Silver Jubilee

वार्षिक प्रतिवेदन
Annual Report
2013-2014

भारतीय मृदा विज्ञान संस्थान
INDIAN INSTITUTE OF SOIL SCIENCE

(ISO 9001 : 2008 Certified)

Nabi Bagh, Berasia Road, Bhopal - 462038 (M.P.)

भाकृअनुप
ICAR

IISS Annual Report 2013-2014

IISS
ANNUAL REPORT
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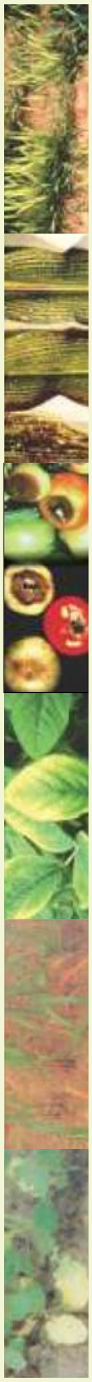

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Correct Citation :

Patra A K, Brij Lal Lakaria, Elanchezhian R, Neenu S, Mandal A, Sinha N K, Meena V D, Subba Rao A (2014) Annual Report 2013-14, Indian Institute of Soil Science, Bhopal, M.P., 132 p.

Printed at :

Bhandari Offset Printers, E-3/12 Arera Colony, Bhopal,
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Preface

Presently, five major problems facing humanity viz. food, water, energy, environment and poverty are directly linked with health of soil resources. There are several human induced factors including excessive tillage, inappropriate crop rotations, excessive grazing, crop residue removal, deforestation, mining, conversion of land into urban areas which have contributed to soil degradation. Under such a scenario, if we are to successfully feed the ever-growing population of our fragile planet, we need to understand and implement sustainable soil management practices to improve our soil health. Newer and advanced information need to be generated in the frontier areas of soil science research for their effective implementation and communication to the stakeholders, policy makers and public at large.

The institute has been able to address the challenges / issues which have been depicted in this report traversing the research involving multi-scale approach from the nanotechnology to the landscape level to the biogeochemical reactions and processes in the environment from the nutrients and food security point of view. On a broader sense, this report encompasses the area of soil health and input use efficiency, conservation agriculture and carbon sequestration, soil microbial diversity and genomics, soil pollution, remediation and environmental security. The report has included the work done on integrated nutrient management, balanced fertilization, nutrient enriched compost and manure preparation, farmers' participatory research and demonstration of the technologies at farmers' fields under the aegis of various AICRP centers across the length and breadth of the country. There has been a considerable progress in the studies on GIS/GPS based mapping of soil resources across the country at district level, carbon sequestration, green house gas emissions, crop modeling & climate change, soil resilience, soil and water quality, bio-fortification with micronutrients and microbial characterization using genomics and meta-genomics. Further, this report presents a glimpse of all the important activities undertaken by the institute during the period reported upon. It is thus, a great pleasure for me to bring out the Annual report 2013-14 of the Indian Institute of Soil Science.

On this occasion, I take this opportunity to express my sincere appreciation to all the Project coordinators and Head of Divisions for compiling the information at AICRP/divisional level. I also extend my gratitude to all the scientists and staff members of the institute for their painstaking efforts in carrying out the research and other developmental activities of institute and for providing the requisite material for compilation of this report.

I place on record my sincere thanks to former Director Dr. A. Subba Rao for his best efforts in pursuing scientists for research, infrastructural developments and bringing out several publications during the year. I also wish to express my sincere appreciation to Drs. Brij Lal Lakaria, R. Elanchezhian, Neenu S, Asit Mandal, Nishant K Sinha, Vasudev Meena and Sanjay Shrivastava for their dedicated efforts in compiling and editing the report. I also thank Mrs. Geeta Yadav and Mr. Sanjay Kumar Kori for their assistance in typing and setting of the manuscript.

I acknowledge with deep gratitude and respect to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR and Dr. A.K. Sikka, Deputy Director General (NRM), ICAR for all round growth and development of the institute that has been possible with their able guidance, encouragement and continuous support. I am highly thankful to Dr. S.K. Chaudhary, Assistant Director General (SWM), for his active involvement and constructive suggestions in carrying out various activities of the institute.

Bhopal
June 2014

(A.K. Patra)
Director

विशिष्ट सारांश

प्रसंग 1: मृदा स्वास्थ्य और इनपुट उपयोग क्षमता

मृदा उर्वरता मूल्यांकन

- 12 राज्यों के 63243 जियोरेफरेंस्ड मृदा नमूनों के विश्लेषण से ज्ञात हुआ है कि 27.8 प्रतिशत मृदाओं में उपलब्ध सल्फर की कमी है। विभिन्न राज्यों में से पश्चिम बंगाल के चित्रित जिलों की 46.5 प्रतिशत मृदाओं में सल्फर की कमी पाई गई। बिहार, गुजरात, हरियाणा और उत्तर प्रदेश की मिट्टियों में यह कमी क्रमशः 46.4, 43.3, 35.8 व 32.5 प्रतिशत पाई गई। पूरे देश के 13 राज्यों के 174 जिलों से लिए गए 70759 नमूनों में से 39.9 प्रतिशत नमूनों में जस्ता की कमी पाई गई। लोहे की कमी लगभग 13 प्रतिशत तथा मैंगनीज की कमी 6 प्रतिशत जबकि ताम्बा की कमी 4.3 प्रतिशत मिट्टियों में देखी गई।
- वर्टीसोल्ज़, इंसेप्टीसोल्ज़, अल्फीसोल्ज़ तथा अल्टीसोल्ज़ मिट्टियों में फसल उपज व पर्यावरण प्रदूषण के लिए फॉस्फोरस संतृप्ति स्तर (DPS) की सीमा ज्ञात करने के लिए नियमित ब्रे व ऑल्सन रसायनों के साथ–साथ मेहलिच 3 और अमोनियम आक्जेलेट नामक विलेयकों को निस्सारण हेतु प्राथमिकता दी जा सकती है। निस्कर्षण विलेयक के प्रयोग द्वारा ज्ञात हुआ है कि इन्सेप्टीसोल मृदाएं फास्फोरस को घुलकर नुकसान होने के प्रति ज्यादा संवेदनशील हैं क्योंकि इनमें फास्फोरस की पर्यावरण सीमा सबसे कम पाई गई।

इनपुट उपयोग दक्षता में सुधार

- मक्का को परीक्षण फसल में उपयोग लाते हुए नैनो रॉक फास्फेट का क्षेत्र प्रयोग करने से यह ज्ञात हुआ कि नैनो रॉक फास्फेट तथा डाईअमोनियम फास्फेट का फसल द्वारा फास्फोरस उपयोग एक जैसा था। जबकि नैनो रॉक फास्फेट के प्रयोग से प्राप्त उत्पादन, डाई अमोनियम फास्फेट की अपेक्षा कुछ कम रहा। परीक्षण परिणामों से यह ज्ञात हुआ कि 45 कि.ग्रा./हे0 की दर से दिया गया नैनो रॉक फास्फेट 60 कि.ग्रा./हे0 डी.ए.पी. के बराबर रहा।
- नैनो रॉक फास्फेट (~48.8 नैनोमीटर, 34 प्रतिशत फास्फोरस) को पाइन ओलियोरेजिन द्वारा लेपित करने का नवाचार तैयार किया गया। परीक्षण परिणामों से ज्ञात हुआ कि लेपित नैनो रॉक फास्फेट दूसरे परम्परागत फास्फोरस उर्वरकों की अपेक्षा गेहूँ, मक्का इत्यादि फसलों के लिए एक आशाजनक विकल्प है।
- दीर्घकालिक एकीकृत पौध पोषक तत्वों के प्रयोग से मक्का के दानों व भूसे की पैदावार प्रभावित हुई। मृदा में उपलब्ध पोषक तत्वों पर आधारित उर्वरक उपयोग द्वारा मक्का के दानों व कुल जैविक पदार्थ की अधिकतम पैदावार प्राप्त हुई, जो कि सामान्य अनुशंसित उर्वरक मात्रा तथा एकीकृत एफ.वाय.एम. आधारित पोषक तत्व प्रबंध के समान थी। मक्का व चना की उपज 5 तथा 1.5 टन/हे0 के लक्ष्य की अपेक्षा 6.85 तथा 1.87 टन/हे0 प्राप्त हुई। इसलिए लक्षित उपज को बढ़ाने की जरूरत भी महसूस हुई।
- जैविक पोषक तत्व प्रबंधन द्वारा गेहूँ, सरसों, चना तथा अलसी की उपज एकीकृत पोषक तत्व प्रबंधन की अपेक्षा अधिक प्राप्त हुई। जैविक प्रबंधन 100 प्रतिशत जैविक खाद द्वारा अन्य विधि (75 प्रतिशत जैविक खाद + 25 प्रतिशत परिवर्तनात्मक जैविक उपयोग) की अपेक्षा ज्यादा उपज हुई। सोयाबीन की RVS-2002-4 किस्म द्वारा अन्य किस्मों जैसे JS-97-52 तथा JS-20-41 से ज्यादा फसल उपज प्राप्त हुई। मक्का की 'अरावली' किस्म द्वारा उच्चतम उपज 21 वि./हे0 तथा पॉपकॉर्न किस्म की उपज न्यूनतम रही। चना की JG-130 किस्म की उपज अधिकतम रही, तत्पश्चात् RVS-203 तथा JG-16 किस्में की उपज देखी गई। गेहूँ की जी.डब्ल्यू.–366 किस्म की उपज 29 वि./हे0 रही जबकि सी–306 किस्म की उपज न्यूनतम थी।

- अकोला, लुधियाना, हिसार, पालमपुर, जबलपुर, पूसा, हैदराबाद, पंतनगर तथा आनंद में बहुपोषक तत्वों के विभिन्न फसलों पर उपयोग से फसल उपज में अर्थपूर्ण वृद्धि दर्ज की गई, हालांकि प्रतिशत अनुक्रिया फसल व पोषक तत्वों के साथ भिन्न रही। जस्ता के अतिरिक्त अन्य पोषक तत्व जैस – सल्फर, बोरॉन तथा मोलिब्डिनम डालने से फसल उपज में अधिक वृद्धि दर्ज की गई। विभिन्न राज्यों की विशिष्ट स्थिति के अनुरूप सूक्ष्म व गौण पोषक तत्वों की कमी को दूर करने के लिए विभिन्न मृदा विशिष्ट सुधार तकनीकें विकसित की गईं।

दीर्घकालीन उत्पादकता निगरानी, मृदा गुणवत्ता एवं पलटाव

- मृदा पलटाव के भौतिक सूचक जैसे कैलिफोरनियन बियरिंग रेशो (CBR) और रेसीलियन्ट मोडुलस देशी खाद + फ्लाई ऐश के उपयोग द्वारा सबसे उच्च (2.79 प्रतिशत एवं 28.88 मैगा पास्कल) रहे। अतः फ्लाई ऐश + देशी खाद का उपयोग उपरोक्त मृदा पलटाव में सहायक होने की शक्ति को चित्रित करता है।
- मृदा में कॉपर तनाव देने पर मृदा सूक्ष्मजीविय कार्बन तथा डिहाइड्रोजिनेज एन्जाइम क्रियाशीलता शुरूआती सप्ताह में कम रही जबकि विभिन्न सुधारकों जैसे देशी खाद, बायोचार, कुकुट खाद तथा फ्लाई ऐश के उपयोग से यह कमी सिर्फ चार सप्ताह तक ही रही। सबसे अधिक मृदा पलटाव सूचकांक (0.74) देशी खाद + फ्लाई ऐश के उपयोग से प्राप्त हुआ।
- मृदा के जैविक कार्बन के घटाव का मृदा नमनीयता गुणों पर असर देखने के लिए चार फसलों के बाद चिकनी–दोमट मिट्टी के नमूनों की लचीलापन सीमा, तरल सीमा तथा लचीलापन सूचकांक का आंकलन किया गया। अध्ययन से ज्ञात हुआ कि मृदा में जैविक कार्बन के घटने से लचीलापन सीमा तथा तरल सीमा गुणों में कमी आई। यह कमी 33 प्रतिशत जैविक पदार्थ घटाने पर काफी प्रबल थी।
- सशक्त कार्बन खनिजीकरण (Potential Carbon Mineralization) के कारकों का अध्ययन करने के लिए विभिन्न प्रकार के 14 मृदा नमूनों को 247 दिनों तक उष्मायन किया गया तथा सशक्त कार्बन खनिजीकरण और क्षय स्थिरता (Decay Constant) की गणना विभिन्न प्रकार की मृदाओं और भू–उपयोग प्रणालियों के लिए की गई। तत्पश्चात् 12 चरों, जिनमें मृदा व जलवायु की दशाएं भी शामिल थी, का प्रमुख घटक विश्लेषण (PCA) विधि द्वारा सशक्त कार्बन खनिजीकरण के कारकों का पता लगाया गया। यह पाया गया कि मिट्टी में सिल्ट, चिकनी मिट्टी और कुल कार्बन नत्रजन सशक्त कार्बन खनिजीकरण के लिए जिम्मेदार है। इस गणना के लिए एक तंत्र (मॉडल) भी विकसित किया गया।
- रांची में स्थाई खाद परीक्षण से प्राप्त मृदा में मृदा कार्बन स्थिरीकरण दर और मृदा कार्बन पूल गतिशीलता में से कुल जैविक कार्बन, खनिजीय कार्बन तथा निष्क्रिय कार्बन पूल में उन सभी उपचारों में वृद्धि दर्ज की गई जिनमें लगातार देशी खाद का उपयोग किया जा रहा था।

प्रसंग 2: जलवायु परिवर्तन के दृष्टिगत संरक्षण कृषि और कार्बन स्थिरीकरण

संरक्षण कृषि एवं जलवायु परिवर्तन

- जड़ों के प्राचल जैसे कि जड़ों की लम्बाई, जड़ों का सतही क्षेत्रफल, जड़ों का आयतन और जड़ों के बनावटी प्राचल जैसे जड़ों के गांठों की संख्या, प्राथमिक एवं द्वितीयक जड़ें महत्वपूर्ण रूप से JS-355 की अपेक्षा JS-9560 में अधिक होता है। यह भी पाया गया है कि प्राथमिक एवं द्वितीयक जड़ों का कोण विन्यास JG-335 की अपेक्षा JG-9560 में अधिक पाया गया है जो कि यह सूचित करता है कि JG-9560 किस्म सूखे की दशा में अधिक सहनशील रहेगी।
- जल अपवाह एवं मृदा क्षरण की सीमा क्रमशः 336 से 479 मि.मी. और 3431 से 5557 कि.ग्रा. प्रति हे देखी गई। अधिकतम जलक्षरण (479 मि.मी.) और मृदा क्षरण (5557 कि.ग्राम. प्रति हे0) एकल फसल एवं मिश्रित फसल के बाद खाली खेत में दर्ज किया गया। एकल फसलों में, अधिकतम जल क्षमता एवं मृदा अपवाह अरहर तथा न्यूनतम सोयाबीन में रिकार्ड किया गया।

- मिश्रित फसलों में, अधिकतम जल एवं मृदा क्षरण मक्का एवं अरहर (1:1) में तथा न्यूनतम सोयाबीन + अरहर (1:1) में दर्ज किया गया। जल एवं मृदा क्षरण का फसलों के अनुसार क्रम इस प्रकार रहा–खाली जोत >अरहर >मक्का >मक्का + अरहर >सोयाबीन + मक्का >सोयाबीन + अरहर >सोयाबीन।

