture was delivered by Dr. Mangala Rai, former Secretary, DARE and Director General, ICAR on February 03, 2011 on the topic 'Indian Agriculture in Perspective: the Tribute to the Son and Soil'. This series of annual lectures was initiated by the Indian Agricultural Research Institute in 1968 as a mark of respect to one of the most illustrious and exemplary sons, and the second Prime Minister of independent India, late Shri Lal Bahadur Shastri ji.

Dr. Mangala Rai, former Secretary, DARE and Director General, ICAR (seated 2nd from left) delivered the 41st Lal Bahadur Shastri Memorial Lecture

Dr. R.S. Paroda, Chairman, Trust for Advancement of Agricultural Sciences (TAAS) and former Secretary, DARE and Director General, ICAR presided over the function. In his lecture, Dr. Mangala Rai expressed his great concern on a number of issues related to agriculture including climate change. He warned that by 2020 we might need 25% more water for irrigation but actual water availability for irrigation might be reduced by 12%. He suggested several measures to salvage the situation and to help in meeting our growing needs on a sustainable basis. Dr. Paroda, in his remarks also reiterated the need for major changes in our organizational structure, functioning and infrastructure to face the emerging challenges.

8.1.3 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	Date	Number of trainee (s)
Division of Agricultural Chemicals		
Training workshop on "Innovative Solutions to Production of Nutraceuticals and Functional Foods"	March 22-26, 2011	16
Division of Agricultural Economics		
Institutional Change for Inclusive Agricultural Growth	February15 to March 7, 2011	18
Division of Agricultural Engineering		
Training programme on "Safety of Chaff Cutter, Feed Block Making Machine, UMMB Machine"	March 25-26, 2011	9
Motor Rewinding Training Programme for Rural Youth	September 16-30,2010	20
Division of Agricultural Extension		
Innovative Extension Models for Sustainable Agriculture Development	January 4 - 24, 2011	25
Awareness-cum Training programme on "Protection of Plant Varieties and Farmers' Rights Act"	November 30, 2010	113
Entrepreneurship Development for Farm Youth (2 courses)	November 11-13, 2010	21
	February 1-3, 2011	19
Market-led Extension through Entrepreneurship Development (DoE sponsored)	August 31- September 7, 2010	25
Skill Development of SHG Members for Non-farm Enterprises	December 9-15, 2010	11
Division of Agricultural Physics		
EDUSAT for "Distance Learning Programme for Remote Sensing, GIS and GPS"	October 4-December 9, 2010	24
Department of Space Sponsored winter school on 'Remote Sensing Applications in Agriculture with Special Emphasis on Enhancing Input Use Efficiency"	February 15-March 11, 2011	20
Division of Agronomy		
Model training programme on "Conservation Agriculture for Enhancing Resource-use Efficiency and Crop productivity" sponsored by the Ministry of Agriculture, Govt. of India, New Delhi	December 18-25, 2010	32
A winter school on "Recent Advances in Chemical and Non-chemical Approaches of Weed Management in Cropped and Non-cropped Areas"	November 15-December 6, 2011	27
Division of Biochemistry		
A short-term training course on "Advanced Techniques in Plant Biochemistry and Molecular Biology." under the aegis of the ICAR-Centre of Advanced Faculty Training (CAFT)	February 18-March 10, 2011	20
Division of Floriculture and Landscaping		
Faculty upgradation programme on "CAD Technology on Landscaping"	August 23-28,2010	20
Commercial Floriculture for Farmers of Kashmir Region	February 26 to March 3, 2011	30
	March 7-9, 2011	23
Awareness programmes on "Protection of Plant Varieties and Farmers Rights"	March 17, 2011	50
	March 24, 2011	50

Topic/Name of the training course	Date	Number of trainee
Division of Genetics		
Computational Approaches in Biological Data Mining	December 21-23 2010	20
Division of Microbiology		
Training on Blue Green Algae: Application in Agriculture and Industry	May 12-18, 2010	24
Entrepreneurship Development Program on Biofertilizers	September 6-13, 2010	8
Training on Blue Green Algae	December 7-16, 2010	24
Training on BGA for Farmers	March 24 -26, 2011	58
Division of Nematology		
Advanced Techniques for Exploiting the ENBI Complexes (Entomopathogenic Nematodes-Bacterial Symbionts and the Insect hosts) for Biomanagement of Insect Pests of Crops under the Auspices of NAIP Project.	February 10-19 2011	25
Division of Plant Pathology		
Mushroom Cultivation Technology	September 21-27, 2010	50
Viral Genomics and Transgenic Development	September 8-28 , 2010	19
Pathogenomics and Diagnostics – Cloning and Sequencing of Plant Pathogens and Development of Specific Diagnostics	December 1-10, 2010	15
Division of Post Harvest Technology		
Post-harvest Management of Fruits and Vegetables for Export	March 28-31, 2011	15
Division of Seed Science and Technology		
Seed Production and Quality Evaluation for AARDO Member Countries	October 22 to November 6, 2010	6
Shakiya Faslon Mein Sankar Beej Uptapadan	January 11-13, 2011	19
On-farm farmers' training programme on *"Gunvatta Yukt Beej Utpadan, Packaging Evam Bhandran"* at Kusaliya Village, Ghaziabad District	February 21-22, 2011	25
On-farm farmers training programme on *"Gunvatta Yukt Bbeej Utpadan, Packaging Evam Bhandran"* at Nekpur Village, Ghaziabad District	March 24-25, 2011	25
Division of Soil Science and Agricultural Chemistry		
7th Advanced level training on "Soil Testing, Plant Analysis and Water Quality Assessment"	September 21 to October 11, 2010	15
Division of Vegetable Science		
A winter school on "Designing Nutraceutical and Food Colorant Rich Vegetable Crop Plants : Conventional and Molecular Approaches"	October 15 to November 4, 2010	25
Water Technology Centre		
Scaling up of Water Productivity in Agriculture for Livelihood through Teaching-cum-Demonstration-Training of Farmers	24 trainings of 7-day each	1200
One-day Awareness Program on Micro irrigation under PFDC, NCPAH Sponsored	18 trainings of 1-day each	900
Capacity Building Training	August 24-28, 2010	100
National seminar on "Advances in Micro irrigation"	February 15-16, 2011	200
Enhancing the Productivity of Irrigated Saline Environment using Remote Sensing, Modeling and GIS	March 3-5, 2011	100
Centre for Protected Cultivation Technology		
Protected Cultivation of Horticultural Crops	November 8-13, 2010	25
Seed Production Unit		
Seed Production of Selected Vegetable Crops (Majra(D), Jhajjar, Haryana)	February 25, 2011	66
Seed Production of Selected Vegetable Crops (Gyaspur, Ghaziabad, UP)	March 8-9, 2011	30
Khadyan Fasolo Me Beej Utpadan, Beeta, Bulandshar (UP)	March 25-26, 2011	39
Rabi Dhayan Fasolo Me Beej Utpadan AvumBhandaran Technique, Kallugarhi, Ghaziabad, UP	March 27-28, 2011	39
Regional Station, Karnal		
Beej Phaslon Mein Padap Suraksha (Crop Protection in Seed Crops)	January 27-29, 2011	25

Topic/Name of the training course	Date	Number of trainee
Regional Station, Pusa (Bihar)		
Quality Seed Production of Field Crops and Vegetables	July 7-16, 2010	29
Resource Conservation Technologies for Improving Productivity of Wheat and Vegetables	September 7-16, 2010	27
Nutrient Management and Plant Protection in Food Crops and Vegetables	February 14 -23, 2011	31
ATIC		
Improved Agricultural Technology for Higher Income and Prosperity for Achiever Farmers of ATMA at Narender Nagar, Tehri Garhwal (Uttarakhand) and ATIC, IARI	April 4-22, 2010	19
Improved Agricultural Technology for Higher Income and Prosperity for Farmers of Madhubani District, (Bihar)	August 16-20, 2010	30
Improved Agricultural Technology for Higher Income and Prosperity for Farmers of West Champaran District, (Bihar)	August 23-27, 2010	30
Improved Agricultural Technology for Higher Income and Prosperity for Farmers of Gaya District, (Bihar)	September 6-10, 2010	30
Improved Agricultural Technology for Higher Income and Prosperity for Farmers of Purnea District, (Bihar)	January 18-22, 2011	30
Improved Agricultural Technology for Higher Income and Prosperity for Farmers of Samastipur District, (Bihar)	February 3-7, 2011	30
Krishi Vigyan Kendra, Shikohpur, Gurgaon (Haryana)		
Vocational Training Courses		
Vermicompost Technology	August 26 to September 9, 2010	22
Commercial Dairy Farming	May 18-29, 2010 & June 2-12, 2010	63
Dress Designing and Tailoring	May 17 to July 2, 2010 & October 20 to December 4, 2010	58
Nursery Management of Fruits, Vegetables and Flowers	August 10-11, 2010 & September 20-30, 2010	37
Bee Keeping	September 14-25, 2010 & December 7-9, 2010	30
Preservation of Seasonal Fruits and Vegetables	September 8-18; December 6-14 & December 20 to January 3, 2011	59
Protective Cultivation of Vegetable Crops	December 23-31, 2010	10
Plant Protection and Pest Control Services	June 2-15, 2010 & February 14-25, 2011	37
Motor Winding	September 20-29, 2010	15
In-service trainings for field extension functionaries		
Integrated Plant Nutrient Management (IPNM)	May 28, 2010 & October 1, 2010	36
Livestock Management	November 2, 2010	16
Integrated Pest Management (IPM)	December 24, 2010	18
Directorate		
Training programme for Enabling Administrative Personnel (conducted by IIPA, New Delhi)	July 19, 2010 to August 6, 2010	03
Training for Administrative Personnel of S&T Department of Govt. of India. (Conducted by IIPA, New Delhi)	September 20, 2010 to October 8, 2010	09
Personnel Professional Development Workshop (ISTM, New Delhi)	September 6-17, 2010	02
Establishment & Financial Matters (conducted by NAARM, Hyderabad)	July 12-21, 2010	14
Establishment & Financial Matters (Conducted by NAARM, Hyderabad)	September 13-22, 2010	14
Establishment & Financial Matters (conducted by NAARM, Hyderabad)	October 15-24, 2010	12
Training for technical employees (T-4 & below) of IARI (conducted by IARI, New Delhi)	July 26-29, 2010	40
Training for Technical Officers of IARI (T-5 & above) (conducted by IARI, New Delhi)	July 30, 2010 to August 2, 2010	40
Laws & Information Security for Scientists and Technologists (conducted by IIPA, New Delhi)	January 31, to February 11, 2011	03
Employer Perspective on Labour Related Law (conducted by NAARM, Hyderabad)	February 17-20, 2011	03

8.1. 4 Revision of PG School Calendar

The PG School Calendar, which contains all relevant rules, regulations, laws and bye-laws applicable from admission to the eligibility of the qualified students to receive M.Sc. and Ph.D. degrees, and complete listing of discipline-wise PG courses and their unit-wise contents was updated in the light of the amendments approved by the Academic Council since 2005.

8.1.5 Post-Graduate Faculty

The main strength of the Institute is its faculty of 505 members (in 23 disciplines), of whom 305 are recognized as research guides. During the period under report, 12 new scientists were inducted in the PG faculty and 15 faculty members were inducted as research guides. The guest faculty was invited to take part in the teaching programmes of their respective subjects, where sufficient faculty was not available for teaching the courses.

8.1.6 Internet Facilities for Students and Faculty

Internet and intranet facilities were provided to the IARI faculty and students. Wi-Fi connectivity were also provided in the hostels and guest houses. An online Post Graduate School Management System was developed in-house by IARI faculty for online submission of roster-cum-registration forms, PPW, ORW, progress reports, trimester results, student and faculty data-bases, etc. Two e-reading halls with on-line and Wi-Fi connectivity were made available in the IARI Library. Periodic trainings were organized for faculty and students for CD-ROM search, digital resources, e-journals, on-line information retrieval, etc. Sports and cafeteria facilities were improved.

8.1.7 Modernization of PG Laboratories and Lecture Halls

Under the scheme for strengthening of PG education programme at deemed university, the modernisation of PG laboratories and lecture halls was undertaken. Some of the PG laboratories and lecture halls were renovated and refurnished. Eequipment were repaired, computer facilities improved and text books procured in the main library as well as divisional libraries. Laboratory manuals were also prepared in teaching disciplines. Teaching facilities were modernized by adding audio-visuals, LCD projectors, multi-media systems, interactive boards, etc.

8.2 INFORMATION AND DATABASE

8.2.1 Bioinformatics

8.2.1.1 Bioinformatics Centre

The bioinformatics centre website presents various research and development activities of USI. During the year under report, four short term projects were carried out by trainees at USI: (i) structure and functional site analysis of bacterial leaf blight and tungro virus resistance gene of rice, (ii) sequence analysis of *Oryzae sativa japonica* (Variety: Nipponbare) using R Language, (iii) sequence analysis of wheat using data mining, and (iv) genome wide analysis of WRKY transcription factors in monocots and dicots.

8.2.1.2 Wheat informatics

Wheat Informatics, a web portal that enabled users to retrieve general, scientific, bioinformatics and other information on wheat was developed. This application was developed in a simple language and user-friendly manner to benefit the students and researchers. The work done at various divisions of IARI was also included.

8.2.1.3 E-prints-IARI

An institutional repository, namely, "e prints @iari.res.in", was developed. More than 220 scientific articles were deposited for visibility and for the benefit of the scientific community. Efforts are on to create awareness among scientists to upload their research papers in the repository.

8.2.2 Agri-informatics

8.2.2.1 Consortium for e-Resources in Agriculture (CeRA)

CeRA platform (www.cera.jccc.in) was updated to cover the publishers being subscribed to since 2008. To increase the usage of CeRA facility, 23 awareness cum monitoring workshops were organized at different places covering 30 institutions under NARS. For helping the researchers to access the full text of journals which are not subscribed by CeRA, but subscribed by a CeRA member, a Document Delivery Request System (DDRS) was introduced. During 2010-11, more than 1500 articles were distributed under this system from IARI to authorized users. More than 10 lakh articles were downloaded from CeRA subscribed publishers. For a subscription of about ₹ 8.0 crores, the consortium has notionally recovered about ₹ 20.0 crores, not to mention the easy online availability.

8.2.2.2 Agroweb-Digital Dissemination for Indian Agricultural Research (ADDSIAR)

Websites (internet and intranet) of the Institute were developed by using an open source software, JOOMLA having several features including remote customization. Faculty and student information systems and useful models were integrated with the website.

8.2.2.3 Rice Knowledge Management Portal (RKMP)

Five information systems (General, Extension, Farming, Research, and Service Information) were developed. Contents for the extension information system (EIS) and farming information system (FIS) were collected and integrated with RKMP portal. Location specific FAQ page was designed and SMS services were initiated. Online bioinformatics tool suits (program for retrieving and analysis of biological database) were developed. The suits contain different tools like DNA Global Alignment, DNA Molecular Weight, DNA Pattern Finder, DNA Statistics, DNA Translator, EMBL to FASTA Converter, and GenBank to FASTA Converter. A web enabled information dissemination system, i.e., SMS based technology was developed. Structure prediction and analysis of protein of *Basmati* rice were done. An online data mining tool to extract information dynamically in the form of graph from database was developed.

8.2.2.4 Strengthening of digital library and information management under NARS (e-Granth)

As a subcomponent of ICDS of Component-I of NAIP Project, e-Granth was started from May 2009 with twelve libraries of ICAR institutes and SAUs as Consortia partners and IARI as the lead centre. Under the project, more than 2.5 lakhs records of publications were sent to Online Computer Library Centre (OCLC) to merge with the Worldcat (catalogue of 71,000 libraries of the world) through batch processing. Cataloguing of recent books was done directly in Worldcat through a connexion software of OCLC. A group catalogue named 'AgriCat' was created as a subgroup of WorldCat to access the combined catalogue of 12 partner libraries. The AgriCat presently has more than 2.5 lakh records. The National Conference of Agricultural Librarians and user community 2011 on "Agricultural Libraries in Knowledge Web" was organized from February 24-25, 2011 at IARI.

8.3 LIBRARY SERVICES

IARI Library is one of the largest and the finest agro-biological libraries in South East Asia housing about six lakh publications including books/monographs, journals reports, bulletins, post graduate theses and other reference materials. The Library functions as the depository of Food and Agricultural Organization (FAO), and Consultative Group of International Agricultural Research (CGIAR) institute's publications. The Library has Wi-Fi connectivity in the student facility wing and in reading halls. The Library has on its roll 2000 members, viz., students, scientists and technical staff. It also serves about 2500 visitors every year.

8.3.1 Acquisition Programme

8.3.1.1 Books

During the period under report, the Library procured 722 publications, which include 165 in Hindi and 555 in English costing ₹ 40,02,137. The Library also acquired 147 gift publications and 171 PG student's theses from IARI.

8.3.1.2 Serials

The Library procured 807 journals/serials through subscription, gifts and exchange. It subscribed to 158 foreign journals (17 are online against print version) and 342 Indian journals, advances, and annual reviews. Exchange relationship is maintained with 67 institutions globally and nationally by sending annual reports, ICAR journals and society publications.

Two hundred sixty annual scientific/technical reports of different institutions and forty-four bulletins were received in the Library during the reported period. The expenditure on serial acquisition from plan and PG Strengthening Scheme was ₹ 1,50,89,628.

8.3.2 Documentation Activities

8.3.2.1 AGRIS Project

The IARI Library is declared as an input center for National Agricultural Research Database (NARD) under AGRIS Project. The Library is assigned the job of scanning articles from 10 Indian journals. The input was done in ISO format by using AGRIN methodology. During the reported period, 407 articles were scanned, processed and sent to Directorate of Knowledge Management in Agriculture, ICAR for inclusion in AGRIS Index.

8.3.2.2 Development News in Agriculture

Four thousand six hundred twenty-two (4622) issues of 14 newspapers were scanned and 22 news items pertaining to IARI as well as ICAR were sent to the Directorate, Principal Scientist (PME) and CATAT.

8.3.2.3 Document processing

In all, 1512 documents consisting of 976 books, 161 bulletins, 155 post-graduate IARI and RFT theses, and 220 Hindi books were processed (classifying and cataloguing).

8.3.3 Resource Management

8.3.3.1 Binding of publications

In all, 1000 volumes consisting of 4000 loose issues of journals, reports and bulletins were bound and 300 volumes accessioned.

8.3.3.2 Reference, circulation and stack maintenance

Apart from approximately 2000 registered members, the Library served everyday approximately 125 to 130 users, who consulted approximately 1500 to 2000 documents. During the period under report, 2650 publications were issued to its members. In all, 55 documents were issued under Inter Library Loan System to various institutions.

8.3.4 Services

8.3.4.1 Reprography services

During the period, 66,481 photocopies were provided to scientific and technical staff from the holdings of library.

8.3.4.2 CD-Rom Workstation

Seven prominent international databases on agricultural aspects were subscribed to for ₹ 23,79,204 to provide CD-ROM services. Ten user terminals were provided to users in CD-ROM workstation of the Library. These databases are accessible to scientists/students/users of IARI through LAN. In all, 4,01,227 references were downloaded by the scientists and students of IARI and research scholars from all over India. The cost-based references downloaded were 33,339, which generated revenues amounting to ₹ 47,724 during the reported period.

8.3.4.3 Training on online access of international database

A training on online access of international databases for retrieval of information was conducted for 150 personnel comprising scientists, students, and technical Staff of IARI. A practical training of one-month duration was given to the students of the Department of Library and Information Science, Delhi University, under their internship training programme. Several demonstrations and lectures for the participants of winter/summer schools, staff and students from NARS institutions under NARS systems were also organized.

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. Publications in the form of research papers, books/chapters in the books, popular articles, etc. are an important component of the information system. During the reported period, the Institute scientists brought out quality publications both in English and Hindi. Apart from these publications, the Institute brought out several regular and adhoc publications both in Hindi and English. The details of these publications are given below:

9.1 RESEARCH/SYMPOSIA PAPERS

a)	Research papers published in international journals	286
b)	Research papers published in national journals	346
c)	Symposia/conference papers	471

9.2 BOOKS/CHAPTERS IN BOOKS

a)	Books	27
b)	Chapters in books	201

9.3 POPULAR ARTICLES 312

9.4 INHOUSE PUBLICATIONS

9.4.1 Regular publications (English)

- IARI Annual Report 2009-2010 (ISSN: 0972-6136)
- IARI NEWS (Quarterly) (ISSN: 0972-6144)-4 issues
- IARI Current Events (Monthly)-12 issues (Available only on IARI website)

9.4.2 *Ad hoc* Publications (English)

- Post-Graduate Research and Human Resource Development at IARI: 1996-2009 (ISBN 978-81-88708-36-9)
- Viral Genomics and Transgenic Development (ISBN 978-81-88708-60-4)
- Designing Nutraceutical and Food Colorant Rich Vegetable Crop Plants: Conventional and Molecular Approaches (ISBN 978-81-88708-61-1)
- Cloning and Sequencing of Plant Pathogens and Development of Specific Diagnostics (ISBN 978-81-88708-63-5)
- Conservation Agriculture (ISBN 978-81-88708-64-2)
- Advances in Weed Management (ISBN 978-81-88708-65-9)
- Water Management for Ensuring Food Security (ISBN 978-81-88708-66-6)
- Technological Options for Enhanced Productivity and Profit (ISBN 978-81-88708-67-3)
- *Kharif* Field Crops' Seed Production Technology (TB-ICN: 76/2010)
- Post Harvest Management of Rice Seed (TB-ICN: 77/2010)
- Hybrid Seed Production in Cauliflower (TB-ICN: 78/2010)
- Remote Sensing for Management of Crop Physical Environment (TB-ICN: 79/2010)
- Fertigation Scheduling for Horticultural Crops (TB-ICN: 80/2010)
- Decision Support System for Water Resources Management (TB-ICN: 81/2010)
- Crop Protection in Seed Crops (TB-ICN: 82/2011)

9.4.3 नियमित प्रकाशन (हिन्दी)

- पूसा सुरभि (वार्षिक) (ICN : H-98/2010)
- पूसा समाचार (त्रैमासिक) (ISSN 0972-7280)
- प्रसार दूत (त्रैमासिक)
- सामयिकी (मासिक) (केवल संस्थान की वेबसाइट पर उपलब्ध)

9.4.4 तदर्थ प्रकाशन (हिन्दी)

- स्वःपरागित फसलों की बीज उत्पादन तकनीकी (ICN : H-94/2010)

- परिनगरीय खेती (ICN : H-95/2010)
- खरपतवार नियंत्रण से फसल सुरक्षा (ICN : H-96/2010)
- खाद्य फसलों एवं सब्जियों का उत्तम बीज उत्पादन (ICN : H-97/2010)
- गेहूं एवं सब्जियों की उत्पादकता में सुधार हेतु संसाधन संरक्षण तकनीक (ICN : H-99/2010)
- बागवानी फसलों के लिए फर्टिगेशन सूचीकरण (ICN : H-100/2010)
- बीज फसलों में पादप सुरक्षा (ICN : H-101/2011)
- खाद्यान्न फसलों एवं सब्जियों में पोषण एवं पादप संरक्षण (ICN : H-102 /2011)
- अधिक उत्पादन के लिए मौसम आधारित परामर्श (ICN : H-103/2011)
- लेजर लेवलर से भूसमतलीकरण (ISBN 978-81-88708-62-8)
- शाकीय फसलों में संकर बीज उत्पादन (ISBN 978-81-88708-68-0)

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:

10.1 PATENTS

A. Patents Filed

1. Novel naphthyridine based hydrazines as potent agrochemicals (Dr. Rajesh Kumar & Others, Division of Agricultural Chemicals).
2. Liquid Bioinoculant of *Azotobacter chroococcum* and the process thereof (Dr. Sangeeta Paul & Others, Division of Microbiology).

B. Patents Granted

1. Synthetic gene encoding Cry 1 Fa 1δ-endotoxin of *Bacillus thuringiensis* (Dr. P. Ananda Kumar, NRCPB).
2. Pusa fruit coring device (Hand operated) (Dr. H.S. Sharma and Dr. Amar Singh, Division of Agricultural Engineering).
3. Polymeric seed coats based on bioactive botanicals (Dr. Jitendra Kumar & Others, Division of Agricultural Chemicals).

C. Patents Renewed

1. A process for the preparation of Mosquito Larvicidal Formulations based on Rabdosia Melissoides Ingredients (Dr. B.S. Parmar & Dr. Lalit Kumar, Division of Agricultural Chemicals).
2. Additives for improved photostability of Azadirachtin-A (Dr. Prem Dureja & Others, Division of Agricultural Chemicals).
3. Process for the preparation of Pesticidal Oxime Esters (Dr. Suresh Walia and Dr. B.S. Parmar, Division of Agricultural Chemicals).
4. Process for the preparation of Mono/Di/Polyol Ester Pesticides (Dr. Suresh Walia & Others, Division of Agricultural Chemicals).
5. A hyper-spectral data analyzing method for characterization and discrimination of natural/man made resources from air borne platforms (Dr. Ravinder Kaur, Division of Environmental Sciences).
6. Efficient process for the preparation of Neem based Reduced Azadirachtin(s) Pesticides (Dr Suresh Walia & Others, Division of Agricultural Chemicals).
7. Biopesticidal formulation with improved shelf life and the process of preparation (Dr. Prem Dureja and others, Division of Agricultural Chemicals).

10.2 TECHNOLOGY COMMERCIALIZED

A. Consultancies /Contract Research Proposals/ Agreements

1. Non-disclosure Agreement for Transgenic Tomato Technology signed with Syngenta India Ltd., Pune.
2. Agreement signed with Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu (SKUAST-J) to promote Academic & Research Co-operation.
3. Consultancy for ASTI survey of Agricultural R & D investments in India (Dr. Suresh Pal, Division of Agricultural Economics).
4. Consultancy for Pesticide Residue Analysis for the FAO Regional TCP project on Pesticide Management (Dr. K.K. Sharma, Division of Agricultural Chemicals).

B. Memorandum of Understanding (MoUs) Signed

Eighteen Memorandum of Understanding signed during the year under report.

10.3 OTHER ACTIVITIES

A. Entrepreneurship Development Programme

Three entrepreneurship development programme (EDP) were conducted to impart skills to those entrepreneurs who have their interest in different agriculture related fields but need to hone their technical as well as entrepreneurial skills. The programmes were on: (i) Production of Biopesticide (August 30- September 5, 2010), (ii) Production of Biofertilizer (September 6-14, 2010), and (iii) Plant Tissue Culture (January 17 -22, 2011).