- मृदा कार्बनिक कार्बन एवं NPK का सबसे अधिक क्षरण कृषि खाली जोत वाले उपचार में रहा। एकल फसलों के उपचार में सबसे अधिक पोषक तत्वों का क्षरण अरहर तथा मक्का में होता है तथा सबसे कम सोयाबीन में होता है लेकिन मिश्रित फसलों में सबसे अधिक पोषक तत्वों का क्षरण मक्का + अरहर (1:1) तथा सोयाबीन + मक्का (1:1) तथा सबसे कम सोयाबीन + अरहर (2:1) में पाया गया।

- विभिन्न जुताई क्रम जैसे पारम्परिक जुताई एवं कम जुताई में 3 वर्षों का विभिन्न फसल चक्र होने पर सोयाबीन दाना बराबर पैदावार पर कोई प्रभाव नहीं पड़ा। फसल पद्धतियों में सबसे अधिक उत्पादन मक्का चना इसके बाद सोयाबीन + अरहर (2:1) तथा सोयाबीन – गेहूँ में देखा गया।

- न्यूनतम जुताई और कम जुताई में सबसे अधिक खरपतवारों की संख्या और खरपतवार का जैविक भार देखा गया।

- विभिन्न जुताई क्रम में मृदा नमी का निर्धारण किया गया, जिसमें पारम्परिक जुताई और कम जुताई की अपेक्षा शून्य जुताई में सबसे अधिक नमी पाई गयी।

- मृदा की 0–5 से.मी. गहराई में कार्बन स्टॉक दर्शाता है कि पारम्परिक जुताई की तुलना में शून्य जुताई एवं कम जुताई के क्रम में 6.1 से 10.9 प्रतिशत कार्बन स्टॉक की वृद्धि हुई है। अतः जुताई क्रम का कार्बन स्टॉक पर कोई अर्थपूर्ण प्रभाव नहीं पड़ा।

- जुताई क्रमों में 0–5 से.मी. की गहराई में सक्रिय कार्बन की मात्रा पारम्परिक जुताई (335 मि.ग्रा./कि.ग्रा.) की अपेक्षा कम जुताई (360 मि.ग्रा./कि.ग्रा.) तथा शून्य जुताई (383 मि.ग्रा./कि.ग्रा.) में अधिक पायी गई। यही क्रम 5–15 से.मी. मृदा गहराई में भी पाया गया।

बदलते जलवायु का फसलों पर प्रभाव

- वातारण तापमान में 1.5° सेल्सियस की वृद्धि होने पर सोयाबीन के दानों की पैदावार में 20 प्रतिशत की कमी आयेगी। इसी प्रकार से वर्षा की कमी भी सोयाबीन की उपज के पक्ष में नहीं होती है। वातावरण के वर्तमान तापमान में 1° सेल्सियस की कमी तथा वर्षा में 10 प्रतिशत की वृद्धि होने पर सोयाबीन फसल का अच्छा उत्पादन होता है।

- सोयाबीन फसल के बढ़वार के दौरान यदि तापक्रम में 1.5° सेल्सियस और वर्षा में 50 प्रतिशत की वृद्धि होती है तो फसल उपज में 5 से 10 प्रतिशत की कमी हो जाती है, जो कि सहन सीमा के रूप में विचारणीय है। तापक्रम 1.5° सेल्सियस से अधिक होने पर और वर्षा के अधिक होने पर सोयाबीन उत्पादन पर कोई सकारात्मक प्रभाव नहीं पड़ता है।

- वातावरण में कार्बन डाइआक्साइड की मात्रा सांद्रण अधिक होने से तथा वर्तमान तापक्रम में 1° सेल्सियस की कमी सोयाबीन पौधों की वृद्धि में सहायक होती है। कार्बन डाइआक्साइड की मात्रा में वृद्धि के साथ–साथ फसल की वृद्धि रूक या घट जाती है क्योंकि तापक्रम में वृद्धि फसल बढ़वार पर नकारात्मक असर डालती है। तापक्रम में 1° सेल्सियस की वृद्धि होने पर और वर्तमान कार्बन डाइआक्साइड का सांद्रण दोगुना होने पर सोयाबीन की उपज अधिकतम 15 प्रतिशत तक कम हो जाती है।

प्रसंग 3: सूक्ष्म जैविक विविधता और जिनोमिक्स

सूक्ष्म जैविक विविधता और जैव उरवर्क

- सोयाबीन और मक्का फसलों के तहत मृदा में अकार्बनिक खाद उपयोग की अपेक्षा जैविक खाद प्रबंधन द्वारा साधारण

फ्लैजिला वाले जीवाणुओं की जाति प्रचुरता अधिक पाई गई। हालांकि यह भिन्नता बहुत अधिक नहीं थी। धान के अंतर्गत मिट्टी में रासायनिक उर्वरकों के उपयोग से संधिपादों की संख्या धान में एकीकृत पोषण प्रबंधन, जैविक सब्जी उत्पादन व जंगल की भूमि की अपेक्षा अधिक थी।

- मक्का व चना की फसलों के लिए होनहार एक्टिनोमाइसिटीज़ जातियों की पहचान की गई। एक्टिनोमाइसिटीज ए–10 ने शुष्क क्षेत्रों में अच्छा प्रदर्शन किया और 25 प्रतिशत नत्रजन व फास्फोरस की बचत की।
- पूर्वोत्तर भारत में अपलैंड चावल की खेती के लिए जैविकी सहायता संघ (साइनोबैक्टीरिया, एजोस्पिरिलम, बेसिल्स सब्टीलिस व समृद्ध माइकोस्ट्रा) अधिक प्रभावी पाया गया।
- फास्फोरस व जिंक की गतिशीलता बढ़ाने हेतु बी.टी. कपास में कल्चर के उपयोग से उपज में वृद्धि दर्ज की गई।
- उत्तर–पूर्वी क्षेत्र व तटीय मिट्टियों में पटसन की खेती के लिए जैव उर्वरक प्रभावी पाये गये। जैव उर्वरकों से मिर्च की फसल में कैपसीयसिन व विटामिन सी की मात्रा में भी बढ़ोत्तरी हुई।
- शुष्क क्षेत्रों की ग्वार व अरहर की फसलों में राइजोबियम नाम जीवाणुओं का आणविक लक्षण वर्णन किया गया। इसके साथ–साथ तापमान सहिष्णुता तथा पी.जी.पी.आर. गुणों की गणना भी गई। शुष्क क्षेत्र के राइजोबिया नामक जीवाणु सहिष्णु भी पाए गए। पांच ऐसे राइजोबिया भी मिले जो चने की फसल के लिए कवक रोग विरोधी थे।
- सोयाबीन फसल में विभिन्न वृद्धि स्तरों के दौरान अमोनियम ऑक्सीडाइजिंग जीवाणु और अरैकिया का अध्ययन समुदाय गतिशीलता को परिभाषित करने के लिए किया गया। कार्यक्षमता नाइट्रीकरण दर से ज्ञात हुआ कि अमोनियम ऑक्सीडाइजिंग जीवाणु व अरैकिया द्वारा नाइट्रीकरण फसल की वृद्धि अवस्था तथा उर्वरक प्रबंधन पर निर्भर करता है। टर्मिनल इलेक्ट्रान स्वीकार करने की प्रक्रिया के दौरान अमोनियम ऑक्सीडाइजिंग जीवाणुओं तथा अरैकिया द्वारा नाइट्रीकरण से यह प्रदर्शित हुआ कि Fe^{3+} रिडक्शन से अमोनियम ऑक्सीडेशन उत्तेजित हुआ।
- सन् 2013–14 के दौरान तीन जैव उर्वरक केन्द्रों पर 114.5 लाख रूपए का जैव उर्वरक तैयार किया गया जबकि परियोजना बजट मात्र 190 लाख रूपए था।
- पी.जी.पी.आर. बेसिलस की खेती के लिए वैकल्पिक साधन संशोधित किया गया जिससे जीवाणु की उच्च संख्या तथा गुणवत्ता मिल सके। पी.जी.पी.आर., राइजोबयम और एक्टीनोमाइसिटीज़ के सहायता समूह ने वर्टिसोल मृदा में चने की फसल पर बहुत अच्छा प्रदर्शन किया।

प्रसंग 4ः मृदा प्रदूषण, निराकरण और पर्यावरण सुरक्षा

कृषि मिट्टी में पुनर्चक्रण और विभिन्न कचरों के तर्कसंगत उपयोग

- शहरी ठोस कचरे में अनेक प्रकार के भारी धातु पाए जाते हैं जिससे इसे कृषि भूमि में उपयोग करने में बाधा आती है। बारीक भारी धातुओं को हटाने तथा अम्लीय आसवन द्वारा उनका निष्कर्षण तनु ई.डी.टी.ए. को प्रयोग में लाते हुए भीगी अवस्था में करने से इन पदार्थों के हानिकारक प्रभाव से बचा जा सकता है।
- शहरी ठोस कचरे से भारी धातु हटाने के लिए एक जैविक निस्पंदन तरीके की खोज की जा रही है जिसमें मिजोफिलिक कवकों का इस्तेमाल किया जा रहा है। इसके लिए छः मिजोफिलिक कवकों की पहचान की गई थी जिनके नाम हैं–ट्राइकोडर्मा वीरीडी, एसपरजिलस हेटरोमोरफस, राइजोम्युकर पुसीलस, एसपरजिलस फ्लेवस, एसपरजिलस टेरस तथा एसपरजिलस अवामोरी। इन सभी कवकों की वृद्धि में 400 पी.पी.एम. सीसा तथा जस्ता की सांद्रता होने पर भी कोई रूकावट नहीं आई। जबकि ट्राइकोडर्मा वीरीडी को छोड़कर सभी कवकों की वृद्धि 10 पी.पी.एम. कैडमियम की मात्रा होने पर रूक गई। यह भी ज्ञात हुआ कि ये सभी कवक 150 पी.पी.एम. निकल की सांद्रता होने पर भी बढ़ते रहे।

- कृषि में खरपतवारनाशी का प्रयोग बहुत जरूरी हो गया है। दीर्घकालीन उर्वरक उपयोग वाले प्रायोगिक क्षेत्र की मिट्टी में एक प्रयोगशाला अध्ययन किया गया जिसमें आइसोप्रोटयूरोन नामक खरपतवारनाशी की भिन्न–भिन्न सांद्रता का उपयोग किया गया और इसका मृदा के गुणों का प्रभाव एक ऊष्मायन अध्ययन द्वारा किया गया। अध्ययन में यह पाया गया कि खरपतवारनाशी उपयोग से मृदा की एन्जाइम सक्रियता शुरूआती सात दिनों में सबसे कम हुई। मृदा में चूने के साथ शत–प्रतिशत रासायनिक उर्वरक डालने से व देशी खाद के साथ शत–प्रतिशत रासायनिक उर्वरकों के प्रयोग से खरपतवारनाशी के पतन की दर एक जैसी रही। मिट्टी में आइसोप्रोटयूरोन खरपतवार की अर्ध आयु 9.9 से 20.8 दिन रही।

प्रसंग 5 : प्रक्षेत्र कृषि अनुसंधान और प्रभाव आंकलन

- विभिन्न फसलों जैसे–जूट, धान, मटर, लहसुन, चन्द्रासुर, सोयाबीन, प्याज और मिर्च पर विभिन्न स्थानों जैसे बैरकपुर, जबलपुर और बैलेनिकारा में फॉलो अप परीक्षण किए गए। सभी परीक्षणों में लक्षित उपज व उच्च लाभ : लागत एकीकृत पोषण प्रबंधन या मृदा पोषक तत्व आधारित उर्वरक उपयोग से हासिल किए जा सके।
- नई दिल्ली व कोयम्बाटूर में दीर्घकालिक एकीकृत पौध तत्व प्रबंधन तथा मृदा विश्लेषण आधारित पोषक तत्व प्रबंधन के प्रदर्शन क्रमशः बाजरा–गेहूँ तथा धान–धान फसल प्रणालियों के तहत किए गए। परीक्षण परिणामों से ज्ञात हुआ कि उपरोक्त उपचारों से मृदा के भौतिक, रासायनिक तथा जैविक गुणों में अर्थपूर्ण वृद्धि हुई।
- कोयम्बाटूर में 10 सीमावर्ती प्रदर्शन मूंगफली, सूरजमुखी और जिन्जैली फसलों पर लगाए गए जिनमें एकीकृत पोषक तत्व प्रबंधन तथा मृदा विश्लेषण आधारित उर्वरक उपयोग द्वारा लक्षित उपज प्राप्त की गई। इसके साथ पोषक तत्व प्रतिक्रिया अनुपात, लाभ, खर्च तथा अधिकतम शुद्ध लाभ भी अधिक रहे।
- किसान के खेत पर पांच विकसित तकनीकों का एक प्रदर्शन (एकीकृत पोषक तत्व प्रबंधन, मृदा विश्लेषण आधारित उर्वरक उपयोग, फास्फोसल्फो–नाइट्रो कम्पोस्ट, ब्रॉड बैड एण्ड फरो तकनीक, कम जुताई तथा जैविक उर्वरक उपयोग) लगाया गया जिसमें पाया कि सोयाबीन की उपज में किसान पद्धति की अपेक्षा एकीकृत पोषक तत्व प्रबंध से 14.3 प्रतिशत, फास्फोसल्फोनाइट्रो कम्पोस्ट से 25.9 प्रतिशत तथा मृदा विश्लेषण आधारित उर्वरक उपयोग से 15.2 प्रतिशत अधिक उपज प्राप्त हुई। जबकि गेहूँ की फसल में यह वृद्धि एकीकृत उर्वरक प्रबंधन, फास्फोसल्फो–नाइट्रो कम्पोस्ट और मृदा विश्लेषण आधारित उर्वरक उपयोग द्वारा क्रमशः 12.0, 16.3 और 12.8 प्रतिशत अधिक रही।

EXECUTIVE SUMMARY

Theme I: Soil Health and Input Use Efficiency

Soil Fertility Evaluation

- Analysis results of 63,243 geo-referenced samples from 12 states of the country collected under AICRP-MSN revealed that 27.8% of Indian soils are deficient in available S. Among the states, 46.5% soils of delineated districts of West Bengal were low in available S, marginally followed by Bihar (46.4%), Gujarat (43.3%), Haryana (35.8%) and Uttar Pradesh (32.5%). Overall, 39.9% of 70,759 samples collected from 174 districts of 13 states across the country were deficient in available Zn. The Fe deficiency in India stayed close to 13% and that of Mn was 6.0% while Cu deficiency (4.3%) was little less than Mn.
- To determine the degree of phosphorus saturation (DPS) threshold values for crop yield and environmental pollution for the Vertisols, Inceptisols, Alfisols and Ultisols, Mehlich 3 and Ammonium oxalate extractants can be preferred over routine soil test procedures like Bray and Olsen. The results obtained with the extractant Mehlich 3 revealed that the Inceptisol are most vulnerable for P leaching because they have the minimum environmental threshold. This is followed by Alfisol, Ultisol and Vertisol which are less susceptible to P leaching.

Improving Input Use Efficiency

- Field experiment was conducted to evaluate the dose of nano rock phosphates, taking maize as a test crop. Results showed that crop utilization of P from nano rock phosphate was at par with that of P from DAP while yield response to P from nano rock phosphate was marginally lower than P from DAP but much more economical. Experimental result of the field trial also revealed that application of nano rock phosphate @ 45 kg ha^{-1} for maize crop was effective as @ 60 kg ha^{-1}.
- A protocol was developed to coat the nano rock phosphate (~48.8 nm, 34% P_2O_5) with pineoleoresin coated urea and experimental results showed that the coated materials are useful to coat the naked nano rock phosphate and the products are promising alternatives of conventional phosphatic fertilizer for crops like wheat, maize *etc.*
- Long-term application of integrated plant nutrient supply modules influenced the grain and stover yield of maize. Grain yield and total dry matter yield of maize was the highest for STCR based recommended dose of fertilizers which was at par with GRD and FYM based INM modules. Maize yield of 6.85 t ha^{-1} and chickpea yield of 1.87 t ha^{-1} were achieved against the targets of 5 and 1.5 t ha^{-1}, respectively, and hence there was a need to enhance the yield target levels.
- Yield performance of wheat, mustard, chickpea and linseed under organic management practice (soybean based cropping system), performed better followed by integrated nutrient management. In organic management, the yield of all *rabi* season crops were found to be higher in 100% organic nutrient management practices than 75% organic + 25% innovative practices. In integrated nutrient management, 75% organic + 25% inorganic treatment was better than 50% organic +50% inorganic nutrient management. Among soybean varieties, RVS-2002-4 was found to produce higher yield followed by JS-97-52 and JS-20-41. In maize, variety Arawali recorded a maximum seed yield of 21 qha^{-1} while popcorn variety produced poor yield. The yield of chickpea variety JG-130 was higher followed by RVS-203 and JG-16. The yield of wheat variety GW-366 recorded maximum seed yield of 2.9 t ha^{-1} while C-306 produced poor yield. Among the HI varieties, HI-1531 was found to give higher grain yield.

- Significant response to multinutrients application was recorded in several crops at Akola, Ludhiana, Hisar, Palampur, Jabalpur, Pusa, Hyderabad, Pantnagar and Anand. Although per cent response varied significantly with crops and nutrients. Besides, Zn being the most crucial nutrient for crops, increased responses were recorded when it was applied along with S, B and Mo. Different soil specific amelioration techniques for micro- and secondary nutrients deficiency were also developed successfully at all the centres of AICRP-MSN catering to the specific conditions of the corresponding state.

Monitoring Long Term Productivity

Soil Quality and Resilience

- The physical indicators of resilience *viz*. Californian Bearing Ratio (CBR) and resilient modulus values were the highest in the treatments with FYM + fly ash (2.79% and 28.88 MPa, respectively) followed by poultry manure + fly ash (2.25% and 23.28 MPa, respectively) depicting their higher strength due to addition of fly ash.
- Application of Cu stress significantly reduced the soil microbial biomass carbon and dehydrogenase enzyme activity from 0 to 6 week in un-amended soil and from 0 to 4 week in soil amended with various amendments such as FYM, biochar, poultry manure and fly ash. The maximum soil resilience index was found under FYM + fly ash (0.74). The resistance capacity of the soil studied under Cu stress is found better in either biochar (0.66) or biochar + fly ash (0.67) treatment.
- To investigate the effect of soil C depletion on the soil plasticity parameters, soil samples of the clay loam texture were collected after four crop seasons and the test was carried out for plastic limit, liquid limit and plasticity index estimation. The data showed that the plastic limit and liquid limit reduced with depletion in soil C level, though the depletion was drastic from no depletion (C1) to 33% depletion (C2). Averaged over management treatments, the plastic limit reduced from 29% (g/g) under C1 to 18% (g/g) under both C2 and C3 (54% depletion) treatments.
- To study the factors affecting potential carbon mineralization (PMC) in soil, 14 samples having different soil and climatic conditions were used for long term incubation studies (247 days) and PMC and decay constant for different soil types and land use systems were computed. Subsequently 12 variables including soil and climatic conditions were subjected to principal component analysis (PCA) technique for determining the factors responsible for PMC in soil. It was observed that silt, clay and C: N ratio are the main factors which affect potential carbon mineralization in Indian soils. Subsequently, a model for computation of PMC in soil was developed.
- To study the soil carbon dynamics, soils samples were obtained from permanent manurial trial of Ranchi and analysed for soil carbon sequestration rate and carbon pool dynamics. It was observed that application of FYM invariably increased total organic C and carbon in mineralizable and passive pool in all the treatments wherever FYM was applied.

Theme II : Conservation Agriculture and Carbon sequestration *vis-a-vis* Climate Change

Conservation Agriculture and Climate Change

- An increase in temperature by 1.5^{0}C will reduce the grain yield of soybean by 20%. Similarly reduction in rainfall does not favours soybean yield. Decrease in temperature from the current climate by 1^{0}C and increase in rainfall by more than 10% would favour the soybean yield the most. On the other hand. Increase in temperature by 1.5^{0}C along with increase in rainfall up to 50% during soybean growth reduces the soybean yield to the tune of 5 to 10% which can be considered as tolerable limit. Beyond 1.5^{0}C increase in temperature, the increase in rainfall doesn't show any positive impact on soybean yield.

- Increase in CO_2 concentration favours soybean growth when the temperature is reduced by 1^0C from the current climate. With increase in CO_2 concentration the yield is masked by the adverse impact of rise in temperature on crop growth. Even by increasing the temperature by 1^0C and CO_2 concentration to double from the current stage, the yield decline in soybean is as high as 15%.
- Rooting parameters such as root length, root diameter, root surface area, root volume and root architectural parameters such as number of nodes, number of primary and secondary roots were found to be significantly higher in JS-9560 than JS-335. It was observed that primary as well as secondary root insertion angles were higher in JG-9560 compared to JG-335 indicating higher lateral spread making the cultivar more tolerant towards stress conditions.
- The of runoff and soil loss varied from 336 to 479 mm and 3431 to 5557 kg ha^{-1}, respectively. The maximum runoff (479 mm) and soil loss (5557 kg ha^{-1}) was recorded under cultivated fallow over sole as well as intercrops. Among the sole crops, the highest runoff and soil loss was recorded under pigeon pea and the lowest was in soybean crop.
- In case of intercrops, the highest runoff and soil loss was in maize and pigeon pea (1:1) and the lowest in soybean + pigeon pea (2:1).The trend of runoff and soil loss was in the order of, cultivated fallow > pigeon pea > maize > maize + pigeon pea > soybean + maize > soybean + pigeon pea > soybean.
- The SOC and total NPK losses were recorded the highest in cultivated fallow over crop treatments. Among the sole crops treatments, higher nutrients losses were recorded in sole pigeon pea followed by maize and the lowest in sole soybean but in case of intercrops, the maximum nutrient losses were recorded in maize + pigeon pea (1:1) followed by soybean + maize (1:1) and the lowest in soybean + pigeon pea (2:1).
- Different tillage practices such as conventional tillage (CT) and reduced tillage (RT) had no effect on soybean grain equivalent yield after three years of crop cycle. Among the cropping systems studied, maize-gram recorded higher yield followed by soybean + pigeon pea (2:1) and soybean-wheat cropping system. No-tillage (NT)/ reduced tillage (RT) recorded the highest number of weeds and total weed biomass (g m^{-2}). Surface soil moisture was measured under different tillage systems. The temporal data revealed that no-tillage recorded higher soil moisture compared to reduced tillage and conventional tillage. Carbon stocks data revealed that about 6.1-10.9% increase of carbon stocks under RT and NT over CT in 0-5 cm. However, tillage system did not have significant effect on carbon stock. Among the tillage systems, no-tillage (383 mg kg^{-1}) and reduced tillage (360 mg kg^{-1}) recorded higher active carbon compared to conventional tillage (335 mg kg^{-1}) in 0-5 cm soil. Similar trend was observed for 5-15 cm soil depth.

Theme III: Microbial Diversity and Genomics

Microbial Diversity and Biofertilizers

- Differences in eubacterial diversity and species richness were higher under organic management in soybean and maize compared to inorganic but the differences were subtle rather than dramatic. Arthropods in soil reduced under chemical farming in paddy soils as compared to INM paddy, organic vegetable soils and forest soils in NEH.
- Promising actinomycetes strains for maize and chickpea identified. Actinomycetes A10 performed well in dry land conditions and saved 25% NP for maize.
- Microbial consortium (Cyanobacteria, Azospirillum, Bacillus subtilis, enriched mycostraw) was found effective on upland rice in eastern India.
- P and Zn mobilizing cultures improved yields of Bt cotton.

- Biofertilizers for jute found effective in NEH and coastal soils. Biofertilizers improved yield and capsicain and Vitamin C content in hot chilli.
- Molecular characterization of arid zone rhizobia of cluster bean, pigeon pea was done and temperature tolerance and PGPR characteristics quantified. Arid zone rhizobia were also highly salt tolerant. Five rhizobial isolates antagonistic to chickpea fungal pathogens identified.
- Diversity of ammonium oxidizing bacteria (AOB) and archaea (AOA) associated with soybean assessed to define community dynamics during crop growth stages. Potential nitrification rate revealed differential nitrification by AOB and AOA in response to crop growth stages and fertilizer management. Nitrification by AOB and AOA during terminal electron accepting process (TEAPs) indicated that Fe^{3+} reduction stimulated NH_4 oxidation through Fe^{2+} coupled NH_4 oxidation.
- Biofertilizer production at 3 centres of the SB-BF project was to the tune of ₹114.5 lakhs during 2013-14 (project budget ₹ 190 lakhs) (76.3% ROI).
- Medium for cultivation of PGPR-Bacillus was modified to obtain high counts which improve the quality. Consortia of PGPR, Rhizobium and Actinomycetes performed extremely well on chickpea in Vertisol.

Theme IV: Soil Pollution, Remediation and Environmental Security

Amelioration of Contaminated Soils

- Compost prepared from unsegregated municipal solid wastes contains high amount of heavy metals restricting its use in agricultural land as amendment material. A laboratory experiment showed that removal of finer size fraction and extraction of metals through wet sieving method using acidic distillery effluent containing dilute EDTA may lesson hazardousness of such composts.
- The total phosphorus in the water sample that enters to the Upper Lake Bhopal from different source ranges from 0.30 to 0.73 mg L^{-1} with a mean value of 0.47 mg L^{-1} with lowest and highest value from Kholukhedi (Agriculture source) and Bhadbada (domestic waste water), respectively. Among the P fractions, the bioavailable P fraction (TDP) was the highest in the domestic waste water, where the dominant P fraction in water samples from agriculture source was particulate phosphorus (PP).
- Municipal solid waste carry heavy metals, as a consequence, these metals degrade soil health, affects plant growth, livestock and human health if they enter the food chain or drinking water supply. A study was carried out to develop bio-filtration method for removal of heavy metals from poor quality of municipal solid waste compost using isolated mesophilic fungi. Six mesophilic fungi were isolated and *identified such as Trichoderma viride; Aspergillus heteromorphus; Rhizomucor pusillus; Aspergillus flavus; Aspergillus terrus* and *Aspergillus awamori*. All the fungal growth were not affected up to 400 ppm of Pb and Zn. However, except *T. viride*, other mesophilic fungal growths were confined at 10 ppm of Cd followed by Cu. Further, it was observed that the growth tolerant of these fungi was up to 150 ppm of Ni.
- To control the weed pests and pest use of pesticide is one of the important inputs in agriculture. A laboratory study was conducted at some of the LTFE centres, in which soils, from long term fertilizer plots were subjected to graded doses of herbicide with differential incubation period. The results indicated that the enzyme activities (dehydrogenase, urease, fluorescein diacetate hydrolyzing activity and acid and alkaline phosphatase) in soil declined significantly after 7 days of application, while treatments having un-weeded control and hand weeding maintained the same status as that of initial. Addition of lime along with 100% NPK enhanced the rate of degradation which was almost similar to treatment receiving 100% NPK+ FYM. The half-life of isoproturon in field ranged from 9.9 to 20.8 days.

- Accumulation and translocation behavior of heavy metals in crops irrigated with contaminated water was studied. Characterization of heavy metals in peri-urban areas of Nagpur and Aurangabad districts of Maharashtra continuously irrigated with sewage water along with profile distribution of these metals was also studied. Threshold toxic limits for heavy metals in different crops like buckwheat were established and effect of organic amendments in minimizing the toxicity was investigated successfully.

On-Farm Research and Impact Assessment

- Follow up/Verification trials were conducted on jute, rice, vegetable pea, garlic, chandrasur, soybean, onion and chilli by the Barrackpore, Jabalpur and Vellanikkara centres, respectively. In all the trials, the targeted yield was achieved with the adoption of IPNS-STCR fertiliser prescription eqation within permissible yield deviation limit (±10%) with higher nutrient response ratio, greater B: C ratio and better net return.
- Long-term IPNS-STCR demonstrations have been conducted on pearlmillet-wheat and rice-rice cropping sequence at New Delhi and Coimbatore STCR centre, respectively. The results showed significant improvement of soil health as indicated by physical, chemical and biological parameters with STCR-IPNS treatment.
- Under frontline demonstrations (FLDs) on oilseeds, the Coimbatore centre has conducted 10 FLDs on groundnut, sunflower and gingelly. In all the demonstrations, the targeted yield was achieved with the adoption of IPNS-STCR fertiliser prescription equation within permissible yield deviation limit (±10%) with the highest nutrient response ratio, B: C ratio and maximum net return.
- A farmers' field demonstration was conducted with five technologies [IPNS, STCR, Phospho-Sulpho-Nitro Compost, Broad Bed and Furrow technique (developed by ICRISAT) with Reduced Tillage, and application of Bio-fertilizers developed by the institute]. It was found that in soybean yield increased by 14.3% with IPNS, 25.9% with Phospho-Sulpho-Nitro Compost, and 15.2% with STCR based fertilizer recommendations over farmers' practices in the selected Agro-ecosystem. However, in the following wheat crop the percentage yield increases with the IPNS, Phospho-Sulpho-Nitro Compost, and STCR over farmers' practice were 12.0, 16.3, and 12.8 respectively.

1. INTRODUCTION

Food security is one of the major global challenges of the 21st century. Soils and their continuing ability to support the sustainable intensification of agriculture will have to play a central and critical role in delivering food security. In order to take up the emerging challenges of increasing food-grain production from shrinking land resources, reorientation of research pursuits addressing the emerging issues such as enhancing nutrient and water use efficiency; sustaining soil and produce quality; soil biodiversity and genomics, climate change and carbon sequestration; minimizing soil pollution *etc.* have to be envisaged. To address these issues Indian Institute of Soil Science was established on 16th April, 1988 with the mission of "Enhancing Soil Productivity with Minimum Environmental Degradation". Since its inception, the institute made every effort to attain its mission and received national and international recognitions. The institute activity has been strengthened further by the scientific and managerial activities of All India Coordinated Research Projects/All India Network Project. These institute based AICRPs act as a part of the "Network-Support Programmes" of the institute with their centres located in State Agricultural Universities, providing access to the diverse soils, agro-ecosystems across the agro-ecological zones of the country for effective implementation of the programme of the Institute. During the year under report the institute has again made significant scientific contributions in the frontier areas of soil science such as nanotechnology, carbon sequestration and climate change, integrated nutrient supply system (IPNS), biofortification, nutrient transformation and dynamics in soil-plant systems, environmental impact on agricultural production, utilization of solid wastes and waste water, bio and phyto-remediation *etc*. The salient research findings, infrastructural development, technology transfer, human resource development, awards and recognitions *etc.* are briefly highlighted in the present report.