B. Technology Promotional Events

1. Meets organized / participated

i. Institute-Industry Meet

An Institute-Industry Meet was oraganized on June 14, 2010 with an objective to commercialize the technologies of IARI and discuss the problems in commercialization of the technology as well as the market demands. Over 35 participants including 11 industry partners attended the meet.

MoUs signed

Sl.No	Technologies	Licensee Companies	Date of MoU
1	Plant Virus Detection Kit	Chromus Biotech	22.04.2010
2	Animal Feed-block Making Machine	Standard Hydraulics	26.04.2010
3	Modified Atmospheric Packaging for Vegetables	Alor Utshya,Hooghly,W.B	18.05.2010
4	Pusa Fruit Drink	Alor Utshya,Hooghly,W.B	18.05.2010
5	PRH-10	Nirmal Seeds	28.05.2010
6	PRH-10	IFSSA(Renewal of MoU which was signed on 7.04.2005)	14.06.2010
7	Event for TOSPO Resistance in Tomato	Advanta India Ltd	14.06.2010
8	Maize Hybrid PEEHM-5	Sampoorna Seeds	28.07.2010
9	*Trichoderma* based formulation as biopesticide	M/S Sai Bio Organics, Punjab	16.09.2010
10	Blue Green Algae (BGA) Biofertilizer Technology	M/S Sai Bio Organics, Punjab	16.09.2010
11	*Rhizobium* Biofertilizer Technology	M/S Sai Bio Organics, Punjab	16.09.2010
12	*Azotobacter* Biofertilizer Technology	M/S Sai Bio Organics, Punjab	16.09.2010
13	*Phosphate Solubilizing Bacteria (PSB)*	M/S Sai Bio Organics, Punjab	16.09.2010
14	Maize Hybrid PEEHM-5	M/s Sri Laxmi Venkateshwara Seeds, Kulnoor (AP)	19.10.2010
15	For Phase III Trial of Bt Brinjal having Cry 1X gene	Bejo Sheetal Seeds Pvt. Ltd.,(Renewal Agreement)	13.12.2010
16	Blue Green Algae Bio-fertilizer	M/s Ecological Products Industries, New Delhi	20.01.2011
17	Pusa Rice Hybrid PRH 10	M/s Bhartiya Beej Nigam Ltd., Rudrapur, Distt.-Udham Singh Nagar, Uttarakhand	15.02.2011
18	Statistical Analysis Software (SAS)	Indian Agricultural Statistics Research Institute (IASRI)	19.03.2011

ii. ICAR-Industry Meet

Participated in ICAR-Industry Meet held at New Delhi from July 28-29, 2010 which showcased the technologies for promoting ICAR-Industry alliances and accelerating the commercialization activities of the Institute and Zonal Technology Management Units.

iii. IARI-Field Day for Industry

IARI- Field day for industry was organized on September 21, 2010 to demonstrate elite varieties and hybrids of important field crops for nurturing a greater collaborative research and commercial perspective between Industry and Institute.

iv. Meet on *"Utpadak se Udhami"*

A meeting on "उत्पादक से उद्धमी" was held on November 9, 2010, with an objective to motivate some of the progressive farmers to organize themselves in defined groups for taking up seed multiplication venture with an ultimate aim of making "Producer Company" in the seed sector. Around 65 farmers representing 8 different districts from Haryana and Uttar Pradesh (NCR) participated in the meet.

v. Zonal Meeting cum Workshop for the Zonal Institutes of North Zone-I

The Zonal Technology Management & Business Planning and Development Unit, IARI organized a Meeting cum Workshop for the Zonal Institutes of North Zone-I at IARI during March 17-18, 2011. The meeting was organized with an objective to promote intellectual property management and technology transfer in ICAR institutes of North Zone-I which consists of 21 institutes. Fifty six participants from 20 Institutes attended the programme.

2. Participation in Exhibitions/ Meetings

i. India Mart 6th Food and Technology Expo-2010 held at New Delhi, August 6-8, 2010.

ii. *Krishi Kumbh Mela* held at GBPUAT, Pantnagar from October 8-11, 2010.

iii. GBM of Farmers Producer Company held at Baswada, Rajasthan on October 24, 2010.

iv. Agribusiness Community of Practices (CoP) organized by Info Dev at ICRISAT Hyderabad from October 26-28, 2010.

v. Indian Chamber of Commerce & NRDC meet held at Kolkata in December, 2010.

vi. Indian Science Congress held at Chennai from January 3-6, 2011.

vii. IARI Flower Show held on February 28, 2011.

3. Business Incubation

The following business incubates associated with the IARI:

i. M/s. Abu Biotech as an incubate in the area of *In vitro* propagation of medicinal and high value plants like *Stevia rubidiana.*

ii. M/s. NutraHelix Biotech Pvt. Ltd. as an incubate works in the area of neutraceutical value of probiotics.

iii. M/s. Neeraj Chandok working as incubate in the area of farm development and management.

4. Corporate Membership

Continuous interaction with the industry and the entrepreneurial community has resulted in the development of a network of corporate members. About 43 corporate members were registered with Business Planning and Development Unit.


Commercialization of IARI technologies


Entrepreneurship Development Programme (EDP) with IARI technologies

11. LINKAGES AND COLLABORATION

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. Similar linkages exist for natural resource and socio-economic research institutes. Collaboration exists with almost all the state agricultural universities (SAUs), selected conventional universities, several of the institutes of the CSIR and the departments of Ministry of Science and Technology such as the Departments of Biotechnology, Space Research, and Meteorology, and several other ministries/departments/organizations of the Government of India.

At the international level, the Institute has close linkages with several of the CGIAR's international agricultural research centres (IARCs), more particularly with ICRISAT, CIMMYT, IRRI, and ICARDA. Among other international organizations, FAO, IAEA, USAID, UNDP, WMO, UNIDO and UNEP have been the closest allies. Several bilateral research linkages involving developed and developing countries exist. These include linkages with USDA, selected universities in USA, Canada, Australia, World Bank, Rockfeller Foundation, European Commission, JAICA, JIRC, JSPS, ACIAR, AVRDC (Taiwan), etc.

The details of externally funded projects in operation during the period from 1.4.2010 to 31.3.2011 are given below:

Details of externally funded projects in operation

Name of funding agency	No. of projects
Within India	
DBT, DST, ICAR, CICR, CPRI (Mini Mission - HP), CSIR, NCPA, CPCB, Ministry of Water Resources, Ministry of New and Renewable Energy, Ministry of Environments & Forest, Basmati Export Development Foundation, Ministry of Earth Sciences, Directorate of Vanaspati, Vegetable Oils and Fats, National Medicinal Plant Board, DAC, SAC, NABARD, National Horticultural Mission, NRDC, BARC, PPV&FRA, ISRO, IIRS, NFBSRA (ICAR), NFBSFARA (ICAR), NAIP (ICAR), etc.	150
AP Cess Fund, National Fellow Scheme of ICAR	08
Outside India	
IPNI India Programme, USAID, UKIERI, CIMMYT, University of Sydney, Indo-Australian Programme	04

12. AWARDS AND RECOGNITIONS

- Dr. T.B.S. Rajput, Project Director, Water Technology Centre received Jain-ISAE Award for his contribution on micro irrigation.
- Dr. K.V. Prabhu, Head, Division of Genetics received the First Best Scientist Award by Young Farmers' Association, Punjab and Government of Punjab for his contribution in the field of wheat and *basmati* rice varietal popularization and redefining *basmati* rice.
- Dr. R.K. Jain, Head, Division of Plant Pathology received (i) VASVIK 2007 Award, (ii) Nominated Chief Editor, Indian Journal of Virology, (iii) Chief Editor, Pusa Agri Science, (iv) Member, DBT Task Force on Agricultural Biotechnology and (v) Member, Institute Bio- safety Committee (IBSC).
- Dr. R.K. Pal, Head, Division of Post Harvest Technology was elected Fellow of the Horticultural Society of India. Dr. Pal was also nominated as National Consultant on Post Harvest Management of FAO of United Nations.
- Dr. P. Kalia, Head, Division of Vegetable Science was elected Fellow of Horticultural Society of India.
- Dr. A.K. Vyas, Head, Division of Agronomy was elected Fellow of the Indian Society of Agronomy.
- Dr. T. Janakiram, Head, Division of Floriculture and Landscaping awarded Lotus Puraskar by ISOH, New Delhi for his outstanding contribution in the field of floriculture
- Dr. A.K. Saxena, Head, Division of Microbiology was elected Fellow of the National Academy of Agricultural Sciences. Dr. Saxena was also nominated Executive Editor, Pusa AgriScience.
- Dr. Suresh Pal, Head, Division of Agricultural Economics received DT Doshi Award of AERA.
- Dr. Anand Swarup, Head and Dr. T.J. Purkayastha, Principal Scientist, Division of Soil Science and Agricultural Chemistry received Dhiru Morarji Memorial Award (First Prize) of FAI 2010.
- Dr. V.P. Singh, Professor and Dr. Ajay Arora, Principal Scientist, Division of Plant Physiology received G.S. Sirohi Award for their best published paper in Indian Journal of Plant Physiology.
- Dr. (Ms.) D.W. Dhar, Professor, Division of Microbiology received Professor K.S. Bilgrami Award.
- Dr. (Ms.) Pratibha Sharma, Professor, Division of Plant Pathology received (i) Outstanding Women Scientist Award of IPS, (ii) Elected Secretary, Indian Phytopathological Society for 2010-2013, and (iii) Nominated as a Member of Management Committee of National Centre for Integrated Pest Management, New Delhi.
- Dr. Subodh Joshi, Professor, Division of Vegetable Science was elected Fellow of the Indian Society of Vegetable Science.
- Dr. (Ms.) Shashi Bala Singh, Principal Scientist, Division of Agricultural Chemicals was elected Fellow of the Indian Society of Weed Science, Jabalpur, and also elected Fellow of the Society of Plant Protection Science, Delhi.
- Dr. Ajay Arora, Principal Scientist, Division of Plant Physiology received J.J. Chinoy Gold Medal Award of the Indian Society for Plant Physiology.
- Dr. J.P. Sharma, Principal Scientist and Incharge, Centre for Agricultural Technology Assessment and Transfer (CATAT) received Best Scientist Award by Young Farmers' Association, Punjab and also received the Best Extension Scientist Award by Progressive Farmers Forum, Faridabad.
- Dr. (Ms.) Uma Rao, Principal Scientist, Division of Nematology was nominated as a Member, Task Force Committee on Biological Control Agents for Agriculture.
- Dr. (Ms.) Aruna Tyagi, Principal Scientist, Division of Biochemistry was awarded the Fulbright-Nehru Environmental Leadership Grant Fellowship, which is

to be availed during the period March 15, 2011 to July 15, 2011 at the School of Plant, Environmental and Soil Sciences of the Louisiana State University Agricultural Center.

- Dr. S.S. Sindhu, Principal Scientist, Division of Floriculture and Land Scaping received YWCA award for his contributions made in landscape and promotion of floriculture in Delhi & NCR.
- Dr. S.K. Chakrabarty, Principal Scientist, Division of Seed Science and Technology received Bhoomi Nirman Award.
- Dr. Anuja Gupta, Principal Scientist & Rajbhasha Prabhari, Regional Station, Karnal received Commendation Certificate from Town Official Language Implementation Committee, Karnal, Department of Official Language, Ministry of Home Affairs, Government of India for promoting the use of Official language (Hindi), and Dr. Gupta also received Shri VP Gokhale Award, 2010 instituted by Prof. DV Gokhale, University of California, Riverside, USA and administered by Maharashtra Association for the Cultivation of Science (MACS) in recognition of her significant research contribution in the area of Phytopathology.
- Dr. D.S. Rana, Principal Scientist, Division of Agronomy received the TSI-FAI Award 2010 on 'Plant Nutrient Sulphur' for his significant contributions on sulphur nutrition of oilseed crops.
- Dr. Amar Singh, Principal Scientist, Division of Agricultural Engineering was elected Fellow of the Indian Society of Agricultural Engineers.
- Dr. B.S. Dwivedi, Principal Scientist, Division of Soil Science and Agricultural Chemistry was elected Fellow of the National Academy of Agricultural Sciences.
- Dr. A.K. Patra, Principal Scientist, Division of Soil Science and Agricultural Chemistry was elected Fellow of the National Academy of Agricultural Sciences.
- Dr. V.K. Baranwal, Principal Scientist, Division of Plant Pathology was elected Secretary, Indian Phytopathological Society.
- Dr. (Ms.) Rashmi Aggarwal, National Fellow, Division of Plant Pathology was elected Editor, Indian Journal of Virology.
- Dr. Vishwa Nath, Principal Scientist, Division of Entomology received Life Time Achievement Award.
- Dr. A.K. Singh, Senior Scientist, Division of Genetics was elected Fellow of the National Academy of Agricultural Sciences.
- Dr S.K. Singh, Senior Scientist, Division of Fruits and Horticultural Technology received distinguished Scientist of the Year Award by the Society for Recent Initiatives in Horticulture, Meerut.
- Dr. A. Sarangi, Senior Scientist, Water Technology Centre received Shankar Memorial Award by Indian Society of Agricultural Engineers.
- Dr. (Ms.) Neelam Patel, Senior Scientist, Water Technology Centre received ISAE Special Award, and Dr. Patel also received Jain-ISAE Award for her contribution on micro irrigation.
- Dr. D.K. Singh, Senior Scientist, Water Technology Centre received Commendation Medal of ISAE.
- Dr. R.R. Sharma, Senior Scientist, Division of Post Harvest Technology was nominated as a Member, Editorial Board, International Journal of Fruit Science, UK, and Dr. Sharma was also nominated Section Editor, Stewart Postharvest Reviews, UK.
- Dr. H. Pathak, Senior Scientist, Division of Environmental Sciences received (i) NAAS Award Recognition in Agriculture research, (ii) Prof. S.K. Mukherjee Commemoration Award, Indian Science Congress, (iii) Gold Medal of the Society of Agricultural Professional, CSAUAT, Kanpur, and (iv) Lead Author IPCC, 5th Assessment Report.
- Dr. B. Ramakrishnan, Senior Scientist and Dr. Surender Singh, Scientist, Division of Microbiology wsa awarded Endeavour Research Fellowship.
- Dr. Dinesh Singh, Senior Scientist, Division of Plant Pathology received Young Scientist Associate Award 2010.
- Dr. Bikash Mondal, Senior Scientist, Division of Plant Pathology was elected Editor, Indian Journal of Virology.
- Dr. G.K. Mahapatro, Senior Scientist, Division of Entomology was selected as a National Fellow of ICAR.