1.1 Mandate

The mandate of the Institute is "To Provide Scientific Basis for Enhancing and Sustaining Productivity of Soil Resources with Minimal Environmental Degradation", with the following objectives:

a) To carry out basic and strategic research on soils especially physical, chemical and biological processes related to management of nutrients, water and energy.

b) To develop advanced technologies for sustainable systems of input management in soils that is most efficient and least environmental polluting.

c) To develop expertise and back-stop other organizations engaged in research on agriculture, forestry, fishery and various environmental concerns.

d) To exchange information with scientists engaged in similar pursuits through group discussions, symposia, conferences and publications.

e) To collaborate with State Agricultural Universities, National, International and other Research Organizations in the fulfillment of the above objectives, and

f) To develop database repository of information on soils in relation to quality and productivity.

1.2 Priorities and Thrust Areas

The priorities of the institute are to broaden the soil science research by encouraging multidisciplinary research for efficient utilization of already created infrastructure and, therefore, carry out research work rigorously in the following critical areas :

Programme 1: Soil Health and Input Use Efficiency

Integrated nutrient management: Indigenous mineral and by-product sources
Nano-technology

- Precision agriculture
- Crop simulation modeling and remote sensing
- Fertilizer fortification
- Resilience of degraded soils
- Developing a workable index of soil quality assessment imbibing influence of different physical, chemical and biological soil attributes

Programme 2: Conservation Agriculture and Carbon Sequestration *vis-à-vis* Climate Change

- Organic farming and produce quality
- Efficient and improved composting techniques
- The carbon sequestration research in the context of sustainable management of land and soil resources and conserving deteriorating environment.
- Conservation agriculture and carbon sequestration
- Tillage and nutrient interactions
- Crop adaptation to climate change and rhizospheric study

Programme 3: Microbial Diversity and Genomics

- Characterization and prospecting of large soil biodiveristy
- Characterization of functional communities of soil organisms
- Testing of mixed biofertilizer formulations

Programme 4: Soil Pollution, Remediation and Environmental Security

- Bio-remediation/ phytoremediation of contaminated soils
- Quality compost production and quality standards
- Waste waters-quality assessment and recycling

1.3 Organization Set-Up

Divisions

- Soil Physics
- Soil Chemistry & Fertility
- Soil Biology
- Environmental Soil Science

Sections

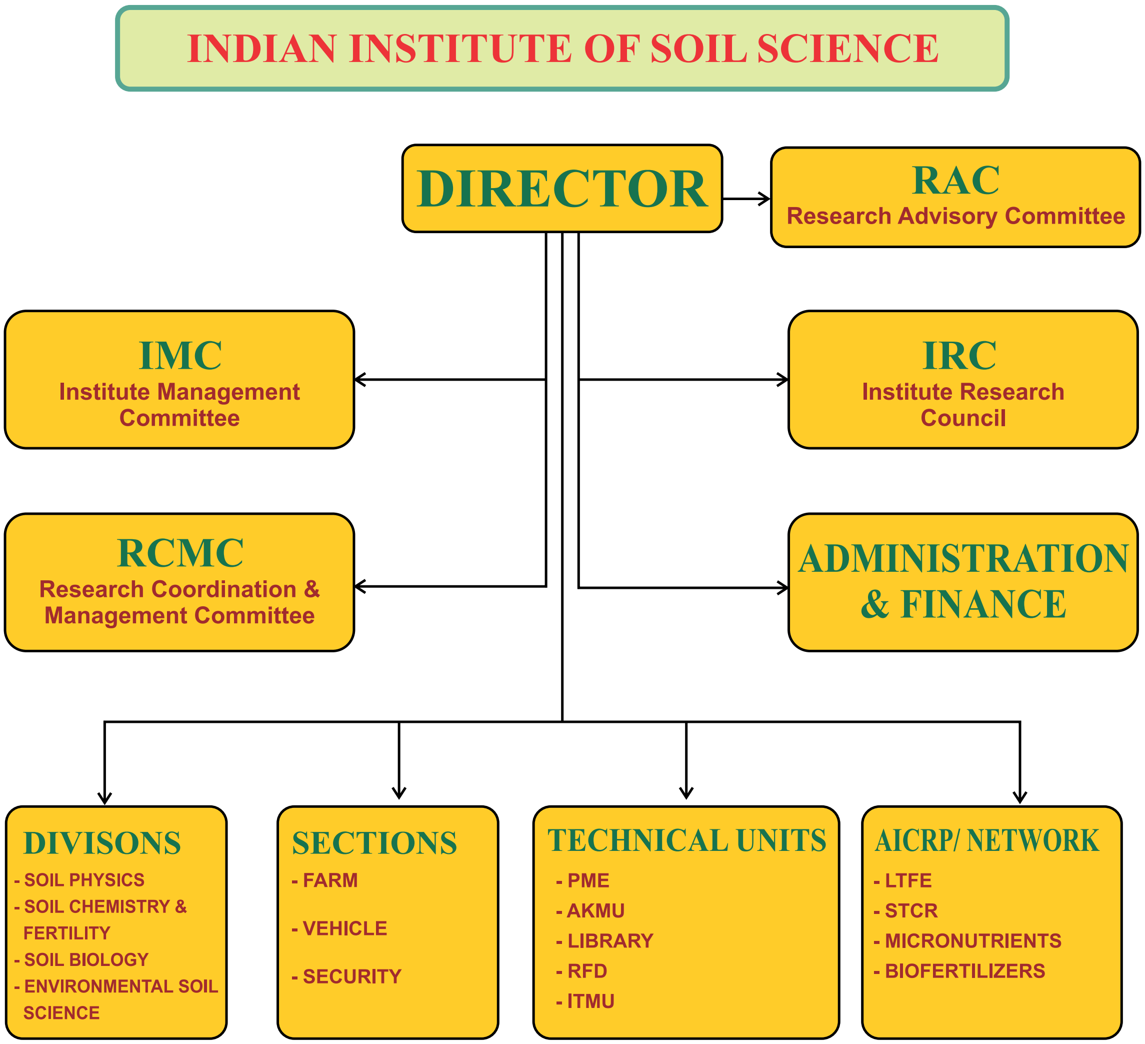
- Statistics and Computer Application
- Farm Section
- Vehicle Section

Technical Units/Cells

- PME Cell
- AKM Unit
- Library, Information and Documentation Unit
- RFD Cell
- ITM Unit

All India Co-ordinated Research Projects (AICRPs)

- Long-Term Fertilizer Experiments (LTFE)
- Soil Test Crop Response Correlation (STCR)
- Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (MSN)
- All India Network Project (AINP) on Soil Biodiversity - Biofertilizers



ORGANIZATIONAL SETUP

1.4 Manpower

a) Scientific

S. No.	Discipline	Sanctioned				In Position			
		PS	SS	S	Total	PS	SS	S	Total
1	RMP	1	0	0	1	1	0	0	1
2	Agricultural Economics	0	1	1	2	0	0	0	0
3	Agricultural Extension	0	0	1	1	0	0	1	1
4	Agricultural Microbiology	1	1	2	4	1	1	2	4
5	Agricultural Statistics	0	1	2	3	0	0	2	2
6	Agronomy	1	2	4	7	0	2	3	5
7	Computer Application	0	1	0	1	0	0	0	0
8	Plant Biochemistry	0	1	1	2	0	1	0	1
9	Plant Physiology	1	1	1	3	1	1	1	3
10	Soil Science	9	8	16	33	9	6	16	31
	Total	**13**	**16**	**28**	**57**	**12**	**11**	**25**	**48**

b) Technical

Sl. No.	Posts	Sanctioned	In Position
1	T-1	11	0
2	T-2	-	1
3	T-3	7	3
4	T-4	-	3
5	T-5	-	4
6	T-6	-	3
7	T-7-8	1	3
8	T-9	-	0
	Total	**19**	**17**

c) Administrative

S. No.	Designation	Sanctioned	In Position
1	Sr. Administrative Officer	1	0
2	Administrative Officer	0	1
3	Finance & Accounts Officer	1	0
4	Asstt. Finance & Accounts Officer	1	1
5	Asstt. Administrative Officer	1	1
6	Private Secretary	2	2
7	Assistant	6	6
8	Personal Assistant	5	4
9	Stenographer Gr-III	2	2
10	Security Supervisor	1	1
11	Upper Division Clerk	2	2
12	Lower Division Clerk	6	3
13	Skilled Supporting Staff	25	20
	Total	**53**	**43**

1.5 Finance

The budget statement (Lakh ₹) for the financial year 2013-14 is as below:

Institute/AICRPs	Budget			Expenditure		
	Non-Plan	Plan	Total	Non -Plan	Plan	Total
Main Institute	910.00	160.00	**1070.00**	879.38	159.46	**1038.84**
AICRP- LTFE	0.00	395.00	**395.00**	0.00	393.79	**393.79**
AICRP- STCR	26.00	720.00	**746.00**	25.99	719.94	**745.93**
AICRP- MSN	42.00	655.00	**697.00**	41.92	654.75	**696.67**
AINP on Biofertilizer	0.00	190.00	**190.00**	0.00	189.99	**189.99**
Total	**978.00**	**2120.00**	**3098.00**	**947.29**	**2117.93**	**3065.22**

1.6 Resource Generation

S. No.	Head of Account	Amount (₹)
1	Sale of Farms Produce	920917
2	Income from Royalty, Sale of Publication and Advertisement	36235
3	Licence Fee	342748
4	Interest earned on Loans and Advances	499545
5	Leave Salary and Pension Contribution	105166
6	Analytical and Testing Fees	25550
7	Interest earned on Short Term Deposits	1097844
8	Income generated from Internal Resource Generation	50000
9	Recoveries of Loans & Advances	2091719
10	Miscellaneous Receipts	15482
	Total	**5185206**

2. RESEARCH ACHIEVEMENTS

Theme I: Soil Health and Input Use Efficiency

2.1 Soil Fertility Evaluation

2.1.1 Development of phosphorus saturation indices for selected soils of India

Degree of Phosphorus Saturation (DPS) indices were developed for some selected Indian soil orders representing Vertisol (Jabalpur), Inceptisol (Delhi), Alfisol (Bangalore) and Ultisol (Trivandrum). The soils from four soil orders were incubated with 0, 25, 50, 100, 150, 200, 400 and 800 per cent P sorption maxima (Smax) corresponding to P1, P2, P3, P4, P5, P6, P7 and P8 treatments, respectively and were used for column leaching and pot experiment. The incubated soils were also analyzed for labile P content with different extractants namely Olsen (Ol), Bray1 (By1), Bray2 (By2), Mehlich 3 (M3), ABDTPA (A.D.) and Ammonium Oxalate (A.O.). The results indicated that Olsen and Mehlich 3 extractants can be used in neutral to alkaline Inceptisol and Vertisol to develop DPS. In acidic Alfisol and Ultisol Bray1, Bray2, M3 and A.O. can be used. Column leaching study was carried out with eleven leaching events to determine P movement and distribution. In Vertisol, Inceptisol, Alfisol and Ultisol the reactive P concentration in leachate ranged from 0 to 9.8 $\mu g\ mL^{-1}$, 0 to 12.3, 0 to 10.6 and 0 to 8 $\mu g\ mL^{-1}$ respectively in different P treatments. The lowest P movement in soil was found in Ultisol followed by Alfisol, Vertisol and Inceptisol. In pot experiment conducted with maize crop, dry matter yield in all the four soil orders indicated that in both Vertisol and Inceptisol, the highest grain yield per plant was obtained in P5 treatment and in Alfisol and Ultisol, it was found in P4 and P5 treatments, respectively.

For determining DPS threshold values for crop yield and environmental pollution for the four soil orders M3 and A.O. can be preferred over routine STP like Bray and Olsen. The productivity and environmental threshold differ in different soil orders and also with the extractants but the trend and the general conclusions remain the same (Table 2.1.1). The results obtained with the extractant Mehlich 3 revealed that the Inceptisol are most vulnerable for P leaching because they have the minimum environmental threshold. This is followed by Alfisol, Ultisol and Vertisol which are less susceptible to P leaching.

Table 2.1.1 Productivity and environmental threshold for DPS in four soils

Soil type	Productivity threshold (%)	Environmental threshold (%)
Vertisol		
DPS_{M3}	16.0	37.5
$DPS_{A.O.}$	11.7	19.3
DPS_{OL}	20.5	52.7
Inceptisol		
DPS_{M3}	2.5	15.6
$DPS_{A.O.}$	3.1	8.10
DPS_{OL}	3.2	29.1
Alfisol		
DPS_{M3}	4.9	27.6
$DPS_{A.O.}$	4.0	11.2
DPS_{By1}	6.8	33.0
Ultisol		
DPS_{M3}	10.3	30.8
$DPS_{A.O}$	6.7	14.5
DPS_{By1}	16.2	45.9

2.1.2 Soil fertility status of Alirajpur District, Madhya Pradesh

Geo-referenced surface soil samples were collected from the farmers' fields of tribal district Alirajpur (MP). About 90 villages were selected randomly and based on the socio-economic status, 6 farmers were selected in each village (2 farmers each in marginal and small, medium and large categories), and the total number of collected samples were 540. Most of the soils in the district were found to have neutral to alkaline pH, medium to low organic carbon, low to medium available P and medium to high available K (Fig. 2.1.1). Soils with alkaline pH were observed in Jobat, Alirajpur and part of Sondwa and Udaigad blocks. Soils of Alirajpur and Babhra blocks were found low in SOC content. The low available P status was found in soils of Sondwa, Kattiwada and Udaigad blocks. Soils of Sondwa, Jobat and Babhra blocks were high and other parts were medium in available K content.