- Dr. N.A. Shakil, Senior Scientist, Division of Agricultural Chemicals received Outstanding Scientist Award from Society of Plant Protection Sciences, Delhi.
- Dr. Jitender Kumar, Senior Scientist, Division of Agricultural Chemicals was elected Fellow of the Society of Plant Protection Sciences, Delhi.
- Dr. Rajesh Kumar, Senior Scientist, Division of Agricultural Chemicals was elected Associate, National Academy of Agricultural Sciences.
- Dr. Supradip Saha, Senior Scientist, Division of Agricultural Chemicals received Pran Vohra Award by ISCA.
- Dr. (Ms.) Anju Kamra, Senior Scientist, Division of Nematology received the Meritorious Scientist Award of the Society of Plant Protection Sciences, New Delhi .
- Dr. Pramod Kumar, Senior Scientist, Division of Plant Physiology was elected Fellow of the Indian Journal of Plant Physiology.
- Dr. I. Sekar, Senior Scientist, Division of Agricultural Economics received D.B. Desai Award.
- Dr. D. Chakraborty, Scientist, Division of Agricultural Physics was elected Associate, National Academy of Agricultural Sciences.

13. BUDGET ESTIMATES

Statement showing Budget Estimates, Revised Estimates and Expenditure under Plan for the year 2010-11 and 2011-12

₹ in lakh

Head	2010-11			2011-12
	Budget estimates	Revised estimates	Expenditure	Budget estimates
A. Recurring				
Pay & Allowances				
TA	60.00	70.00	69.97	95.00
HRD	30.00	33.00	32.92	59.30
Contingencies	775.00	980.00	980.00	515.88
Total (A)	**865.00**	**1083.00**	**1082.89**	**670.18**
B. Non-Recurring				
Equipments	600.00	1105.69	1105.39	2309.57
Furniture	40.00	95.00	95.00	77.43
Works	845.00	2020.20	2020.17	2208.04
Library	200.00	200.00	200.00	200.63
Land	-	-	-	-
Provision for OBC	100.00	274.50	274.26	1934.15
Total (B)	**1785.00**	**3695.39**	**3694.82**	**6729.82**
Grand total (A+B)	**2650.00**	**4778.39**	**4777.71**	**7400.00**

Statement showing Budget Estimates, Revised Estimates and Expenditure under Non-Plan for the year 2010-11

₹ in lakh

Head	2010-11		
	Budget estimates	Revised estimates	Expenditure
Estt. Charges	10780.00	11375.00	11374.97
OTA	2.50	4.00	3.64
TA	20.00	26.00	25.95
Contingencies including equip.	1384.50	3023.51	3043.05
Works			
i) Office building	300.00	830.18	840.69
ii) Residential building	200.00	445.00	449.37
iii) Minors works	70.00	154.00	139.09
Other items	250.00	265.00	243.44
Total	**13007.00**	**16122.69**	**16120.20**

Statement showing Budget Estimates under Non-Plan for the year 2011-12

₹ in lakh

Head	2011-12
	Budget estimates
Capital	**1.00**
Revenue	
Establishment Expenses	
(A)Salary	
i. Establishment charges	12525.00
ii. Wages	0.00
iii. Overtime allowance	4.00
(B) Pension	9450.00
(C) Loan & Advances	11.00
Total -Establishment Expenses	**21990.00**
TA	**20.00**
Research & Operational Expenses	
(A)Research expenses	180.00
(B)Operational expenses	243.00
Total -Research & Oper. Expenses	**423.00**
Administrative Expenses	
(A) Infrastructure	1000.00
(B) Communication	20.00
(C) Repair & Maintenance	
i. Equipments, vehicles & others	100.00
ii. Office building	350.00
iii. Residential building	200.00
iv. Minor works	66.00
Others (exc.TA)	200.00
Total -Administrative Expenses	**1936.00**
Miscellaneous Expenses	
(A) HRD	
(B) Other items (fellowships, etc.)	350.00
(C) Publicity & exhibitions	0.00
(D) Guest house-maintenance	0.00
(E) Other miscellaneous	240.00
Total -Miscellaneous Expenses	**590.00**
Total (Revenue)	**24959.00**
Grand total (Capital+Revenue)	**24960.00**

14. STAFF POSITION

(As on 31.03.2011)

Category		Number of posts			
		Sanctioned	Filled		
			Direct Recruitment	By Assessment	Total
A.	**SCIENTIFIC STAFF**				
1)	Research Management Personnel	6	4	-	4
2)	Principal Scientist	68	43	97	140
3)	Senior Scientist/Scientist (S.G.)	179	82	102	184
4)	Scientist	345	272*	-	73
	Total	**598**	**401**	**199**	**401**
B.	**TECHNICAL STAFF**				
1)	Category III	25	18		
2)	Category II	308	258		
3)	Category I	395	307		
4)	Auxiliary	02	02		
	Total	**730**	**585**		
C.	**ADMINISTRATIVE STAFF**				
1)	Group A	20	14		
2)	Group B	278	201		
3)	Group C	172	181		
	Total	**470**	**396**		
D.	**SKILLED SUPPORTING STAFF**	1307	1146		

Note: * Out of 272 positions of Scientist filled through direct recruitment only 73 are working in the grade of Scientist. The remaining 199 scientists (i.e. 97 Principal Scientists & 102 Senior Scientists) have been promoted as Principal Scientist and Senior Scientist through assessment.

15. MISCELLANY

I. On-going Projects at IARI as on 31.03.2011

a)	School of Crop Improvement	34
b)	School of Resource Management	19
c)	School of Crop Protection	30
d)	School of Basic Sciences	14
e)	School of Social Sciences	12
	Total	109
	Other projects	12
	Challenge projects	05

II. Scientific Meetings Organized

a)	Workshops	10
b)	Seminars	14
c)	Summer institutes/Winter school	13
d)	Farmers' day (s)	59
e)	Others	96
Total		**192**

III. Participation of Personnel in Scientific Meetings

India

a)	Seminars	222
b)	Scientific meetings	156
c)	Workshops	134
d)	Symposia	88
e)	Others	52
Total		**652**

Abroad

a)	Seminars	11
b)	Scientific meetings	9
c)	Workshops	06
d)	Symposia	04
e)	Others	18
Total		**48**

IV. Significant Suggestions Given/Decisions Taken at the Meetings of Senior Management Personnel

Board of Management

- Many equipments were replaced by different divisions, stations, etc. These equipments were approved in the EFC Memo of XIth Plan.
- A new Research-Cum-Study Centre was established at Shimla in the name of Dr. B.P. Pal Research-Cum-Study Centre.
- Proposal to establish a Multi-disciplinary Centre for Nitrogen Research (CNR) at IARI

Academic Council

- Adoption of the recommendations of the coordination committee for ICAR deemed universities for uniformity in academic requirements, fee structure and management procedures.
- Recognition of the distinguished scientists and teachers who have made very significant contributions in their respective disciplines, as notified adjunct and guest faculty of IARI.
- Memoranda of understanding to be executed between IARI and select ICAR Institutes for collaborative study programmes at PG level.
- Finalization of guidelines governing the institution of new Divisional and Institute level awards at IARI.
- New format of the theses submitted by the PG students, with the results chapter to be written on the pattern of research papers instead of narrative form.
- Re-nomenclature of the M.Sc. degree in Agricultural Engineering as M.Tech. (Agricultural Engineering) to maintain uniformity with other universities.
- Establishment of a European Language and Communication Lab at IARI.

Executive Council

- Best Worker Award - New guidelines were approved by the Hon'ble Chairman for 4 award in each category total 12 award per year carrying a certificate and an amount of ₹ 5000/- each.
- Proposal to start course of M.Sc. (Bio-Informatics) at IARI instead of IASRI because the faculty for this programme are mostly from the IARI.

Research Advisory Committee

School of Crop Improvement

- Due emphasis needs to be given to germplasm enhancement and conservation of important crops involving breeders, cytogeneticists, entomologists, plant pathologists and seed technologists.
- QTLs for rice and wheat for yield enhancement needs to be identified.
- Efforts be made to evolve short duration mungbean varieties that fit well into the rice-wheat cropping system. Economic benefits of rice-wheat system also need to be worked out.
- Research programme pertaining to terminal heat tolerance and quality improvement in wheat should be given priority.
- Research work on *Kabuli* chickpea and lentil (for disease resistance) needs to be persued and strengthened in collaboration with ICARDA.
- Characteristics of selected mango hybrids for export purpose may be studied.
- Low cost protected cultivation technology, including seed production of selected vegetable crops (broccoli, baby carrot, cucumber) may be developed.
- Papaya improvement programme for virus resistance needs to be strengthened.

School of Basic Sciences

- Work on iron and zinc deficiency in relation to phytosiderophores in rice may be taken up.
- Research work on improved biotic stress tolerance in selected crop plants be published in the form of success stories.
- Focused biotechnological work in selected crops and high priority areas is required in collaboration with plant breeders in the Division of Genetics.
- Major emphasis be given now to the research studies in hybrid mustard. Concerted efforts for improving resistance to aphids and *Alternaria* blight are also required.

School of Natural Resource Management

- Relevance and practicability of the research experiments needs to be looked into in order to arrive at logical conclusions.
- Decision support systems and sensor development for precision farming needs to be developed in association with Agricultural Engineering discipline.
- Due emphasis needs to be given to micro irrigation system in canal command areas.
- Research studies on carbon sequestration under green manuring need to be intensified.
- Alternatives to the existing rice-wheat system for high productivity and better water use efficiency may be looked into.
- Prime importance needs to be given to screening of rice and wheat germplasm for high WUE and NUE.
- Research programmes pertaining to conservation agriculture may be intensified.
- Equipments for placing plastic mulches in vegetable fields for water saving and weed protection need to be developed.

School of Social Sciences

- Studies on integrated farming system approach to be given due emphasis.
- Innovative methodogical approaches in agricultural extension research needs to be brought out.
- An effective model for dissemination of IARI technologies needs to be developed.
- Research programmes on impact assessment of IARI technologies to be given high priority.
- Special attention be given to link farmers with market for enhanced income.
- Major emphasis be given to the work on economic empowerment of farmers through SHGs or Cooperatives.
- Efforts should be made to impart vocational training to TOT agents for effective transfer of technology information to the farmers.

- Role of KVK in technology dissemination needs to be highlighted and made know

School of Crop Protection

- Management strategies for controlling viral, fungal and bacterial diseases of national importance need to be addressed.
- Technologies with respect to the *Trichoderma* and *Chaetomium* based formulations and Nemagel formulation for integrated disease / pest management needs to be demonstrated for the benefit of end users.
- Research studies on fungal / bacterial taxonomy needs further strengthening.
- Large scale field experiments for demonstrating the effect of Pusa Hydrogel on water and nutrient use efficiency in selected crops should be taken up.
- Services of referral lab for pesticide residue evaluation may be extended to large number of users.
- Research studies on entomopathogenic nematodes and biocontrol agents needs to be intensified.
- Strong linkages with private sector is required for viral research related programmes.
- Due emphasis be now given to IPM studies in collaboration with NCIPM.

Post Graduate School Activities

- Capacity building of young students / scientists need to be improved by imparting them advanced trainings in both new and emerging areas of research at the best institutions abroad.
- More sandwitch programmes for higher education needs to be developed in collaboration with CGIAR international centers / institutions and Advance Research Institutes (ARI's) abroad.
- Intake of PhD. students at IARI should be increased compared to the M.Sc. students. Gradually, M.Sc. programme could be phased out and emphasis be laid on post-doctoral programme in specialized fields.
- Post-graduate students research programmes need to be closely linked with the Divisional / Institute research agenda.
- IARI should make efforts in developing modern infrastructural facilities for attracting foreign students for both teaching and research progarmmes. In this context, renovation of hostel buildings, improvement in the IARI library services and construction of the international student's hostel be given high priority.
- The position of Professor in each discipline may be filled through ASRB by direct recruitment for a specified period of five years in first instance or till retirement age as the case may be.

Challenge Programmes

- A technical advisory committee involving peers having broad national/international exposure needs to be constituted for each Challenge Programme.
- Emphasis be given to promote public-private partnership by liaisoning and establishing contacts with the private seed companies in the area of hybrid development of both field and vegetable crops.
- Studies on therapeutic value of the active components/ ingredients present in bitter gourd may be undertaken.
- Technical innovations and approaches for multiplication of good quality seeds in vegetable crops are required. Efforts be made to improve packaging with proper labelling of these hybrid seeds for providing good quality seeds to farmers.
- Work on high temperature tolerance in wheat and rice be given due emphasis in research programmes relating to climate change.
- Aerobic rice may be included in the mitigation/ adaptation studies to climate change.
- Research programmes on conservation agriculture should take into account both water and nutrient management studies as well.
- Studies on the use of biocontrol agents in conservation agriculture and weed management through solarization of soil may be taken up.
- Research related to improved productivity under rainfed agriculture has to be strengthened and given high priority.
- Technologies for aquifer recharge needs to be developed.
- Focused work on integrated water conservation and management is required for the benefit of farming community.

Financial and Administration

- A special recruitment effort through ASRB / ICAR be made to fill up the vacant scientific posts in various disciplines.

- Process of recruitment and assessment of technical staff in the Institute may be speeded up.
- High importance be given for the capacity building of administrative and technical staff at the Institute.

Staff Research Council

Crop Improvement

Division of Genetics

- The Division of Genetics should take lead in the development of short duration varieties of wheat for Central India, keeping in view the changing climatic scenario.
- Breeding for terminal drought resistance in wheat through MAS breeding to be strengthened.
- Hybrid programme in rice, wheat and *Brassica* should be strengthened.
- Research programme pertaining to development of increased resistance to stem borer in *basmati* rice / *Helicoverpa* resistance in wheat and tobacco caterpillar in pulse crops needs to be undertaken.
- Breeding programme for increased nutrient use efficiency in rice to be undertaken.
- Improvement of yield potential in Pusa Basmati 1 and rice hybrids through CMS approach/inter-specific crosses to be given due emphasis.
- Studies on synchronization of flowering in parental lines of rice should be carried out for the development of rice hybrids.
- Screening of heat and drought tolerant traits in wheat for parents/donors to be carried out under controlled conditions using phytotron facility.
- Studies on the environmental impact on grain protein content in wheat may be undertaken.
- Early growth resistance in wheat in addition to adult plant resistance (APR) needs to be studied.
- Genetic enhancement of yield in cotton and screening of cotton germplasm for important traits and high yield to be taken up.
- Research work on *Fusarium* wilt / root rot resistance in chickpea and hybridization programme for drought tolerance to be strengthened.
- Short duration mungbean varieties with minimal water requirement and less shattering need to be developed.
- Efforts should be made to broaden the genetic base in chickpea and also to develop pure inbred lines in order to obtain uniform hybrids with respect to various characters.
- Work in water logging tolerance in pigeonpea may be taken up in future research programmes.
- Mapping populations for different characters related to productivity and abiotic stress tolerance in pearl millet needs to be developed. Genetics for iron and zinc content in pearl millet may be worked out.
- Biotechnological approaches for increasing resistance to *Alternaria* blight / aphids in *Brassica* may be given due emphasis.
- Photo-thermosensitivity of soybean may be exploited for developing varieties for summer planting.
- Research work on molecular breeding and introgression of genes for BLB resistance in rice and rust resistance in wheat to be strengthened and pursued with full vigour.
- Due emphasis should be laid on heterosis breeding in cereals and pulses.
- A reliable system for screening for drought tolerance in segregating plant populations may be developed.
- Profitability and input use efficiency should form an integral component of all the in-house projects of the Division.

Division of Vegetable Science

- Breeding programme in temperate vegetable crops (cabbage, cauliflower, beetroot, and carrot) may be further strengthened with PGR augmentation.
- Development of inbred lines of temperate vegetable crops may be taken up on priority
- Research programmes on short-duration leguminous vegetables in periurban areas may be taken up by theDivision.
- Characterization of germplasm and development of superior varieties of exotic vegetables (red capsicum, European carrot, broccoli) to be given due emphasis.
- Breeding programmes for varieties having high nutritive value (high lycopene / β-carotene content) and tolerant to biotic stresses (diseases/nematodes/bacteria) may be taken up in near future.
- Efforts should be made to develop tropical parthenocarpic gynoceious lines in cucumber.

- In cauliflower, early / mid early / late CMS based hybrids needs to be developed.
- Focused research programme on leafy vegetables/ Capsicum/pumpkin along with vegetables based cropping systems may be undertaken by the Division.
- Hybrid seed production and a comparative evaluation of vegetable hybrids developed by the Division with respect to the performance and improved traits needs to be made along with the promising hybrids of private sector.
- Hybrid seed production of vegetables to be taken up on large scale to meet the requirement of the farmers.
- MAS/transformation of vegetable crops for improved traits to be given due emphasis.
- Major thrust on commercialization of CMS based hybrids of carrot, cauliflower, onion and cabbage required in collaboration with the Regional Station, Katrain.
- Public private partnership to be strengthened for commercialization of technologies of vegetable varieties/hybrid seeds.

Division of Fruits and Horticultural Technology

- The Division of Fruits and Horticultural Technology should focus on both basic and applied research with respect to varietal development in fruits.
- Survey and identification/selection of elite clones of mango/citrus/guava/kinnow to be taken up on priority.
- Mango hybrids developed by the Division should be evaluated and tested at AICRP multi-location testing and farmer's field before release by Delhi State Varietal Release Committee.
- Studies on pest and disease management (fruit fly/ hoppers/mango malformation) may be given due emphasis in mango hybridization programmes.
- Clonal selection programme of citrus/guava/kinnow needs immediate attention.
- Multiplication of planting material of the improved mango hybrids should be undertaken on larger scale by the Division.
- A holistic grape breeding programme, production technology package needs to be developed to meet the demand of grape growers in Northern India.
- Efforts should be made to identify early maturing, juice yielding and seedless grape varieties in the grape breeding programmes.
- Focused research work on grapefruit/sweet orange/ kinnow required.
- Research programme on identification of dwarf and salt tolerant rootstocks in citrus may be strengthened. New polyembryonic rootstocks tolerant to salt may be tried.
- Work on grapefruit germplasm collection and evaluation should be intensified.
- Package of practices developed by the Division for controlling mango malformation needs to be tested and status report prepared before arriving at meaningful conclusions.
- Work on guava wilt may be reviewed for developing future line of action.
- Chemicals which can trigger flowering mechanism in mango may be tried in order to complete flowering process in short time and thus achieving control over mango malformation.
- Clonal selection in mango (for increased fruit size, red peel and round fruit shape) and in guava (for dwarf tree stature and better nutritive value) to be taken up in future research programmes.
- Development and identification of markers for resistance to mango malformation to be given due emphasis.
- Prime importance may be given to breeding of early maturing grape varieties for table/juice/wine making purpose. Molecular markers for resistance to downy mildew in grape also needs to be identified.
- Research programmes on the selection of summer maturing, seedless and high yielding lime and lemon varieties may be taken up.
- Plant architecture and planting density in the newly released mango varieties needs to be standardized.
- *In planta* transformation especially of the horticultural crops may be undertaken in future research programmes.

Division of Floriculture and Landscaping

- Research work on white coloured varieties of *Chrysanthemum* for loose flower production may be taken up.

- More systematic efforts on rose crop required.
- Collection and evaluation of *Gladiolus* germplasm along with development of new hybrids may be given due emphasis.
- Production technology of minor cut flowers (*Antirrhinum*, *Clandula* and Sweet William) needs to be standardized.
- Research work pertaining to xanthophyll extraction in marigold may be carried out in the Division.
- Prime importance needs to be given to value addition of flowers.
- Research studies on mutation breeding in various flower crops required.

Division of Post Harvest Technology

- Technologies developed by the Division needs to be commercialized.
- Focused research work on high value temperate fruits (apple/kiwi/kinnow/grapes) required.
- Research work pertaining to browning of litchi to be strengthened.
- The Division should lay emphasis on post harvest handling of flowers (roses, gladiolus, and carnation) in collaboration with the Division of Floriculture and Landscaping.
- Packaging of dried ripe tomato powder/*aonla* segments may be improvised and promoted on a small scale.
- Few crops needs to be targeted with respect to processing, packaging and commercialization with high priority.
- Product development in mango having commercial and export value may be given prime importance.
- Strawberry (var. *Chandler*) may be included in the future research programmes of the Division.
- Efforts should be made to undertake research work on soybean, pearlmillet and fortified wheat to tackle the problem of malnutrition.
- Novel Pusa products developed by the division needs to be promoted and commercialized on a large scale.
- Emphasis should be given for the development of various Pusa products.

Division of Seed Science and Technology

- Scientific publications needs to be brought out on the extensive work done on hybrid seed production technology in tomato in the Division.
- Collaboration with Regional Station, Katrain required for undertaking work on cauliflower seed production.
- Molecular characterization of the popular IARI varieties for DUS testing may be taken up by the Division.
- Efforts should be made to strengthen hybrid development and seed production in wheat. Purification and seed maintenance of extant varieties to be taken up on priority.
- Economics for alternatives of grow-out tests needs to be worked out.
- Training programme on seed processing to be undertaken in collaboration with Regional Station, Karnal.
- Papaya seed production programme may be strengthened and monitored at the Regional Stations, Indore, Karnal and Pusa, Bihar.
- The Division should lay emphasis on creating better seed processing and storage facilities and improving the packaging of IARI seeds for further use.
- Farmers' participatory seed and planting material production should be taken up in the nearby areas of NCR.
- Technical bulletins on hybrid seed production of tomato/ brinjal/cauliflower needs to be published for the benefit of farmers and industries.

Regional Station, Amartara Cottage, Shimla (Cereals and Horticultural Crops)

- Technology for staggering Kiwi fruit harvest needs to be developed to ensure timely availability in the market.
- Mass multiplication of the promising apple fruit hybrids and simultaneous testing in KVK farm required before release by State Varietal Release Committee.
- Multiplication of all the released wheat and barley varieties to be taken up in a big way to ensure sufficient supply of the seeds to the farmers.
- Release of *Malus baccata* Shillong to be taken up on priority for commercial cultivation.

Seed Production Unit

- Seed production, processing, packaging and storage needs significant improvement.
- Collaboration with plant breeders required for maintenance breeding and nucleus / breeder seed production.
- Major thrust in vegetable seed production required.
- Practical training in the area of seed production and certification may be given. Due emphasis should also be given to field inspections.
- Seed production programme of all the important field crops of the Institute to be further strengthened.

Centre for Protected Cultivation Technology

- Low cost protected cultivation technologies to be worked out for the benefit of the farmers including vegetables and flower crops.
- Large number of flower crops needs to be tested and evaluated in the polyhouse for year round production.
- The Centre should take lead in commercialization of the technologies (shade net/polyhouse/greenhouse) developed.
- Collaboration with the Divisions of Post harvest Technology and Plant Physiology required.
- Possibility of designing and establishing a rain harvesting system may be explored.

School of Natural Resource Management

Division of Agronomy

- The Division of Agronomy should take lead in undertaking cutting edge agronomic research beyond realms of sustainability.
- Scope of organic farming in context of country's food security needs to be relooked into.
- Integrated Production Technology based on ICM needs to be emphasized.
- Focused research studies on rice-wheat- mungbean cropping system and also other pulse based cropping systems to be taken up on priority.
- The Division should undertake research programmes on coarse cereals.
- Studies with respect to the effect of climate change on sustainable food production and food security to be given due emphasis.
- More comprehensive and long-term experiments are required on zero tillage to draw valid conclusions.
- Prime importance need to be given to conservation agriculture and farming system research for livelihood and profitability of small farm holdings.
- Integrated approach for weed management in crop production needs to be followed, rather than promoting herbicides.
- Studies pertaining to the mode of application of fertilizers in the raised bed system to be undertaken.
- Collaborative research with the Divisions of Plant Physiology, Environmental Sciences, Genetics, and WTC required.
- The Division should undertake need based research taking into consideration the problems faced by the farmers in the fields.
- Project on soil fertility to be taken up in collaboration with the Division of SS&AC.
- Fertigation and drip irrigation may be used in agronomic experiments in crops like maize, cotton and soybean on a large scale.
- Due emphasis needs to be given to conservation agriculture in the proposed research programmes undertaken by the Division.
- Recycling of crop residues and solid waste management at IARI campus to be taken up on priority.

Water Technology Centre

- Relevance, applicability and economics of runoff modeling needs to be looked into.
- Assessment of the water resources, efficient water management, roof top water harvesting and treatment of municipal waste water at IARI needs to be addressed by the Centre on priority.
- Studies on climate change needs to be correlated with crop yield on a long-term basis.
- Demonstration and dissemination of microirrigation technology to be taken up on large scale for the benefit of the farmers. Cost benefit analysis of the technology to be worked out.
- Work on water use efficiency and precision farming technology to be strengthened by the Centre.

- Possibility of designing rain water harvesting reservoirs for rain water reuse and conservation may be explored.
- Benefits accruing from the sophisticated techniques used in watershed studies needs to be demonstrated.
- Relevance of the experiments comparing rainfed and irrigated system may be looked into.
- A holistic comparison of the studies on the use of sewage water for growing crops with and without drip needs to be made.
- Training on watershed management may be extended to policy makers.