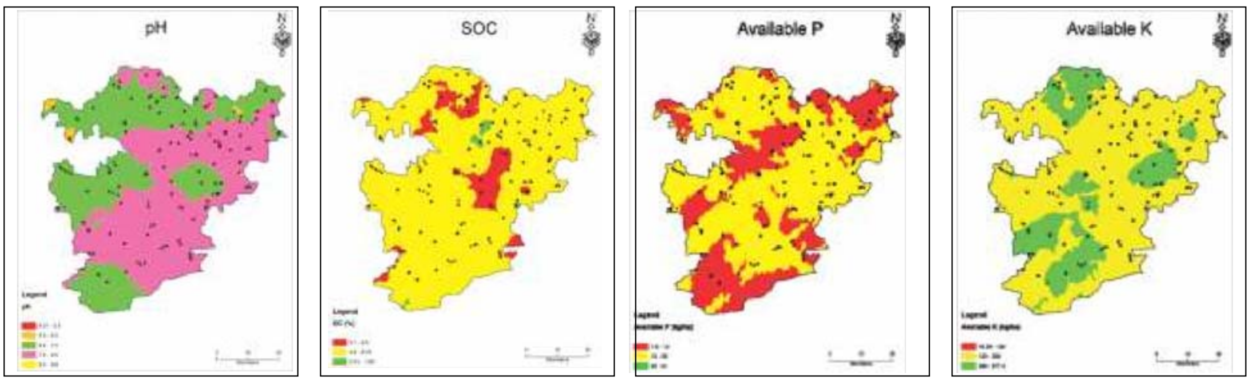


Fig. 2.1.1 Soil pH, SOC, available P and K status of Alirajpur (MP) with sampling points

2.1.3 Delineation of micro- and secondary nutrients deficient areas

Compilation of GPS based soil sample analysis results was done in order to have comprehensive picture of micro- and secondary nutrients deficiencies. Total 63,243 soil samples from 12 states of the country were collected by different AICRP (MSN) centres and analyzed for available sulphur (Table 2.1.2). Among the states, 46.5% soils of delineated districts of West Bengal were low in available S (<10 ppm S) marginally followed by Bihar (46.4%), Gujarat (43.3%), Haryana (35.8%) and Uttar Pradesh (32.5%). Interestingly, sulphur deficiency was more than 20% in all states, except in Tamil Nadu (16.5%). Overall, S deficiency in Indian soils (27.8%) is a cause of concern for farmers and other stake holders. Among micronutrients, 39.9% of samples collected across the country (70,759 samples from 174 districts of 13 states) were deficient in available Zn which varied among states with a minimum of 8.0% in West Bengal to as high as 62.2% in Tamil Nadu (Table 2.1.2). The Fe deficiency in India stayed close to 13% but in some of the states like Gujarat (23.6%), Maharashtra (22.8%), Haryana (21.6%) and Andhra Pradesh (17.3%), its deficiency is increasing rapidly. On an average, Mn deficiency in the country was 6.0% but in Punjab (26.8%) and Haryana (10.8%), its deficiency is coming in a big way. The overall Cu deficiency (4.3%) is close to the Mn but its extent is high in Tamil Nadu and West Bengal.

Table 2.1.2 Status of sulphur and DTPA-micronutrients deficiency in different states

State	Sulphur		Micronutrients				
	No. of samples	Percent deficient samples (PDS)	No. of samples	Zn	Fe	Mn	Cu
				PDS			
A. P.	5795	29.1	9780	22.8	17.3	2.9	1.5
Assam	5146	21.6	5146	27.4	8.6	0.0	3.9
Bihar	2963	46.4	2963	44.2	5.8	2.9	2.7
Gujarat	5218	43.3	5218	34.2	23.6	6.6	0.4
Haryana	5673	35.8	5673	15.3	21.6	6.1	5.2
M. P.	5632	25.7	6713	60.3	9.8	1.6	0.2
Maharashtra	7819	25.5	7819	53.7	22.8	4.0	0.2
Odisha	2621	29.7	2621	20.5	1.7	1.0	0.3
Punjab	-	-	1098	21.9	5.8	26.8	3.5
Tamilnadu	14557	16.5	14557	62.2	9.5	8.9	13.1
U. P.	3950	32.5	4788	33.1	7.6	6.5	6.3
Uttarakhand	2212	20.9	2212	9.8	1.7	5.5	1.4
West Bengal	1657	46.5	2171	8.5	0.8	1.7	1.1
Overall	**63243**	**27.8**	**70759**	**39.9**	**12.9**	**6.0**	**4.3**

From the results of 52,423 samples analyzed for available B, deficiency of B in highly calcareous soils of Bihar, Odisha and Gujarat are more common (Fig. 2.1.2). Little more than half of the samples analyzed from Odisha state fell in the category of low B availability followed by West Bengal (46.3%), Gujarat (35.1%), Bihar (33.2%), and Assam (17.7%). Interestingly, in Uttar Pradesh also 16.2% soils were found to be low in B availability which was little higher than another intensively cultivated state Tamil Nadu (10.2%).

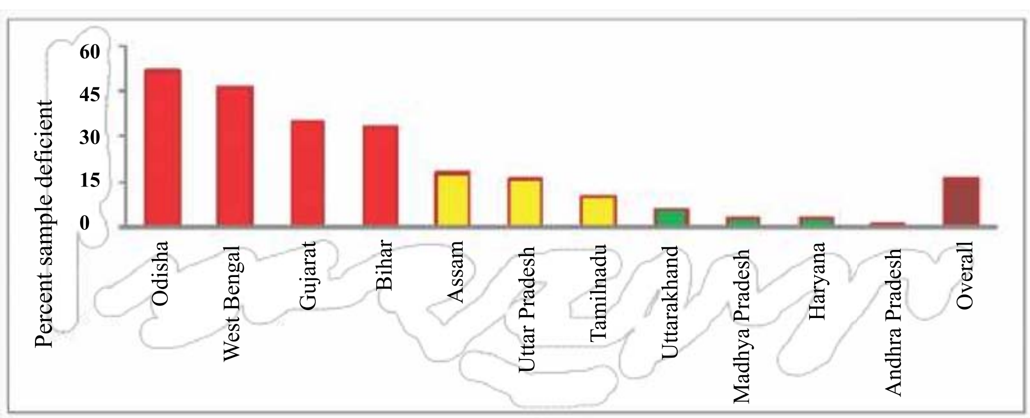


Fig 2.1.2 Deficiency status of boron in soils of different states

2.1.4 Decision Support System for Soil Health Assessment and Soil Test Crop Response Based Plant Nutrient Management

User friendly interactive software to provide readymade solutions for various soil situations, to user's requirement is being developed. While in use, the first screen of the software displays different states for which information can be generated, on clicking the state name the soil health parameters menu can be accessed and space for filling the values for different physical and biological parameters will be displayed. After furnishing desired information the soil health status, causes and recommendations will be generated. After this the user can furnish values for various soil chemical properties. After furnishing the values and clicking on "Determine chemical health" button the assessment of soil chemical health status, will be generated and the space for making choice of season, crop, varieties, yield etc. will be displayed to the user. After making all the entries the crop nutrient requirement to obtain the desired yield level based on soil test crop response equations will be displayed and after selecting type of fertilizers available with the farmer their quantities to be applied will be generated. The software is also being provided with an inbuilt system to analyze various problematic situation and accordingly wherever necessary will advice the quantity of soil amendments to be applied to maintain soil health.

2.2 Improving Input use Efficiency

2.2.1 Study on nanoporous zeolites for soil and crop management - Density functional theory (DFT) based pore volume distribution patterns of fractions of Clinoptilolite

To understand the pore volume distribution patterns of fractions of clinoptilolite collected from St. Cloud Mining Co, New Mexico, USA, the material was divided into three physical fractions using mechanical sieves (fraction 1, <125 μ (Z8); fraction 2, 125-250 μ (Z9) and fraction 3, >250 μ (Z10)). Each fraction was washed up with distilled water to remove dirt and extraneous materials causing turbidity and was air dried. The adsorption/desorption isotherms of the samples showed inverted-S-shaped curves. The pore volume distribution over pore diameter was expressed in terms of the distribution function f (v) = - (dV/d logD), where 'V' is pore volume and 'd' is the pore diameter. The function is such that area under the function in any pore diameter range yields volume of pores in that range. The pore-size/volume distribution function of a porous medium is very important, since it influences the transport and equilibrium of molecules adsorbed in the structure. The density functional theory (DFT) based method for the calculation of pore size/volume distribution of zeolites from nitrogen adsorption isotherms is a standard characterization procedure in recent years. Considering the micropore region of the fractions, differential pore volume distribution patterns for the three fractions have shown sharp minima/parallel to the X axis between 1.6 nm and 6 nm. There was no peak point for adsorption for the 1-2 nm region, which might be due to the artificial layering steps inherent to the theoretical isotherms causing artificial gaps on the calculated pore size distributions around 1 and 2 nm (Fig. 2.2.1 a & b).

DFT theory models the physical adsorption process at the fluid-solid interface, as the adsorbing gas condenses at the surface of a solid. Density profiles are calculated over a range of relative pressures that reflect the density of the gas with distance from the surface. Porosity distribution was studied by original density functional theory method N_2 @ 77°K on carbon, slit pores, and non-negative regularization method without smoothing. The occurrence of the minima at the same positions for different fractions seems to be a model-related artifact. In this region there was no change in the adsorption for each incremental increase in the pore width, irrespective of the fraction. In the mesopore region, there were only two peaks at 35 and 40 nm with a zig-zag distribution pattern. In the macro pore region, upto 170 nm pore width, the pattern was zig-zag for all the fractions but thereafter it followed the exponential curve. However, between 170-175 nm pore widths, the fractions behaved differently. Z9 and Z10 exhibited a sigmoid curve with peaks at 230 and 280 nm respectively. Z8 have a downward trailing curve which is unusual. There is typically a low pressure region, where DFT under predicts the course of adsorption, whilst at high pressure it over predicts it.

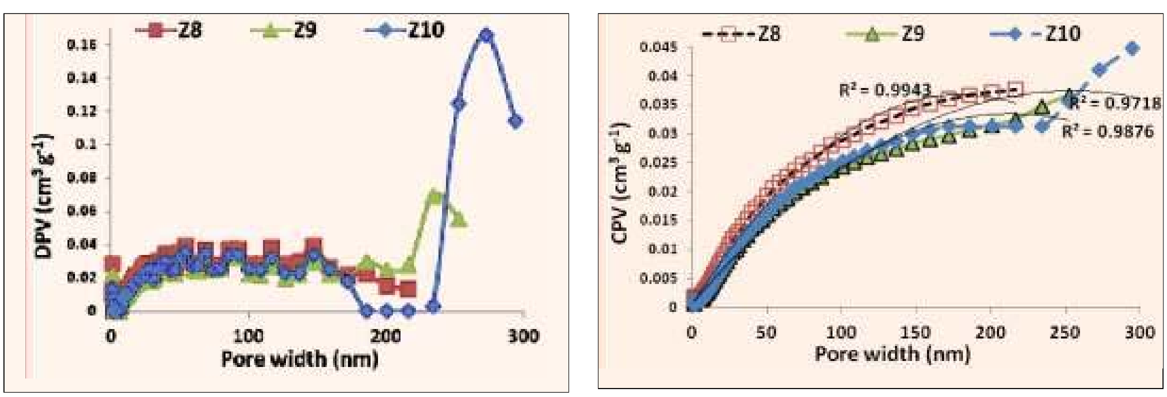


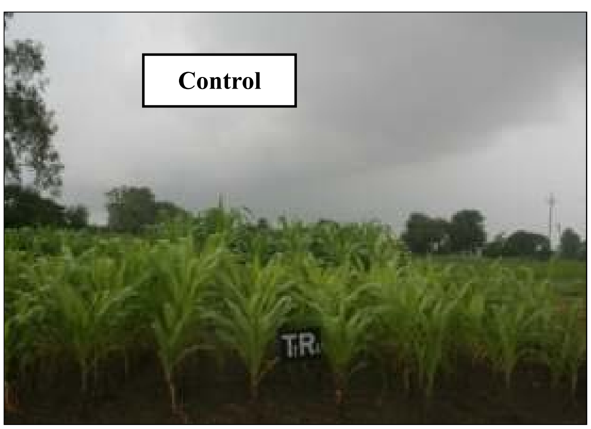
Fig. 2.2.1. Differential pore volume (DPV) (a) and Cumulative pore volume (CPV) (b) distribution pattern for Clinoptilolite fractions (DFT model)

2.2.2 Nano-technology for enhanced utilization of native phosphorus by plants and higher moisture retention in arid soils

Efficacy of nano rock phosphate in multi location trials

Multi location (Akola, Pantnagar, Bhubaneshar, Hyderabad and Anand) field trials (Plate 2.1, 2.2 and 2.3) of nano rock phosphate (NRP) were conducted to investigate the efficacy of nano rock phosphate for different cropping systems like soybean-chickpea, rice-wheat, rice-rice, rice-rice, and maize-wheat in Akola, Pantnagar, Bhubaneshar, Hyderabad, and Anand respectively. The results for the first crop (soybean, rice, maize) showed that crop utilization of P from nano rock phosphate was at par with that of P from SSP while yield response to P from nano rock phosphate was marginally lower than P from SSP but much more economical. A field experiment was also conducted with treatments *viz.* Control, NK (100 %), NPK (100 %), NK (100 %) + 30 kg P_2O_5 as Sagar Nano-R/P, NK (100 %) + 45 kg P_2O_5 as Sagar Nano-RP, NK (100 %) + 60 kg P_2O_5 as Sagar Nano-RP, on maize (variety GK 3017) to determine the dose of nano rock phosphate in comparison to conventional P fertilizer. Experimental results of the field trial revealed that application of nano rock phosphate @ 45 kg ha^{-1} to maize crop was as effective as @ 60 kg ha^{-1} DAP application.

Plate 2.1 Mixing of nano rock phosphate with FYM at OUAT, Bhubaneswar



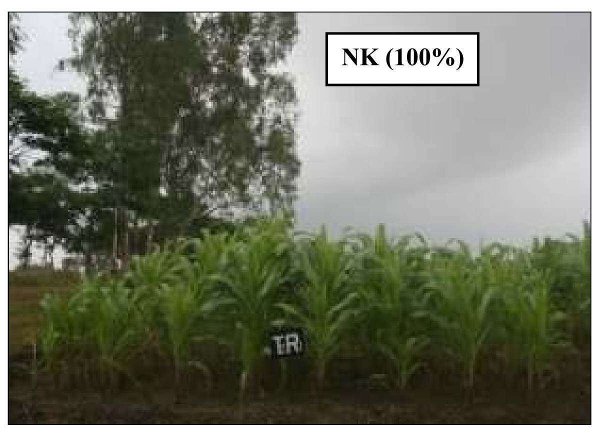


Plate 2.2 Effect of nano rock phosphate on growth of maize crop at AAU, Anand

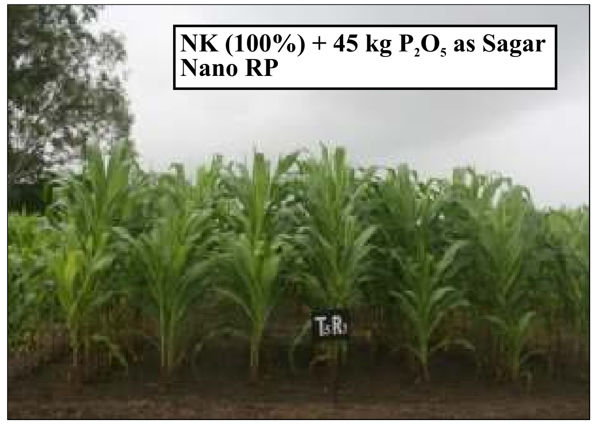


Plate 2.3 Effect of nano rock phosphate on growth of maize crop at Bhopal, Farm

Protocol for application of nano rock phosphate (NRP) for crop production

Protocol for the coating of nano rock phosphate (~48.8 nm, 34% P_2O_5) with pine oleoresin (POR) coated urea involved the dissolution of 20% POR in commercial petrol. The requisite amount of urea (1kg) was mixed with above solvent (250 mL) in the ratio of 4:1 in a wide mouth glass bottle and shaken for 5 minutes. Immediately after mixing, the whole content was transferred to a plastic tray fitted snugly on a horizontal shaker. After the start of the shaking operation, requisite amount of nano rock phosphate was spread through a 53 micron sieve over the POR coated urea and shaking operation was continued with maximum speed for an hour with intermittent scrubbing with a hard brush. After the complete evaporation of solvent (petrol), the product *nano rock phosphate coated urea* became loose and friable and thereafter kept in oven (50-60°C) for an hour for hardening.