Division of Soil Science and Agricultural Chemistry

- The Division of Soil Science and Agricultural Chemistry should focus on multidisciplinary research programmes. Linkages with the Divisions of Genetics, Agronomy and Environmental Sciences are desirable.
- Research work related to carbon sequestration, nanotechnology, soil fertility, fertilizer use efficiency and nutrient management under elevated CO_2 conditions needs to be strengthened and demonstrated on an operational research scale.
- Basic research work on humus chemistry, soil genesis and clay mineralogy requires immediate attention.
- The Division should lay emphasis on the work pertaining to soil health and soil biotechnology.
- Integrated nutrient management practices and water management for different cropping systems may be worked out.
- Field studies with respect to both integrated nutrient and water management needed.
- Investigations on carbon sequestration for monocrop rainfed systems needs to be undertaken.
- Good soil quality indexes for improving soil quality to be developed. The Division should undertake research studies on GM crops affecting soil health, if any.
- Focussed research on organic carbon sequestration required.
- Crop based systems for green manuring purpose may also be studied.

Division of Environmental Sciences

- Studies on survey and useful utilization of biomass waste to be given due emphasis.
- Research programme on the impact of global rising temperature levels on food production may be undertaken by the Division. Identification of suitable cultivars / management practices for high temperature stress environment to be taken up on priority.
- Problem of waste water management to be addressed in collaboration with the WTC.
- Research work on the impact of climate change on soil fertility, nutrient and water balance in major crops to be given prime importance.
- Remedial measures for utilization of agrowaste management to be worked out.
- Demonstration plants to be revived for solid state fermentation technology.
- Practical knowledge of burning of rice husk and producer gas needed before undertaking experiments on application of value added products from biomass waste.
- Cost effectiveness of reducing the greenhouse gas emissions by mitigation strategies may be worked out.
- Studies on carbon sequestration to be pursued, strengthened and propagated.

Unit for Simulation and Informatics

- Unified information database system with respect to different crops to be created.
- The Unit should take lead in the research studies pertaining to bioinformatics.
- Possibility of uploading the technologies developed by the Institute in Hindi, and information on education and the IARI Alumni on the website may be explored.
- Research work on yield estimations of agricultural crops/simulation modeling may be strengthened in collaboration with the Division of Agricultural Physics, and IASRI.
- Collection of the meaningful algal, fungal, bacterial, insecticidal and nematodes collection may be put on the IARI website for public use.

Division of Agricultural Physics

- Input use efficiency of water and nutrients in relation to soil physical environment and tillage, etc. should be worked out.
- Lot of work needed on soil and plant stress indicators based on interacting effects of soil and environmental parameters.
- Validation of the soil quality indices developed should be attempted at different locations.
- Practical utility of the maps prepared on drought vulnerability should be highlighted.
- In-depth studies on the effect of hydrogel on the hydro-physical properties of soil need to be conducted. Suitability, economics and mode of application of hydrogel may also be worked out.
- Efforts should be made to find out the cause and effect relationship of the magnetic treatment of seeds. Changes in chemical composition / metabolic activity / hydrolytic conductivity of seeds in relation to magnetic treatment should be studied.
- Hyperspectral indices which can accurately differentiate disease susceptibility and tolerance of varieties may be developed.
- Models predicting the impact of climate change in relation to crop productivity must be validated at different locations.
- Impact of Agromet advisory services should be assessed.
- Studies on carbon sequestration to be given high priority.
- Research studies on enhancing the water retention capacity in soils may be taken up.
- Soil physical characteristics and nitrogen-phosphorus use efficiency in rice-wheat system to be evaluated.
- Remedial measures for soil pests/diseases in series of cropping patterns using remote sensing may be worked out.

Division of Agricultural Engineering

- Modernization and commercialization of the farm machinery/implements developed by the Division to be taken up on priority.
- Work on chaffcutter, harvesters/seeders and extruded food products should be strengthened and commercialized.
- An agro-processing centre needs to be established in KVK, Shikohpur.
- Modification of the design of garlic planter and carrot harvester desired for commercialization.
- Intensified work on solar energy utilization required.
- The Division should focus on the development of precision drills / planters and also on special implements useful under drought.
- Evaluation of greenhouses / polyhouses existing in CPCT may be taken up for further improvements.
- Efficient manual machines for harvesting rice and sugarcane crops may be developed.
- Research studies on the utilization of crop residues for conservation farming to be taken up.
- Efforts should be made to develop a zero tillage machine for irrigated and rainfed agriculture.

Division of Microbiology

- Focussed research on soil microbial diversity required.
- Studies on organic matter decomposition for improving yield of composting may be undertaken by the Division.
- Efforts should be made to improve and maintain the quality of bio-fertilizers. The Production Unit of bio-fertilizers to be strengthened.
- Research work on organic farming needs to be documented and popularized.
- Role of organic fertilizers in the nutrient availability in the soil and also on the crop growth and yield needs to be studied.
- The Division should pursue work on biofilms with more vigour in the near future.
- Studies on the utilization of excess CO_2 and methane by algal and *Azolla* in rice fields may be carried out.
- Efforts should be made to study the effect of high temperature on the microbes in the rainfed areas, under the changing climatic scenario.
- Focussed research on integrated nutrient management required for enhancing the availability of nutrients in the soil.
- Due emphasis should be given to look into the germplasm diversity in the north-east and hilly regions having acidic soils.

- *Azolla* wash having insecticidal and growth promoting properties may be developed.

School of Crop Protection

Division of Plant Pathology

- Integration of basic research with the modern molecular biology approaches is required to address some of the emerging challenges in plant diseases.
- Studies on the impact of climate change on plant diseases may be given due emphasis.
- Emphasis to be given to epidemiology, disease forecasting and monitoring.
- Bioformulation of Kalisena, *Chaetomium*, and *Trichoderma* sp. needs to be demonstrated and commercialized further.
- Bigger repository of rice blast isolates needed.
- IPM modules for different diseases may be developed.
- Research work on Tungru virus in rice to be strengthened.
- Work on mango malformation may be carried out in collaboration with the Division of Fruits and Horticultural Technology.
- Focused research in Chirke and Foorkey diseases required in collaboration with IARI Regional Station, Kalimpong.
- Biosafety aspects of pathogens may be emphasized, keeping in view tremendous movement of plant pathogens beyond boundaries.
- Focused research programmes on diseases of national importance may be taken up.
- Infectious clones of RNA viruses need to be identified.
- Concerted efforts for transformation of papaya for PRSV resistance required.
- The Division may be strengthened with more taxonomists.

Regional Station, Kalimpong

- The Regional Station, Kalimpong needs to be strengthened with a virologist for undertaking work on diagnostics of viruses.
- The Station should concentrate on producing high quality disease free planting materials for the benefit of farmers.

Regional Station, Pune

- The Regional Station, Pune should concentrate on producing high quality disease free planting materials for the benefit of farmers.

Division of Nematology

- Studies on the management of root knot nematode infection to be given top priority.
- Survey for important key nematode pests should be carried out in association with SAUs.
- Technologies developed by the Division should be demonstrated on the large scale through collaboration with other Institutes or through coordinated projects for the benefit of end users.
- Strategies for eliminating seed borne nematodes (e.g. radiation treatment) to be developed for increasing export potential of crops in bulk consignments.
- Nematodes collected from different places should be deposited in NNC as slides or wet collections.
- Package of practices involving combination of treatments (Botanical antagonistists / neem cake / oil cake/*Trichoderma viridi* / *Pseudomonas fluoroscens,* etc.) needs to be developed for integrated nematode management in polyhouses in collaboration with CPCT.
- Corrective measures for the control of *M. graminicola* at nursery level needs to be taken in rice-wheat cropping system to avoid further nematode infection.
- EPN has great potential in nematode control and its technique for mass production should be patented.
- Mass multiplication of bioagents involved in the control of termites at the IARI fields to be taken up on priority.
- Research work on Nemagel technology needs to be demonstrated on a large scale and popularised for the benefit of farmers.
- Studies on carbofuran nanoformulations for nematode management to be pursued with full vigour in collaboration with the Divisions of Agricultural Chemicals and Plant Pathology.
- Dual constructs for nematode and viral resistance genes needs to be prepared for tomato transformation with the help of a plant pathologist.

Division of Entomology

- Work on bollworm resistance to *Cry1Ac* be undertaken in collaboration with CICR under TMC to avoid duplicacy of research work.
- Good insect rearing facilities to be developed by the Division. Biology of pink bollworm needs to be studied.
- Research studies on the baseline susceptibility of insecticides against sucking pests to be carried out.
- Controlled IPM strategies for different crops to be worked out in collaboration with NCIPM.
- Due emphasis needs to be given on studies pertaining to termite queen management.
- Status paper on neem based formulation required in collaboration with the Division of Agricultural Chemicals.
- Research work on storage insect pests needs to be given due emphasis. Efforts should also be made to develop suitable structures for storing seeds/ grains.

Division of Agricultural Chemicals

- Research programmes on screening of plants for active molecules to be undertaken in collaboration with other Institutes.
- Practical applicability of water formulation products need to be commercialized for the benefit of the farmers.
- Work on development of new synthetic / plant based pesticides and safety aspects of pesticide residues may be further pursued and strengthened.
- Identification of metabolites in the pesticide residue studies need to be carried out.
- The Division should take lead in carrying out research on the isolation of microbes for bioremediation in collaboration with NRCPB.
- Interaction with plant pathologists, nematologists and entomologists needed for undertaking work on bioassay testing of different compounds.
- Multilocational experiments needed for fixing MRL values of different pesticides; and therefore may not be recommended on the basis of single experiment.
- Concerted efforts on the development of fewer pesticides, nitrification inhibiters and controlled formulations required.
- Emphasis should be laid on commercialization of the biopesticides developed by the Division.

NCIPM

- Data generated with respect to monitoring of pests / diseases needs to be shared with other plant protection divisions of the Institute to avoid duplication of work.
- Biotic stress maps may be developed for parasitoids.

School of Basic Sciences

National Research Centre on Plant Biotechnology

- The research work being carried out by the Centre needs to be extended for the benefit of end user.
- Efforts should be made to undertake applied research aimed at product development.
- The Centre should lay emphasis in linking molecular biology with biotechnological work.
- Basic research on heterosis requires further strengthening.
- More patents needs to be filed by the Centre on the original research findings of commercial value.
- For research studies pertaining to expression of senescence associated genes, *Brassica* may be taken up as an alternative system to *Arabidopsis* for transformation purpose.

Division of Biochemistry

- Applied and problem solving studies aimed at benefiting the farmers to be given due priority.
- The Division should lay focus on identification of heat tolerant wheat varieties in view of the changing climatic scenario. Effect of elicitors / chemicals for enhancing heat tolerance in wheat may be taken up.
- Focussed biochemical and molecular work related to the elimination of off flavour during storage in the commercial soybean varieties required.
- Important antioxidant enzymes, apart from SOD to be studied while undertaking research on salinity tolerance in wheat.
- Research programmes on the genetic transformation of wheat for enhanced tolerance to abiotic stress may be taken up.
- Research linkages with other disciplines e.g. Genetics, Plant Pathology, Entomology, Horticulture, etc. required for undertaking high quality need based research.
- Studies on heat tolerance in wheat should take into account other heat shock proteins apart from HSP 20.

- Practical aspects of off flavour in soybean needs to be studied for soybean quality improvement programme.

Division of Plant Physiology

- Basic and problem solving research aimed at product development needs to be carried out by the Division.
- Technologies developed by the Division, specially in the area of Post Harvest Technology to be commercialized at the earliest for the benefit of end user.
- Research studies aimed at improving thermo tolerance in wheat in response to elevated temperatures to be taken up on priority.
- Efforts should be made to understand the underlying biochemical and molecular mechanism for the effect of gamma radiation on post harvest storability and grain / seed development in wheat/chickpea.
- Adaptation/mitigation strategies to climate change (high CO_2/high temperature) may be given due emphasis.
- Studies pertaining to iron and zinc enrichment in wheat to be carried out in collaboration with the Division of Genetics.
- Focussed research in the area of drought resistance, plant hormones and mineral nutrition needed with the required facilities.
- Emphasis needs to be given to carbon sequestration studies in rhizosphare/biosphere by integrating with the Division of Soil Science and Agricultural Chemistry.
- Physiological/biochemical/molecular markers associated with salinity stress need to be identified.
- Research studies with respect to the phosphate transporters may be taken up.
- Studies on improving thermal tolerance in wheat to be taken up on priority in collaboration with the Division of Genetics and NRCPB.
- Adaptation and mitigation strategies with respect to climate change (high CO_2 and high temperature) be given due emphasis.

Nuclear Research Laboratory

- Studies on the effect of magnetic treatment on seed storability of field crops should lay emphasis on some basic research with respect to seed structure, seed behaviour and its relationship with crop yield.
- The NRL should focus on developing strategies for conserving rainwater for ground water recharging. The possibility of designing rainwater reservoirs for the purpose may be explored.
- Reliability of the data generated using the mobile handset for estimating nitrogen status of plants may be looked into for making it more user friendly.

School of Social Sciences

Division of Agricultural Economics

- Research studies on energy use in modernization of agriculture to be strengthened.
- Both primary and secondary data needs to be generated for most of the research projects being under taken by the Division.
- Collaboration of extension scientists needed while conducting studies on marketing.
- Studies on allied agricultural activities (livestock/ fishers) need immediate attention.
- Research programmes aimed at expanding the non-farm sector may be taken up and status paper be prepared.
- Focussed work on the policy changes in the area of fertilizer consumption and water conservation required.
- A realistic comparison of the kisan credit cards issued by various banks/companies be made for the benefit of the farmers.
- Research linkages with Delhi School of Economics/ NCAP/IASRI/state universities needed.
- The Division should take lead in research planning, prioritizing, monitoring and impact assessment of the technologies developed by the Institute.
- Methodological innovations in agricultural economics research are needed.
- Biological research in collaboration with biologist to be incorporated with the research studies in agricultural economics for impact assessment studies.
- Market reforms to improve quality of produce for commercialization of technologies needs to be looked into.
- Studies on credit linked marketing, rural non-farm sector, skill development and rural entrepreneurship to be given due emphasis.
- Research programmes for enhancing the energy productivity need to be addressed.