Packaging of nano particles as a fertilizer product

Nano rock phosphate (NRP) was coated with the different materials *viz*. (i) Oleic acid (ii) mixed with FYM (iii) Pine oleoresin, (iv) Linear alkyl benzene sulphonate (LAS) (v) Gum acacia, and mixed with POR coated urea with different percentage of NRP (15, 20, 25 and 35%) for direct application in field. Field study and pot culture experiments revealed that the tested coating materials are useful to coat the naked NRP and the products are promising alternatives of conventional phosphatic fertilizer for crops like wheat and maize.

Effect of Pine oleoresin coated urea on maize performance

A study was conducted with maize in Vertisol, Inceptisol, Alfisol and Aridisol to evaluate the efficacy of the pine oleoresin coated urea fertilizers (coated with 1.25, 2.50, 3.75 and 5.0% pine oleoresin) using petrol as a solvent. The N content of resultant final products (coated urea) was 45.4, 44.8, 44.3 and 43.8%, respectively. In all the four soils, application of N @138 ppm as uncoated urea resulted significant increase in biomass yield of maize to the tune of 46.2, 57.1, 88.3 and 69.2%, in Vertisol, Alfisol, Inceptisol and Aridisol, respectively over the control (without N). Further, application of equivalent amount of N through urea coated with increasing amount of POR (ranging from 1.25-5.0% POR) showed increasing trend in biomass yield of maize in all the four soils. In Vertisol, Alfisol and Aridisol, significant increase in biomass yield was observed when urea was coated with POR @ 3.75% or more, while in Inceptisol significant increase in biomass yield was observed with urea coated with POR @ 2.5% or more. The increase in biomass due to coated urea application might be attributed to sustained release of N for the crop. The slow release of N from coated urea inhibits urease activity through antibacterial properties and reduces volatilization loss by acidifying alkaline micro-sites in soil.

The N use efficiency (*i.e*. ratio of N removed by the harvested crop from fertilizer N to total N applied as fertilizer) of urea fertilizer increased remarkably, ranging from 19.3 to 32.8% in Vertisol, 13.0 to 28.2% in Alfisol, 13.8 to 23.8%

in Inceptisol and 10.6 to 20.2% in Aridisol, due to coating of urea with POR. Application of urea coated with 2.5% POR showed significant improvement in N use efficiency over uncoated urea in both Vertisol and Alfisol, but as the content of POR increased to 3.75%, the N use efficiency increased with a higher magnitude from 23.38 (with 2.5% POR) to 29.95% in Vertisol and from 17.69 (with 2.5% POR) to 25.65% in Alfisol. Further increase of POR content (5.0%) in urea did not show significant improvement in N use efficiency. However, in Inceptisol and Aridisol, application of urea coated with 1.25% POR showed significant improvement in N use efficiency over uncoated urea and there was gradual increase in N use efficiency with the increase in POR content from 1.25 to 5.0%. Maximum N use efficiency in Inceptisol (23.86%) and Aridisol (20.23%) was observed with urea coated with 5.0% POR.

2.2.3 Nanoparticle delivery and internalization in plant systems for improving nutrient use efficiency

The impact of nanoparticles on growth and metabolism of plants *viz*. wheat and maize was studied under hydroponic system using ZnO, CuO and Fe_3O_4 nanoparticles. Various growth parameters *viz*. plant height, root length, shoot biomass, root biomass and chlorophyll content were recorded at different duration of growth up to 45 days after sowing (DAS) (Fig.2.2.2). The activity of antioxidant enzymes *viz*. SOD, catalase and peroxidase were recorded in maize and wheat plants treated with nanoparticles to ascertain their impact on plant metabolism. The nanoparticles *viz*. ZnO, CuO and Fe_3O_4 were analyzed in Transmission Electron Microscope (TEM) for characterization of size and shape (Plate 2.4)

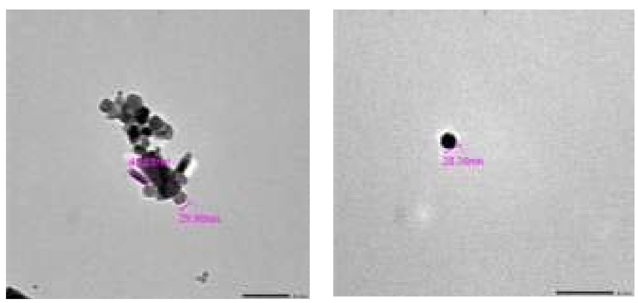


Plate 2.4 a) TEM of ZnO nanoparticle b) TEM of CuO nanoparticle

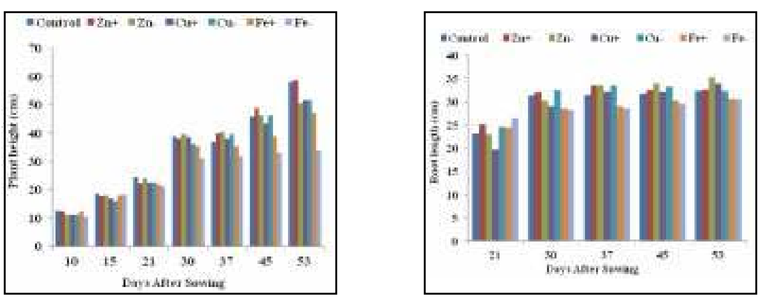


Fig. 2.2.2 Plant height and root length of wheat treated with micronutrients containing nanoparticles

2.2.4 Evaluation of plant nutrition product (NP1) for nutrient use efficiency in cereal crops

The plant nutrition product (NP1) was evaluated during *rabi* 2012 in combination with various treatments involving conventional fertilizers in wheat variety Malwa shakti for improving nutrient use efficiency (plate 2.5). The crop growth including morphological and physiological parameters, yield and nutrient use efficiency (NUE) of crop was recorded. The nutrient product did not exhibit any significant effect on grain yield in comparison to urea N (Table 2.2.1). However, NUE was found to be moderately higher with 50% and 75% of the NP1 product.

Plate 2.5 Effect of NP1 Product on wheat performance

Table 2.2.1 Effect of fertilizer product on plant yield attributing parameters and NUE of wheat

Treatment	Grain Yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index	NUE (%)
CF 100N + 100PK	4.80	9.9	0.49	36.63
CF 75N + 100PK	4.23	8.4	0.50	29.09
CF 50N + 100PK	3.46	8.2	0.42	26.80
CF 75N^{S} + 100PK	4.53	9.1	0.50	38.37
NP 100N^{S} + 100PK	4.26	8.3	0.51	21.21
NP 75N^{S} + 100PK	4.36	8.7	0.50	31.77
NP 50N^{S} + 100PK	4.13	8.4	0.49	57.73
NP 75N^{S} + 100PK*	4.20	8.5	0.49	40.87
NP 75N^{S} – P + 100K	3.80	7.7	0.49	12.54
0N + 100PK	3.53	6.9	0.51	0.00
0P + 100NK	4.33	9.5	0.46	42.24
100NPK by DAP	4.66	9.1	0.51	36.78
0NPK	2.90	5.9	0.49	0.00
CF 75 NPK + 5t FYM	4.40	9.8	0.45	44.17

*N^{S}–N as single dose, *- P adjusted, CF- Commercial Fertilizer, NP- Plant Nutrient Product 1*

Another field trial with Maize (hybrid PROAGRO) was conducted in *kharif* 2013 to study the effect of plant nutrition product (NP1) on the NUE (Table 2.2.2) (Plate 2.6). The effect of the product on morpho-physiological parameters like growth and yield attributing traits of maize crop was studied. The N status of the plants was also studied in the various treatments and N use efficiency was computed. The treatment with NP1 product produced lesser yield over urea N treatments in maize crop.

Plate 2.6 Maize and rice evaluated with NP1 product

Table 2.2.2 Effect of fertilizer product on plant yield attributing parameters and NUE of maize

Treatment	Grain Yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Total N uptake (kg ha^{-1})	NUE (%)
CF 100N + 100PK	4158	4836	76.80	41.59
CF 75N + 100PK	3931	4788	53.97	22.56
CF 50N + 100PK	3435	4688	52.17	21.06
CF 75N^S + 100PK	2863	4051	38.1	9.35
NP 100N^S + 100PK	2721	3926	36.81	8.27
NP 75N^S + 100PK	2670	3956	36.21	7.77
NP 50N^S + 100PK	2646	3296	35.94	7.54
NP 75N^S + 100K	2773	3931	36.10	7.67
NP 75N^S – P + 100K	2522	3216	30.47	2.98
0N + 100PK	2261	3167	34.52	0.00
0P + 100NK	3588	4983	53.83	22.45
100NPK by DAP	4276	5143	66.91	33.35
0NPK	1936	2808	26.89	0.00
CF 75 NPK + 5t FYM	2676	3923	36.66	8.14

*N^S – N as single dose, *- P adjusted, CF- Commercial Fertilizer, NP- Plant Nutrient Product 1*

2.2.5 Integrated assessment of some IISS technologies for enhancing agro-ecosystem productivity and livelihood sustainability

Adoption of the technologies by the farming community is important to enhance and sustain the agro-ecosystem health. To demonstrate some promising technologies in farmers' fields, a study was initiated of Meghra Kalan, in Berasia sub division of Bhopal district. The technologies chosen for demonstration are Integrated Plant Nutrient Supply System (IPNS); Use of Phospho-Sulpho-Nitro Compost; Soil Test based Fertilizer Recommendation (STCR); Broad Bed and Furrow Technique with Reduced Tillage; and application of Bio-fertilizers. Prior to demonstration, a Participatory Diagnosis for Constraints and Opportunities (PDCO) survey, was conducted and an inventory of the available resources of the village was prepared. The village represents farmers with a range of economic and social strata and has sufficiently large site variability in soil and other natural resources. Based on PDCO survey thirteen farmers were selected representing different economic strata. The cropping system selected for the study is soybean (JS-9560)-wheat (Lok-1/ Sujata). The seed inoculation was done in IPNS and phospho-sulpho-nitro compost application (Plate 2.7) treatments. Even though the general yield levels of soybean crop were suppressed, it still showed a yield increase of 14.3 % with IPNS, 25.9 % with phospho-sulpho-nitro compost, and 15.2% with STCR based fertilizer recommendations over farmers' practice (Fig.2.2.3). In the following wheat crop the percentage yield increase with the IPNS, phospho-sulpho-nitro compost, and STCR over farmers' practice were 13.7, 19.5, and 14.7%, respectively. The recommended seed rate was used in IISS technologies as against around 35% higher seed rate in the usual farmers' practice.

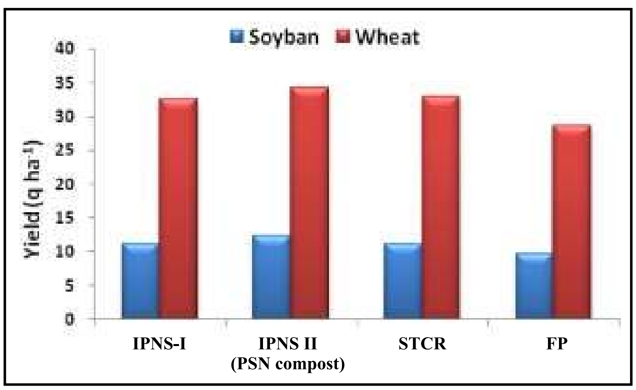


Fig. 2.2.3 Yield of soybean and wheat in farmers' fields in Meghra Kalan village
IPNS: Integrated Plant Nutrient supply, PSN: Phospho sulpho nitro, STCR: Soil Test Crop Response, FP: farmers' Practice

Plate 2.7 a. Wheat seed treatment with biofertilizer

Plate 2.7 b. Adjustment of seed rate Filling of treated seeds

2.2.6 Physiological as well as biochemical changes including metabolism of different crops as influenced by low and excess supply of micronutrient and pollutant elements

Effect of Cu supply on mustard varieties was studied and results showed that Cu deficiency symptoms were marked in variety Nidhi-1 and BIO-902 as compared to Pusa Bold and Neha. The specific activity of enzymes was also altered under Cu deficiency and toxicity. In black gram, total chlorophyll content decreased both at low (3.0 µM B) and excess B (60 µM B) supply. In another study, increase in Mo supply from low (0.002 µM) to adequate (0.2 µM), significantly enhanced the nitrogen use efficiency in cowpea by increasing dry matter, seed yield, 100 seed weight, Mo concentration, nitrate reductase activity and seed protein content. In order to find out suitable method of B application to cowpea, B applied either through roots (30µM) or spray (300 µM) could mitigate the visible effects of low B partially and recovered the growth and yield to some extent. In another experiment, Zn stress affected the uptake and translocation of nutrients in maize; for example, Fe and P uptake decreased in low and excess Zn supply, whereas Mn uptake decreased under low Zn and increased with excess Zn. Critical and toxic limits of Cd and B in soil as well as plants were established for Fenugreek and Toria. Available sulphur in medium black soils of Dewas district was extracted with 0.15% $CaCl_2$ and Morgan's extractants which registered a significant correlation (r=0.85** and r=0.81**, respectively) with Bray's per cent yield of linseed.

2.2.7 Amelioration techniques for micro- and secondary nutrients deficiency

At Bhavanisagar in Tamil Nadu, IPNS technology involving combined application of FYM at 12.5 t ha^{-1} with $ZnSO_4$ at 37.5 kg ha^{-1} to the main crop (*Kharif*) alone performed better in increasing the cumulative rice productivity in rice-rice cropping system in a zinc deficient soil. In Odisha the highest yield of 4.53 t ha^{-1} was obtained when Zn was applied @ 2.5 kg ha^{-1} with FYM to rice. At Pantnagar, foliar spray of 2 kg Zn ha^{-1} at 30 and 60 days after planting increased the grain yield of basmati rice by 8.8% over the no Zn control. In other experiment at Jabalpur, 0.5% salt spray of Zn-EDTA, $ZnSO_4$ and $Zn_3(PO_4)_2$ were used to ameliorate the Zn deficiency in crops. In a field experiment on Inceptisol of Bhubaneshwar, application of B @ 1 kg ha^{-1} gave significant and the highest grain yield (5.04 t ha^{-1}) of rice which was 39% higher than control. At three locations in Maharashtra, the highest grain yield of soybean was observed with application of Zn @ 5 kg ha^{-1} which was significantly superior over all the treatments followed by application of B @ 1 kg ha^{-1}. In iron toxic soil, application of K @ 40 kg ha^{-1} and Zn @ 5.0 kg ha^{-1} along with recommended dose of fertilizer gave the highest grain yield of rice which was increased by about 19 per cent over control. Application of different concentration of micronutrients helped in increasing the green fodder yield of jowar significantly, the highest green fodder yield of 21.67 t ha^{-1} was recorded due to combined application of micronutrients of 0.5% Cu, Zn, Fe, Mn and 0.05% B.