Division of Agricultural Extension

- Thrust on extension education, skill development, entrepreneurship and vocational training required.
- Issues of national importance, e.g., climate change and nutritional security may addressed.
- Cyber-extension model for dissemination of agricultural technologies to the farmers needs to be further strengthened. Group of farmers (400-500) may be selected and be trained for the purpose.
- Models for demonstrating farming systems to large/ marginal farmers may be developed. Extension models developed by the Division needs to be given to CATAT for further dissemination of technologies.
- Extension programmes aimed at building model farms in farming systems mode to be emphasized.
- Multilocation trials/demonstrations of IARI technologies need to be undertaken at different sites in order to arrive at meaningful conclusions.
- Possibility of open distance learning for transferring agriculture related information may be explored.
- Adoption of a block for dissemination of agricultural technologies may be taken up on priority.
- Linkages with SAUs and ICAR institutes are required for collaborative research programmes.
- Innovative credit delivery system to be strengthened for income generation and ensuring timely availability to the farmers.
- Possibility of fitting pulses in rice-wheat system may be explored. Economics of such a system also needs to be worked out for the benefit of the farmers.
- Peri-urban agriculture in the NCR region needs to be strengthened and popularized.
- Mechanisms for collecting authentic data from the field may be developed for improving the quality of research experiments. More field visits are required for this purpose by extension scientists.
- Effective models for dissemination of technology need to be developed and demonstrated.

CATAT and ATIC

- Studies on the impact assessment of IARI technologies need to be taken up by the Centre.
- Efforts should be made to popularize the Pusa varieties of field crops.
- A booklet comprising of the success stories of the farmers who have adopted Pusa technologies be published.
- Minimum of three visits to the selected experimental sites at the farmer's field demonstration needs to be made to arrive at meaningful research data and observations.
- Refinement, assessment and upscaling of technologies for commercialization to be given due emphasis in future.
- Models for diversification of agriculture may be developed in collaboration with the Divisions of Agricultural Extension and Agricultural Economics on priority.
- Weekly bulletin on weather forecasting and farming may be published in collaboration with the Division of Agricultural Physics for the benefit of the farmers.

KVK, Shikohpur

- Soil testing analysis data needs to be reported for arriving at meaningful conclusions in the executed experiments.
- E-connectivity facility and on-line reporting of data to be strengthened.

V. Resource generation

1) Consultancy & other services

Consultancy services	₹ 263120
Contract research	₹ 905103
Contract service	₹ 361210
Training	₹ 137630
Total (A)	**₹ 1667063**

2) Revolving fund	**Sale Proceeds Revenue Generated**
(a) Seed	₹ 14346868
(b) Commercialization	₹ 2165279
(c) Prototype manufacturing	₹ 4133478
Total (B)	**₹ 20645625**

3) Post Graduate School receipt

Training Programme

(a) Foreigners & Indians	₹ 86630

M.Sc./Ph.D Programme	
(b) Institutional economic fee from foreign scholars under Work Plan	₹ 4250905 + US$ 9600
(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.	₹ 1867843
(d) Cash transferred from Syndicate Bank to Director's Account No. C-49(9029.305.17) from sale of information bulletin	₹ 667550
(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)	₹ 154335
Total (C)	**₹ 7027263 + US$ 9600**
Grand Total (A+B+C)	**₹ 29339951 + US$ 9600**

VI. Infrastructural Development

- A Memorandum of Understanding (MoU) between the IARI and the University of Agricultural Sciences, Dharwad signed for 10 acres of agricultural land for 50 years to streamline the research activities of the IARI Centre at Dharwad, Karnataka. Irrigation facility developed at the IARI Centre, compound wall (front) with security cabin and main gate constructed on the 10 acres of newly leased land.
- Development of the Lecture Hall with false roofing and smart classroom aids like Electronic team board, Ultra short throw projector and visualizer at Division of Floriculture and Landscaping.
- Renovation of committee room, net house, 13 rooms and labs, roof water sealing treatment of main building at the Division of Agronomy.
- Water harvesting reservoir of 1500m^3capacity, 1.5 acre area under low pressure drip system, modern nursery 500m^2, net house 1000m^2 and farm lab were developed at the farm of CPCT.
- Constructed new irrigation channels and farm development, procured general purposed combine, four tractors, two laser levelers at FOSU.
- The Division of Microbiology has been renovated. All the laboratories, lecture hall, committee room and administrative office were renovated. A new biofertilizer unit was set up in the division with the facility of mass production of bacterial biofertilizers. A unit was developed for the mass production of compost inoculants.
- At the Division of Agricultural Chemicals, state-of-the-art modern wet laboratory for botanical and biopesticides, nutraceuticals, functional foods and other bioactive natural products was developed and put to use. State-of-the-art modern analytical laboratory was also developed.
- Five laboratories, divisional auditorium, and divisional corridors were renovated at the Division of Biochemistry.
- Renovation of nine laboratories, class room, corridors and change of false ceilings and procurement of several modern equipments at the Division of Plant Physiology.

VII. All India Coordinated Research Projects in Operation during the year April 1, 2010 to March 31, 2011

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 Tillage Requirements of Major Indian Soils for Different Cropping Systems
5. All India Coordinated Research Project on Floriculture Improvement
6. All India Coordinated Research Project on Renewable Energy Sources for Agriculture and Agro-based Industries
7. All India Coordinated Research Project on Honey Bees
8. All India Coordinated Research Project on Biological Control of Crop Pests
9. All India Coordinated Research Project on Soybean
10. All India Coordinated Research Project on Sub-Tropical Fruits

VIII. Foreign Visitors during April 1, 2010 to March 31, 2011

S. No.	Visitor (s)	Month
1.	A 13- member delegation from RNR Research & Development Centre, Deptt. of Livestock, Ministry of Agriculture & Forest, Bumthang, BHUTAN	April, 2010
2.	An 11-member delegation from NARC, Ministry of Agril. and Cooperation, NEPAL	April, 2010
3.	A high level 12- member delegation headed by H.E. Mr. Vu Quang, Ambassador alongwith Vietnamese Officials, VIETNAM	May, 2010
4.	A high level delegation led by Mr. Jebogo Mtome, Chief Executive Officer and Board of Director for local Enterprise Authority (LEA), BOTSWANA	May, 2010
5.	A 15- member delegation of student's alongwith 3 Faculty Members from Deptt. of Agricultural Science, Kansas State University, Manhattan, Kansas, USA	May, 2010
6.	H.E. Mr. Tian Chengping, Vice-President, China Central Rural Work Leading Group, CHINA	May, 2010
7.	Mr. Anil Thayuman, Director, Bio-Central Laboratory Ltd., AUSTRALIA	June, 2010
8.	Mr. Kum Dong Woo, Dy. Director, Food Gvain Management Department Overseas Market Analysis Team, KOREA	June, 2010
9.	An 11- member delegation from UKRAINE	June, 2010
10.	Mr. Mehdi Ekar, Minister of Agriculture & Rural Affairs, TURKEY	June, 2010
11.	A 3- member delegation from Bangladesh led by Dr. Wasis Kabir, Executive Chairman, Bangladesh Agricultural Research Council, BANGLADESH	June, 2010
12.	A 10- member delegation from United Kingdom	July, 2010
13.	A 10- member delegation from Vietnam led by Dr. Bui Ba Bong, Deputy Minister, Ministry of Agriculture and Rural Development, Socialist Republic of VIETNAM.	August, 2010
14.	A 4- member delegation from BRAZIL	September, 2010
15.	A 10- member delegation from China led by Mr. Zhang Laiwu, Vice-Minister, Ministry of Science and Technology, (MOST) CHINA	September, 2010
16.	H.E. Mr. Amandio Emilio Guebuza, President of Mozambique, MOZAMBIQUE	October, 2010
17.	A group of 50- participant from six Sub- Saharan African Counties	November, 2010
18.	A 2- member delegation, viz., Dr. Steve Visscher, Deputy Chief Executive and Chief Operating Officer and Dr. Brian Harris, Head of Agriculture, Food and Energy Research Group from the Bio-Technology and Biological Sciences Research Council (BBSR), UK	November, 2010

19.	A group of 22 African Scientists from Eastern and Southern African under South-South Collaboration in the area of Integrated Water-shed Management under work plan between ICAR-ASARECA	November, 2010
20.	A group of Trainers attending Training Programme of Fertilizer Quality Control for Foreign Participants at Central Fertilizer Quality Control & Training Institute, NH IV, FARIDABAD	November, 2010
21.	Mr. Eduardo Sampio Marques, Director of International, Department of Agribusiness of the Brazilian Ministry of Agriculture, Livestock, and Food supply- MAPA, BRAZIL	December, 2010
22.	A group of 32 participants from African, Asian and Latin American Countries	December, 2010
23.	A delegation of 7 Faculty Members of University of Illinois, USA	January, 2011
24.	Dr. Torsten Rodel Berg, Coordinator for International Research, Faculty of Agricultural Sciences, Arhus University, DENMARK	January, 2011
25.	A 3-member delegation led by Dr. Rose Manglona,Director, Northern Marianas Colleges, USA	January, 2011
26.	A 5-member delegation of Livestock Research Group, National Agriculture Research System, ETHIOPIA	January, 2011
27.	A group of 40- member foreign delegation from the Member ASEAN Countries and ASEAN Secretariat attended 1st Meeting of the ASEAN- India Working Group on Agriculture at New Delhi	January, 2011
28.	A 4-member delegation from Chinese Academy of Agricultural Sciences, CHINA	February, 2011
29.	His Excellence, Mr. Ghani Ghuriani,Dy. Minister of Technical Affairs, Ministry of Agriculture, Irrigation and Livestock (MAIL), AFGHANISTAN	February, 2011
30.	A 12-member delegation from FAO, AFGHANISTAN	March, 2011
31.	Prof. Hu Hong Dy. Div. General of Vegetable & Flowers, and Prof. Li Xi Xiang, Head, Deptt. of Vegetable Germplasm Resources, Institute of Vegetable and Flowers, Chinese Academy of Agricultural Sciences (CAAS), CHINA	March, 2011
32.	Her Royal Highness Princess Maha Chakri Sirindhorn of Thailand and other delegates	March, 2011
33.	A 5-member delegation for Afghan Women's Business Council, AFGHANISTAN	March, 2011

His Excellency Mr. Amandio Emilio Guebuza, President of Mozambique (Right) being welcomed at IARI by Dr. H.S. Gupta, Director, IARI

Appendix 1
Members of Board of Management of IARI
(As on 31.03.2011)

Chairman

1. Dr. H.S. Gupta
   Director, IARI

Members

2. Dr. H.S. Gaur
   Dean & Joint Director
   (Education), IARI
3. Dr. Malavika Dadlani
   Joint Director (Research), IARI
4. Dr. K. Vijayaraghvan
   Joint Director (Extention), IARI
5. Dr. Gurbachan Singh
   Agril. Commissioner,
   Deptt. of Agril. and
   Cooperation, Min. of Agril.
   Krishi Bhawan, New Delhi
6. Financial Advisor
   ICAR, Krishi Bhawan,
   New Delhi
7. Development Commissioner
   Delhi Administration
   Govt. of NCT of Delhi,
   5/9 Under Hill Road,
   Delhi-54
8. Shri Subhash Bapurao Patil
   (up to 02-02-2011)
   Post PALSA
   Taluka Hadgaon, Distt. Nanded,
   Maharastra
9. Shri Bipin Shankar Rao Kohle
   (up to 02-02-2011)
   Chairman, Sanjivani Sugar Factory
   At post Kopargaon,
   Distt. Ahmadnagar.