2.3 Monitoring Long Term Productivity

2.3.1 Long – term evaluation of integrated plant nutrient supply modules for sustainable productivity in a Vertisol

Grain and stover yield of maize was influenced due to application of various integrated plant nutrient supply modules. Grain yield and total dry matter yield of maize was the highest for STCR based recommended dose of fertilizers which was at par with GRD and FYM based INM module (Table 2.3.1). All the INM modules, irrespective of sources of organics, were at par in recording grain and dry matter yield. Among the different INM modules, the highest total nitrogen uptake by maize crop was recorded under the FYM based INM module (75% NPK of T3 +5 t FYM) followed by GRD which was at par with STCR based recommended dose of fertilizers (Table 2.3.2). Among the different organic manures, yield performances at different treatments seemed to have better linkages with freshly applied N (rather than total NPK) taking both organic and inorganic sources into account. While total phosphorus and potassium uptake was the highest under the STCR based recommended dose of fertilizers which was at par with

GRD and FYM based INM module (Table 2.3.2). Maize yield of 6.85 t ha^{-1} and chickpea yield of 1.87 t ha^{-1} were achieved against the targets of 5 and 1.5 t ha^{-1}, respectively, and hence there is a need to enhance the yield target levels.

Table 2.3.1 Treatment details during *kharif* and *rabi* crops

Designation	Maize	Chickpea
T1 Control	No Fertilizer/ Manure	No Fertilizer/ Manure
T2 GRD	120- 60- 30	20-60-20
T3 RD (STCR)	135-55-50 (Target-5 t maize)	0-0-0 (Target-1.5 t chickpea)
T4	75% NPK of T3	100% P only
T5	75% NPK of T3 +5 t FYM	100% P only
T6	75% NPK of T3+ 1 t PM	100% P only
T7	75%NPK of T3 + 5 t UC	100% P only
T8	75% NPK of T3 +MR	100% P only+ MR as Mulch
T9	MR +1 t PM+Gly 2 t ha^{-1}	100% P only+ MR as Mulch
T10	MR + 5t FYM+Gly 2 t ha^{-1}	100% P only+ MR as Mulch
T11	20 t FYM (every season)	5 t FYM (Every Season)
T12	75% NPK of T3 +20 t FYM* (once in 4 years)	100% P only

PM-Poultry Manure, UC-Urban Compost, MR- Maize Residue, Gly- Glyricidia leaves

Table 2.3.2 Effects of integrated nutrient management (INM) modules on yields and nutrient uptake in maize- chickpea cropping sequence.

Treatment	Maize						Chickpea				
	Yield (t ha^{-1})			Total Nutrient Uptake (kg ha^{-1})			Yield (t ha^{-1})		Total Nutrient Uptake (kg ha^{-1})		
	Grain	Stover	Total	N	P_2O_5	K_2O	Grain	Straw	N	P_2O_5	K_2O
T1	2.99	5.08	8.07	52.3	17.3	40.5	1.06	2.15	29.7	10.9	42.5
T2	6.33	8.30	14.63	128.2	44.8	93.2	1.95	3.96	66.4	20.8	90.4
T3	6.85	8.95	15.80	125.2	50.5	103.0	1.87	3.97	59.1	22.5	79.0
T4	5.46	7.28	12.74	106.3	42.9	78.2	1.38	2.93	45.5	19.2	47.5
T5	6.66	8.52	15.18	143.6	49.9	105.9	1.89	4.43	65.0	26.8	75.9
T6	6.32	8.23	14.55	113.0	45.4	89.5	1.6	3.56	53.5	20.5	82.8
T7	6.08	7.94	14.02	115.9	44.7	82.3	1.78	3.96	53.7	23.1	88.9
T8	5.64	7.17	12.81	96.61	34.8	61.0	1.56	3.31	47.2	18.2	70.4
T9	4.51	7.26	11.77	92.91	37.8	70.5	1.72	4.01	63.4	24.7	93.9
T10	4.91	7.64	12.55	103.6	42.4	89.0	1.49	3.48	55.2	19.5	67.2
T11	6.17	8.67	14.84	120.8	50.4	110.6	1.92	4.48	69.6	26.4	98.0
T12	5.74	7.14	12.88	107.1	34.2	78.69	1.95	4.34	66.9	23.7	97.9
LSD(P=0.05)	0.52	0.46	0.77	16.6	15.2	14.1	0.28	0.69	11.7	3.3	4.8

2.3.2 Evaluation of organic, inorganic and integrated production systems

During the *kharif* 2013 season, there was a slight modification in the treatment structure (Table 2.3.3). The productivity of soybean crop in all the cropping systems was higher in organic nutrient management than integrated nutrient management (INM) and inorganic nutrient management. in organic management, the yield of soybean was found to be higher in 100% organic nutrient management practice than 75% organic + innovative practices. With respect to INM, 75% organic + 25% inorganic treatment was better than 50% organic + 50% inorganic treatment. Within the cropping systems, the yield of soybean was found higher in CS2 (Soybean-Mustard) under 100% organic treatment, 75% organic + 25% innovative treatment (Table 2.3.3). Similar results were followed in *rabi* season also, all the crops (wheat, mustard, chickpea and linseed) performed better under organic management followed by INM as compared to inorganic management. In organic management, the yield of all *rabi* season crops were found to be higher in 100% organic nutrient management practices than 75% organic + 25% innovative practices.

Table 2.3.3 Yield of crops during *kharif* and *rabi* season (kg ha^{-1}) under different management practices and cropping systems

CS	Organic management (as per NPOP standards)		Inorganic management		Integrated crop management	
	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5	Practice 6
Kharif						
CS1	511	475	423	430	451	473
CS2	533	487	362	391	399	481
CS3	456	489	389	412	425	490
CS4	511	459	383	403	391	461
Rabi						
CS1	2722	2689	2344	2422	2511	2656
CS2	1003	978	882	896	907	947
CS3	1478	1404	1163	1278	1319	1374
CS4	1393	1367	1244	1267	1315	1333

CS (Cropping Systems): (CS1) Soybean-Wheat, (CS2) Soybean-Mustard, (CS3) Soybean- Chickpea and (CS4) Soybean-Linseed

Practice 1- 100% organic (Organic manures equivalent to 100% N requirement of the system)
Practice 2- 75% organic (Organic manures equivalent to 75% N requirement of system) + Innovative organic practices
Practice 3- 100% inorganic package (No organic manures)
Practice 4- State recommendat ions or farmers package
Practice 5- 50% organic package + 50% inorganic package
Practice 6- 75% organic package + 25% inorganic package

2.3.4 Performance evaluation of important crop varieties under organic management practices

Three to four groups of varieties based on crop duration were selected in crops like wheat, soybean and chickpea and evaluated for yield performance under organic management practices (Plate 2.8). Twelve varieties each of soybean and maize with varying duration were grown during *kharif* of 2013 and chickpea and wheat varieties during *rabi*. The yield of soybean variety RVS-2002-4 was found to be the highest followed by JS-97-52 and JS-20-41. Two varieties Bragg and JS- 8021 failed due to heavy rainfall. Among the JS varieties, JS-97-52 and, among RVS varieties, RVS-2002-4 was found to give higher yield. The yield of maize variety Arawali recorded a maximum seed yield of 21q ha^{-1} while popcorn variety produced poor yield. The yield of chickpea variety JG-130 was higher followed byRVS-203 and JG-16. Among the JG varieties, JG-130 was found to give higher yield. The yield of wheat variety GW-366 recorded the maximum seed yield of 29 q ha^{-1} while C-306 produced low yield (Table 2.3.4). Among the HI varieties of wheat HI-1531 (wheat) was found to give higher grain yield.

Plate 2.8 Performance of different varieties of chickpea crop (Rabi 2013-14)

Table 2.3.4 Performance of different varieties of major crops under organic farming

Soybean	Seed yield (kg ha^{-1})	Maize	Seed yield (kg ha^{-1})	Wheat	Seed yield (kg ha^{-1})	Chickpea	Seed yield (kg ha^{-1})
JS -335	410	Kanchan	1339	C-306	2180	RVG -202	1734
JS -93 -05	392	Pratap 5	1098	HI -8663	2272	JG -16	1807
JS -95 -60	394	Arawali	2137	HI -1544	2546	JGK -3	1159
JS -20 -41	705	Sona 222	1410	Malwa shakti	2684	RVG -203	1870
NRC -7	671	Pratap 6	1265	GW -322	2493	JG -11	1489
NRC -37	423	JM 216	960	GW -366	2907	JG -6	1433
RVS -2002 -4	726	Popcorn 1	886	HI -1531	2718	JG -130	2152
RVS -2002 -6	384	JM 8	1537	HI -8498	2640	JG -315	1483
RVS -2002 -7	651	JM 12	1251	HI -1500	2461	JG -63	1736
JS -97 -52	723	Proagro 4412	1801	JW -1202	2708	JG -74	1467
Bragg	-	Sweet Corn	1171	HD -932	2383	VIRAT	1248
JS -8021	-	CPBG 4202	1633.5	LOK -1	2281	UJJWALA	963
CD (0.05)	48		272		275		215

2.4 Soil Quality and Resilience

2.4.1 Studies on soil resilience in relation to soil organic matter in selected soils of India

An investigation was made to the relationship between soil native carbon level and soil plasticity parameters in a clay loam soil. The soil was subjected to two levels of native carbon (C) depletion and thus yielding three carbon levels (C_1 – no depletion, C_2 – 33% depletion, and C_3 – 54% depletion). The C levels were treated with four management practices: M_1 (control), M_2 (50% RDF + 10 t FYM ha^{-1}), M_3 (20 t FYM ha^{-1}) and M_4 (150% RDF), and experiment was continued since *kharif* 2011.

To investigate the effect of soil C depletion on the soil plasticity parameters, soil samples of the clay loam soil were collected after four crop seasons and the test was carried out for plastic limit, liquid limit and plasticity index estimation. The data showed that the plastic limit and liquid limit reduced with depletion in soil C level, though the depletion was drastic from C_1 to C_2. Averaged over management treatments, the plastic limit reduced from 29% (g/g) under C_1 to 18% (g/g) under both C_2 and C_3 treatments. Upon management, the plastic limit of both C_2 and C_3 soils increased and the effect of M_3 treatment was higher (Fig.2.4.1).

The effect of soil C depletion was also observed in terms of liquid limit. The liquid limit reduced from 45% (g/g) under C_1 to 34 and 35% (g/g) under C_2 and C_3, respectively. Similar to plastic limit, the effect of management treatments was also conspicuous in reclaiming the liquid limit from the depleted soil C levels. Among the treatments, M_3 showed best reclamation effect. The plasticity index (PI) was computed from the difference between plastic limit and liquid limit. When estimated for the treatments, there was a trend of increase in PI, though not much variation was observed between the treatments.

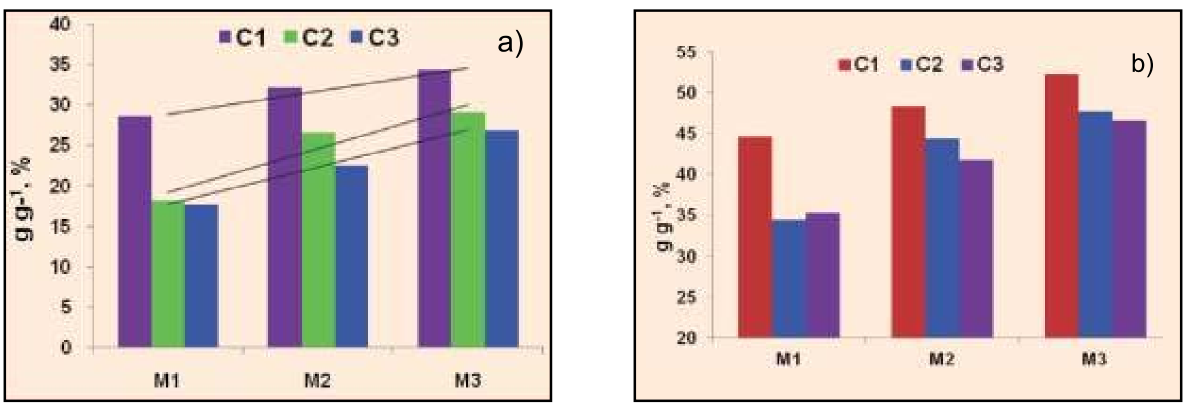


Fig. 2.4.1 Effect of management treatments on plastic limit (a) and liquid limit (b)

2.4.2 Factors affecting potential carbon mineralization (PCM) in soil

Potentially organic C mineralization (PMC) indicates the total metabolic activity of heterotrophic microbes releasing labile organic carbon as CO_2. The investigation was carried out using the samples collected from different land use systems (agriculture, fallow and forest) from three different agro-ecological regions of the country (Palampur, Jabalpur, and Ranchi). All together 14 soil samples having different soil and climatic conditions were used for determining potential carbon mineralization by conducting long-term incubation studies (247 days). The amount of C evolved in the form of C-CO_2 during different time intervals of incubation study was used for computation of PMC in soil. The cumulative C-CO_2 evolved during different time intervals were fitted with non-linear regression using statistical software. PMC and decay constant were computed for different soil types and land use systems (Table 2.4.1). PMC ranged from 61.9-146.1 mg C-CO_2 evolved 100 g^{-1} soil whereas decay constant of

PMC ranged from 0.013 -0.041 day^{-1}. Subsequently 12 variables including soil and climatic conditions were subjected to Principal Component Analysis technique for determining the factors responsible for PMC in soil. Finally, it was observed that silt, clay and C: N ratio are the main factors which are affecting potential carbon mineralization in Indian soil. Subsequently, a model for computation of PMC in soil has been developed.

Table 2.4.1 Potential mineralizable carbon content of soil in different agro-climatic locations of India

Locations	PMC mg C 100 g^{-1} soil	PMC (% of TOC)	Decay constant day^{-1}	MRT* days
Vertisol				
Control	81.08	6.8	0.0496	20.2
Jabalpur NPK	78.28	5.8	0.045	22.2
Jabalpur NPK+FYM	111.91	6.4	0.064	15.6
Jabalpur Fallow	118.01	5.9	0.054	18.5
Bhopal Forest	308.68	8.8	0.015	64.9
Bhopal-Agriculture-1	67.24	8.2	0.019	53.2
Bhopal-Agriculture-2	160.31	12.9	0.015	67.1
Bhopal-Agriculture-3	102.61	10.3	0.017	58.8
Alfisol				
Control	32.87	3.0	0.069	14.5
Palampur NPK	70.23	5.3	0.048	20.8
Palampur NPK+FYM	82.34	4.7	0.065	15.5
Palampur Pine forest	105.21	4.2	0.057	17.6
Alfisol				
Control	35.81	6.2	0.041	24.2
Ranchi-NPK	48.76	6.5	0.042	24.0
Ranchi-NPK+FYM	55.48	5.9	0.05	20.2
Ranchi-PMT NPK	56.94	5.6	0.05	20.0
Ranchi-PMT FYM	102.03	5.9	0.055	18.2
Ranchi-PMT Fallow	73.02	5.7	0.054	18.5
Agra-agriculture land	67.80	11.3	0.014	71.0

** MRT- Mean residence time TOC-Total organic carbon PMT- Permanent Manurial Trial*

2.4.3 Soil carbon dynamics in permanent manurial trial of Ranchi

The soils samples were obtained from permanent manurial trial of Ranchi and analysed for soil carbon sequestration rate and carbon pool dynamics under different treatments. It was observed that application of FYM invariably increased total organic C and carbon in mineralizable and passive pool in all the treatments (Fig. 2.4.2). Application of lime along with NPK was found good for sustaining crop yield but failed to increase soil carbon content. This was probably due to the lime induced rapid carbon mineralization.