Member-Secretary

10. Sh. B.N. Rao
    Registrar & Joint Director (Admn.)
    IARI

Appendix 2

Members of Research Advisory Committee of IARI

(As on 31.03.2011)

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 (MPUAT)
   71, Gokul Nager,
   Udaipur-313001
   (Rajasthan)

4. Prof. A.N. Mukhopadhyay
   Sangini, 151 Akanksha
   Udhyan II, Raibareilly Road
   Lucknow -226025, UP

5. Dr. R.K. Pathak
   Vice Chairman,
   Manas Rural Development Institute
   304, Sunflower Tower,
   Parvati Bhawan,
   Kharkar Ali Lane
   Thane West 400601

6. Dr. H.S. Gupta
   Director,
   IARI, New Delhi

7. Dr. Ram Prakash Dua
   Asstt. Director General (FFC)
   Indian Council of Agricultural
   Research, Krishi Bhawan,
   New Delhi

Two non official members of Board of Management (up to 02-02-2011)

8. Shri Subhash Bapurao Patil,
   Post PALSA
   Taluka Hadgaon, Distt. Nanded,
   Maharastra

9. Shri Bipin Shankar Rao Kohle,
   Chairman, Sanjivani Sugar Factory
   At post Kopargaon,
   Distt. Ahmadnagar.

Member-Secretary

10. Dr. Malavika Dadlani
    Joint Director (Research)
    IARI, New Delhi

Appendix 3
Members of Academic Council of IARI
(As on 31.03.2011)

Chairman

1. Dr. H.S. Gupta
   Director, IARI

Vice-Chairman

2. Dr. H.S. Gaur
   Dean & Jt. Director (Education)
   IARI

Members

3. Dr. Arvind Kumar
   Dy. Director General (Edn.)
   ICAR
4. Dr. K.C. Bansal
   Director, NBPGR, New Delhi
5. Dr. V.K. Bhatia
   Director, IASRI, New Delhi
6. Dr. P.A. Kumar
   Director, NRC on Plant
   Biotechnology, New Delhi
7. Dr.(Ms.) Malavika Dadlani
   Jt. Director (Research), IARI
8. Dr. K. Vijayaragavan
   Jt. 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. Prof. A.K. Tyagi
    Director
    National Institute of Plant
    Genome Research
    Aruna Asaf Ali Marg,
    P.O. Box No. 10531
    New Delhi -110 067
12. Dr. U.S. Singh
    STRASA Coordinator
    IRRI, Indian Liaison Office,
    NASC Complex, DPS Marg
    New Delhi-110012
13. Dr. R Sai Kumar
    Project Director
    Directorate of Maize Research
    New Delhi
14. Dr. Ramesh Kumar
    Directorate of Floriculture
    New Delhi
15. Dr. Suresh Walia
    Professor, Agril. Chemicals
16. Dr. V.C. Mathur
    Professor, Agril. Economics
17. Dr. D.V.K. Samuel
    Head & Professor, Agril.
    Engineering
18. Dr. Prem Lata Singh
    Professor, Agril. Extension
19. Dr. (Ms.) I.M. Santha
    Professor, Biochemistry
20. Dr. V.K. Bhatia
    Professor, Agril. Statistics
21. Dr. A.R. Sharma
    Professor, Agronomy
22. Dr. (Ms.) Usha K. Chopra
    Professor, Agril. Physics
23. Dr. P.K. Malhotra
    Professor, Computer Application
24. Dr. R.D. Gautam
    Professor, Entomology
25. Dr. S.D. Singh
    Professor
    Environmental Sciences
26. Dr. (Ms.) Shanti Chandrasekharan
    Professor, Genetics
27. Dr. Subodh Joshi
    Professor, Horticulture
28. Dr. V.R. Sagar
    Professor
    Post Harvest Technology
29. Dr. A.K. Singh
    Head, Division of Fruits &
    Horticultural Technology
30. Dr. T. Jankiram
    Head, Division of Floriculture &
    Landscaping
31. Dr. Pritam Kalia
    Head, Division of Vegetable
    Science
32. Dr. (Ms.) Dolly Wattal Dhar
    Professor, Microbiology
33. Dr. Srinivasan
    Professor, Moleculer Biology &
    Biotechnology

34. Dr. (Ms.) Sudarshan Ganguly
Professor, Nematology

35. Dr. (Ms.) Pratibha Sharma
Professor, Plant Pathology

36. Dr. V.P. Singh
Professor, Plant Physiology

37. Dr. S.K. Jain
Professor, Seed Science & Technology

38. Dr. R.K. Rattan
Professor, Soil Science & Agricultural Chemistry

39. Dr. R.K. Sharma
Professor
Water Science & Technology

40. Dr. I.S. Bisht
Professor
Plant Genetic Resources

41. Dr. R.S. Chhillar
Master of Halls of Residences

42. Ms. Usha Khemchandani
In-charge, IARI Library

43. Dr. Jitendra Kumar
Faculty Representative

44. Dr. (Ms.) K. Annapurna
Faculty Representative

45. Dr. K.M. Manjaiah
Officer Incharge, AIM Cell
PG School

46. Shri Biswajit Mondal
President, PGSSU

47. Shri Sanjeev Kumar
Students' Representative

Member-Secretary

48. Sh. B.N. Rao
Registrar &
Joint Director (Admn.)

Appendix 4
Members of Extension Council of IARI
(As on 31.03.2011)

Chairman

1. Dr. H.S. Gupta
   Director, IARI,
   New Delhi

Members

2. Dr. Baldeo Singh
   (up to 31-07-2010)
   Dr. K. Vijayaragavan
   (w.e.f. 21-10-2010)
   Jt. Director (Ext.), IARI,
   New Delhi

3. Sh. G.R. Deshbandhu
   (up to 20-07-2010)
   Sh. B.N. Rao
   (w.e.f. 21-07-2010)
   Jt. Director (Admn.), IARI, N.D.

4. Dr. K.R. Koundal
   (up to 31-12-2010)
   Dr. Malavika Dadlani
   (w.e.f. 01-01-2011)
   Jt. Director (Research)
   IARI, New Delhi

5. Dr. K.V. Prabhu
   Head, Genetics
   IARI, New Delhi

6. Dr. A.K. Vyas
   Head, Agronomy
   IARI, New Delhi

7. Dr. R.K. Jain
   Head, Plant Pathology
   IARI, New Delhi

8. Dr. Ram Bahal
   Prof., Agril. Extn.
   IARI, New Delhi

9. Dr. D.V.K. Samuel
   Head, Agril. Engg.
   IARI, New Delhi

10. Dr. Anand Swarup
    Head, Soil Science &
    Agricultural Chemistry
    IARI, New Delhi

11. Dr. G.T. Gujar
    Head, Entomology
    IARI, New Delhi

12. Dr. Suresh Pal
    Head, Agril. Economics
    IARI, New Delhi

13. Dr. T.B.S. Rajput
    Project Director, WTC
    IARI, New Delhi

14. Dr. S.S. Aitwal
    Head, IARI Regional Research
    Station, Karnal
    (Haryana)

15. Dr. Gurbachan Singh
    Agril. Commissioner (Crops)
    Dept. of Agriculture &
    Cooperation, MOA,
    Krishi Bhavan, New Delhi

16. Dr. D.K. Thakur
    Jt. Director (Agriculture)
    Govt. of NCT of Delhi
    MSO Building, 11th Floor,
    I.P. Estate, New Delhi

17. Sh. Kailash Chandra
    Director (Agril. Marketing)
    Govt. of NCT,
    49, Shamnath Marg,
    Old Secretariat,
    New Delhi

18. Dr. D.S. Brar
    Principal Scientist (Extension)
    NDRI, Karnal, (Haryana)

19. Dr. M. Kazmi
    Director (Farm Information)
    Directorate of Extension,
    Krishi Vistar Sadan,
    IARI Campus, New Delhi

20. Dr. K.D. Kokate
    Dy. Director General (AE)
    ICAR, KAB, Pusa, New Delhi

Member-Secretary

21. Head, Agril. Extn.
    IARI, New Delhi

Appendix 5
Members of Staff Research Council of IARI
(As on 31.03.2011)

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 (PME), IARI

Appendix 6
Members of Executive Council of IARI
(As on 12.02.2011)

Chairman

1. Dr. H.S. Gupta
   Director, IARI

Members

2. Dr. K.R. Koundal
   (up to 31-12-2010)
   Dr. Malavika Dadlani
   (w.e.f. 01-01-2011)
   Jt. Director (Research), IARI
3. Dr. H.S. Gaur
   Dean & Joint Director
   (Education), IARI
4. Dr. Baldeo Singh
   (up to 31-07-2010)
   Dr. K. Vijayaragavan
   (w.e.f. 21-10-2010)
   Jt. Director (Ext.), 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. (Ms.) Dolly Wattal Dhar
   Prof., 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
    Prof., 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. Sh. G.R. Deshbandhu
    (up to 20-07-2010)
    Sh. B.N. Rao
    (w.e.f. 21-07-2010)
    Jt. Director (Admn.), IARI

Appendix 7
Members of Institute Joint Staff Council (IJSC)
(As on 31.03.2011)

Chairman

1. Dr. H.S. Gupta
   Director

Members (Official Side)

2. Dr. H.S. Gaur
   Dean & Jt. Director (Education)
3. Dr. P. Natu
   Sr. Scientist (RPM)
   Directorate
4. Dr. Jagdish Kumar
   Head, R.S. Wellington
5. Sh. Puspendera Kumar
   Chief Admn. Officer
6. Sh. Radhey Sham
   Comptroller

Secretary (Official Side)

7. Sh. B.N. Rao
   Registrar & Jt. Director (Admn.)

Members of the Staff Side (Elected)

1. Sh. S.C. Dixit
   T-4, Division of Genetics
2. Sh. Veer Pal Singh
   Technical Officer (T-5)
   Centre for Protected Cultivation Technology
3. Sh. Mithlesh Narayan
   (T-4), Division of Genetics
4. Sh. Chetan Swaroop Issar
   AAO, Directorate
5. Sh. Radhey Krishan Thakur
   UDC, Directorate
6. Sh. Yogesh Kumar
   UDC, Directorate
7. Sh. Ajit Singh Rainu
   UDC, Division of Entomology
8. Sh. Umesh Thakur
   SSS, Directorate
9. Sh. Bijender Singh
   SSS, CATAT
10. Sh. Dharm Singh
    SSS, Division of Soil Science & Agricultural Chemistry
11. Sh. Shashi Kant Kamath
    SSS, Seed Production Unit

Secretary (Staff Side)

12. Sh. Ganesh Rai
    T-2, Division of Entomology

Appendix 8
Members of Grievance Committee of IARI
(As on 31.03.2011)

Chairman

1. Dr. H.S. Gaur
   Dean & Jt. Director (Education)

Members (Official Side)

2. Dr. Suresh Pal
   Head, Division of Agril. Economics
3. Ms. Piyush Malyan
   AO, Directorate

Member-Secretary

4. Chetan S. Issar
   AAO, Directorate

Members Staff Side (Elected)

1. Dr. Vijendendra Singh
   Sr. Scientist, Division of Genetics
2. Sh. Vijender Singh
   Technical Officer
   (T-7/8), Division of Nemaology
3. Sh. Rohtash Sharma
   Admn. Officer, Division of Nematology
4. Mohd. Azam
   SSS, Unit of Simulation & Informatics

Appendix 9
Personnel
(As on 31.03.2011)

Directorate

Director
Dr. H.S. Gupta

Dean & Joint Director (Education)
Dr. H.S. Gaur

Joint Director (Research)
Dr. Malavika Dadlani

Joint Director (Extension)
Dr. K. Vijayaragavan

Joint Director (Admn.) & Registrar
Mr. B.N. Rao

Principal Scientist (PME)
Dr. B.R. Atteri

Principal Scientist (ITMU)
Dr. Archna Suman

Comptroller
Mr. Radhey Sham

Chief Administrative Officers
Mr. P.K. Jain

Mr. Pushpendra Kumar

Chief Finance & Accounts Officer
Ms. Bharti Jhade

Agricultural Chemicals

Head
Dr. V.T. Gajbhiye

Professor
Dr. Suresh Walia

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. Ram Bahal

Professor
Dr. Prem Lata Singh

Agricultural Physics

Head
Dr. Ravender Singh

Professor
Dr. Usha Kiran Chopra

Agronomy

Head
Dr. A.K. Vyas

Professor
Dr. A.R. Sharma

Biochemistry

Head
Dr. R.D. Rai

Professor
Dr. I.M. Santha

Entomology

Head
Dr. G.T. Gujar

Professor
Dr. R.D. Gautam

National Fellow
Dr. G.K. Mahapatro

Environmental Sciences

Head
Dr. H.C. Joshi

Professor
Dr. Shiv Dhar Singh

National Fellow
Dr. Ravinder Kaur

Floriculture and Landscaping

Head
Dr. T. Janakiram

Fruits and Horticultural Technology

Head
Dr. A.K. Singh

Genetics

Head
Dr. K.V. Prabhu

Professor
Dr. Shanti Chandrashekharan

Microbiology & CCUBGA

Head

Dr. A.K. Saxena

Professor

Dr. Dolly Wattal Dhar

Nematology

Head

Dr. A.K. Ganguly

Professor

Dr. Sudershan Ganguly

Project Coordinator

Dr. R.K. Jain

Plant Pathology

Head

Dr. R.K. Jain

Professor

Dr. Pratibha Sharma

National Fellow

Dr. 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. S.S. Parihar

Professor

Dr. S.K. Jain

Soil Science and Agricultural Chemistry

Head

Dr. Anand Swarup

Professor

Dr. R.K. Rattan

Vegetable Science

Head

Dr. Pritam Kalia

Professor (Hort.)

Dr. Subodh Joshi

NRC on Plant Biotechnology

Director

Dr. P. Ananda Kumar

National Professor

Dr. N.K. Singh

Nuclear Research Laboratory

Scientist - in-charge

Dr. M.S. Sachdev

Water Technology Centre

Project Director

Dr. T.B.S. Rajput

Professor

Dr. R.K. Sharma

National Fellow

Dr. Renu Khanna Chopra

Agriculture Technology Information Centre (ATIC)

Scientist-in-Charge

Dr. 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. Man Singh

National Phytotron Facility

Scientist-in-charge

Dr. K.V. Prabhu

Seed Production Unit

Scientist-in-charge

Dr. B.S. Tomar

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. Y.P. Sharma

IARI Regional Station, Indore

Head

Dr. A.N. Mishra

IARI Regional Station, Kalimpong

Scientist-in-charge

Dr. K.K. Biswas

IARI Regional Station, Karnal

Head

Dr. S.S. Atwal

IARI Regional Station, Katrain

Head

Dr. R.N. Barwal

IARI Regional Station, Pune

Head

Dr. V.M. Chavan

IARI Regional Station, Pusa

Head

Dr. I.S. Solanki

IARI Regional Station, Wellington (The Nilgiris)

Head

Dr. Jagdish Kumar

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