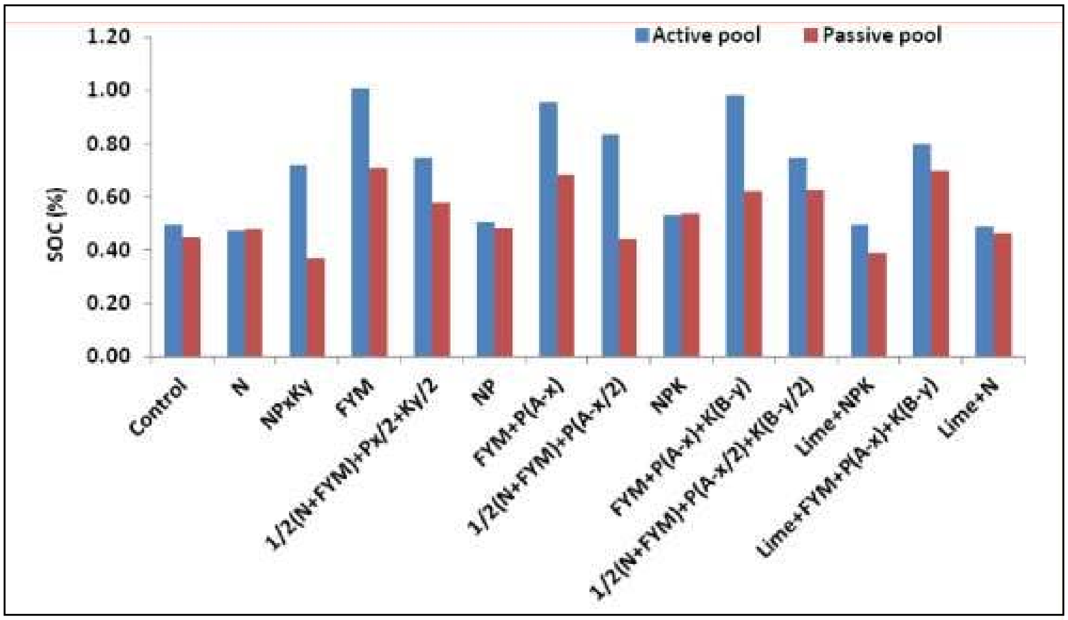


Fig. 2.4.2 Soil carbon dynamics in permanent manurial trial of Ranchi

2.4.4 Biochar effect on wheat and spinach performance

Pot culture studies were carried out to assess the effect of biochar application on wheat and spinach performance. Biochar application was done with and without FYM and inorganic fertilizers. The wheat grain yield varied from 6.9 to 11.8 g pot^{-1}. Application of biochar alone increased the wheat grain yield by 28.4 per cent over control (Fig. 2.4.3). Application of inorganic fertilizers alone increased the yield by 32.6 per cent over control. Combined use of biochar + FYM along with NPK resulted in about 16.8 per cent higher grain yield over normal fertilizer application. A similar trend was also observed in case of wheat straw yield. Likewise, biochar application also improved spinach performance. The leaf yield of spinach at first stage increased 63 per cent with biochar application alone. Use of biochar and FYM along with NPK resulted in 40 and 25 per cent increase in leaf yield over 100 % NPK application, respectively during first cutting (Fig. 2.4.4). The effects were also visible during second cutting of spinach leaves. The mean yield of the spinach increased by 49 per cent with application of biochar along with inorganic fertilizers as compared to inorganic fertilizer application alone. The full benefit of biochar application could be made by using it with FYM, though the benefits were not additive. (Plate 2.9 a & b)

Plate 2.9 a)Biochar effects on performance of wheat

b) Biochar effects on performance of spinach

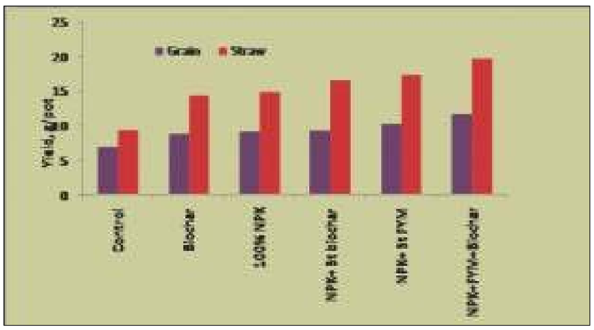


Fig. 2.4.3 Effect of biochar on wheat yield

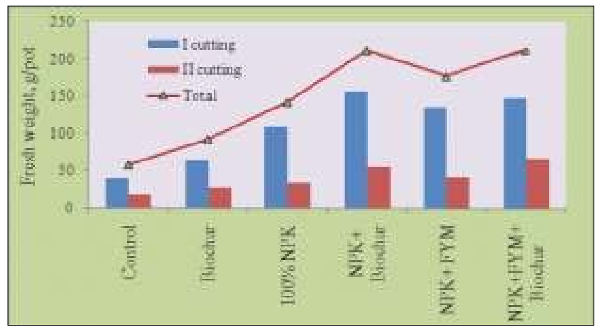
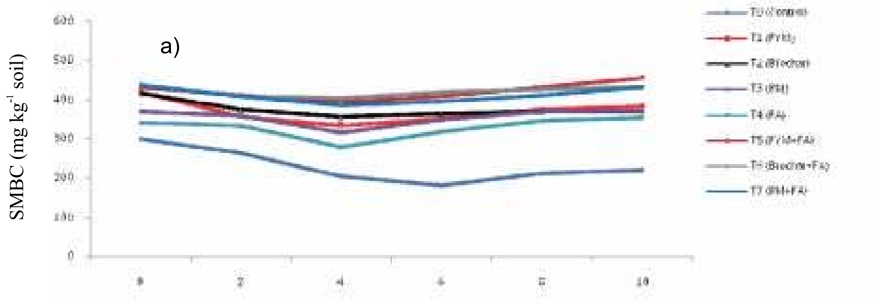


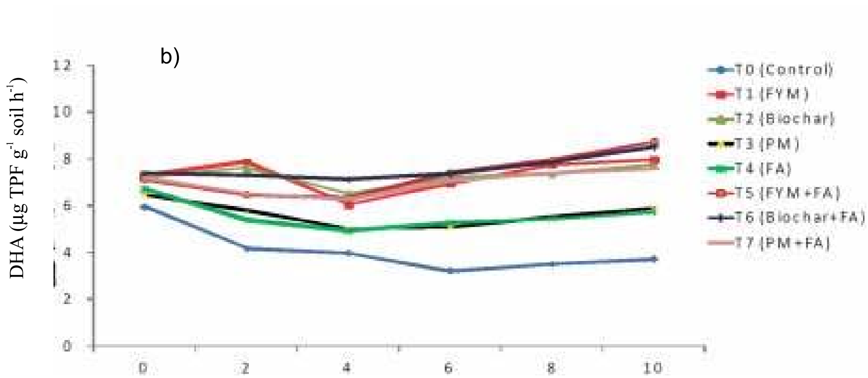
Fig. 2.4.4 Effect of biochar on fresh leaf yield of spinach

2.4.5 Soil resilience /recovery rate as influenced by organic amendments in Vertisol

An Incubation study was conducted ascribing the recovery rate of Vertisol under various organic amendments i.e. FYM, biochar and, poultry manure @ 25 t ha^{-1} and fly ash @ 1% weight of soil with and without Cu stress. The physical indicators of resilience *viz*. Californian Bearing Ratio (CBR) and resilient modulus values were the highest in the treatments FYM + fly ash (2.79% and 28.88 MPa, respectively) followed by poultry manure + fly ash (2.25% and 23.28 MPa, respectively) depicting their higher strength due to addition of fly ash. Study showed that application of Cu stress significantly reduced the soil microbial biomass carbon (SMBC) and dehydrogenase enzyme activity (DHA) from 0 to 6 week in un-amended soil and from 0 to 4 week in soil amended with various amendments (Fig. 2.4.5). Soil without amendment showed the lower resistance, hence higher reduction in SMBC and DHA (40.20 and 46.13%, respectively) followed by other treatments (range 7.92–20.97 and 3.44–26.76 %) at the end of 4-6 weeks after incubation. The resistance capacity of the soil studied under Cu stress is found better either in biochar (0.66) or biochar + fly ash (0.67) treatment. The maximum soil resilience index was found under FYM + fly ash (0.74) followed by other treatments. It is also evident from the data on recovery rate in SMBC and DHA under various treatments. The minimum reduction in SMBC and DHA value at 4 weeks after incubation was found in those treatments with biochar (7.92 and 14.39% for SMBC; 3.44 and 9.76% for DHA), whereas in other treatments the reduction ranges in between 14.65 and 40.20% for SMBC and 11.62 and 46.13% for DHA. However, the recovery from 4-10 weeks after incubation was the highest under FYM + fly ash treatment (25.71 and 38.10% for SMBC and DHA, respectively) followed by poultry manure + fly ash treatment (22.02 and 31.66% for SMBC and DHA, respectively). Biochar, being an inert material having recalcitrant carbon, may be more helpful for soil resistance, whereas the other organic amendments like FYM or poultry manure in association with fly ash are more beneficial for resilience/recovery of Vertisol.



Weeks after incubation with Cu stress



Weeks after incubation with Cu stress

Fig. 2.4.5 SMBC (a) and DHA (b) status of various treatments throughout the incubation study after Cu stress

2.5 Biofortification

2.5.1 Biofortification of grain sorghum & finger millet varieties with zinc through agronomic measures

In a dietary food, mole ratio of phytic acid to zinc is an important factor for determining potency of zinc bioavailability. This index has been used widely and considered as a good index for zinc bioavailability by World Health Organization and International Zinc Nutrition Consultative Group. In a Zn biofortification study on sorghum and finger millet, the phytic acid to zinc mole ratio in the different treatments and genotypes are shown in Fig. 2.5.1a and b. In sorghum, the high zinc genotypes showed higher bioavailability in all the treatments of different mode of zinc application (T_1= Control, T_2 = Zn with NPK, T_3 = Zn with FYM, T_4 = Zn with EDTA). Based on control treatment, the average zinc was around 30 ppm. Above 45 ppm is normally classified as high zinc genotypes while 30 to 45 is considered medium and below 30 ppm as low zinc genotype. The ranges of mole ratio were 1.02 to 0.75 in high, 1.07 to 0.80 in medium and 1.02 to 0.85 in low genotypes, respectively. The chemical treatments T_2 and T_4 seem to promote the bioavailability. Similarly, in finger millet, genotypes had no significant effects, while the T_2 and T_4 showed similar effect on bioavailability.

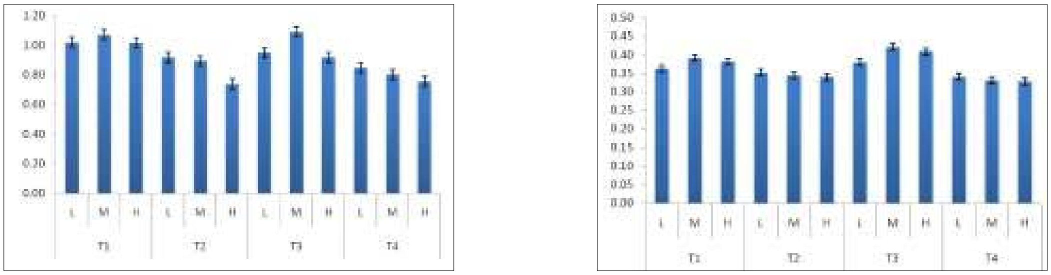


Fig. 2.5.1 a&b Phytate: Zn molar ratio in sorghum and finger millet

Theme II: Conservation Agriculture and Carbon Sequestration *vis a vis* Climate Change

2.6 Conservation Agriculture and Climate Change

2.6.1 Effect of conservation tillage on crop yields

A study was laid out in a split-plot design with two tillage treatments namely conventional tillage (CT) and reduced tillage (RT) along with six cropping systems i) soybean- Fallow, ii) maize- gram, iii) soybean- fallow, iv) soybean + pigeon pea (2:1), v) soybean+ cotton (2:1) and vi) soybean– wheat. Total rainfall received during 2012 was 966.8 mm of which 886 mm was received during the crop growth period. Yield parameters were recorded during third crop cycle and yield data were converted into soybean equivalent yield (q ha^{-1}). The study revealed that tillage had no effect on soybean grain equivalent after three years of crop cycle. Among the cropping systems studied, maize-gram recorded higher yield followed by soybean+ pigeon pea (2:1) and soybean-wheat cropping system. Barring soybean-wheat system and soybean-fallow under CT, all other crop yields were under RT after third crop cycle. This was possibly attributed to improvement in soil structure due to three years of continuous reduced tillage. The interaction effect of tillage and cropping system recorded significantly higher soybean grain equivalent yield under soybean-wheat and soybean+ pigeon pea (2:1) (Table 2.6.1) cropping system.

Table 2.6.1 Effect of conservation agricultural practices on soybean grain equivalent yield (q ha^{-1}) during 2012-13

Treatments	CT	RT	Mean
Soybean - Wheat	31.52	27.96	29.74
Soybean + Cotton (2:1)	20.36	23.57	21.96
Soybean -Fallow	5.31	4.58	4.94
Soybean+ Pigeon pea (2:1)	28.25	34.99	31.62
Soybean -Fallow (R)	3.56	4.31	3.94
Maize -Gram	44.89	46.51	45.70
Mean	22.3	23.7	
CD (5%)			
Tillage		NS	
Cropping system		2.33	
T×CS (Within Column)		3.30	
T×CS (between Column)		3.31	

SGY calculated based on MSP on 2012-13

2.6.2 Evaluating conservation agriculture for stabilizing crop productivity and carbon sequestration

Evaluation of conservation agriculture stabilizing crop productivity was done through imposing three tillage treatments namely conventional tillage (CT), reduced tillage (RT) and No-tillage (NT) along with four cropping systems namely i) Soybean-Wheat, ii), Soybean + Pigeon pea (2:1), iii) Maize-Gram and iv) Maize+ Pigeon pea (1:1). The rainfall received during crop growing period was 886 mm. The rainfall received in the month of June alone was 448.6 mm, which severely hampered the crop growth. From June to October, the total amount of rainfall was 1347 mm. Due to continuous rainfall, the soybean crop during *kharif* season (2013) completely failed. *Kharif* crop yields were severely affected by continuous rains during the monsoon season. After *rabi* crop harvest, yields were converted into soybean grain equivalent (SGE) yield. It was inferred that both tillage and cropping system had significant effect on crop yields (Table 2.6.2). The yield data also revealed that maize-gram was on par with maize + pigeon-pea, which were significantly different from other cropping systems.

Table 2.6.2 Effect of conservation agriculture on SGE crop yield* (2013-14)

Treatments/Cropping system	CT	RT	NT	Mean
Soybean -Wheat	18.58	29.27	25.01	24.29
Soybean+ Pigeon pea (2:1)	24.35	24.35	24.11	24.27
Maize + Pigeon pea (1:1)	10.89	10.60	12.22	11.24
Maize -Gram	16.28	19.58	18.56	18.14
Mean	17.52	20.95	19.97	
CD (5%)				
Tillage		1.63		
Cropping system		2.02		

**Yields were converted based on MSP of 2013-14. *Yidd levels were very low due to low yield ofkharif crops.*

Weed Biomass under conservation agriculture

Weed biomass observation were taken under different tillage treatments during *kharif* season. No-tillage (NT)/ reduced tillage (RT) recorded higher number of weeds and total weed biomass (g m^{-2}) than the conventional tillage (Fig 2.6.1).

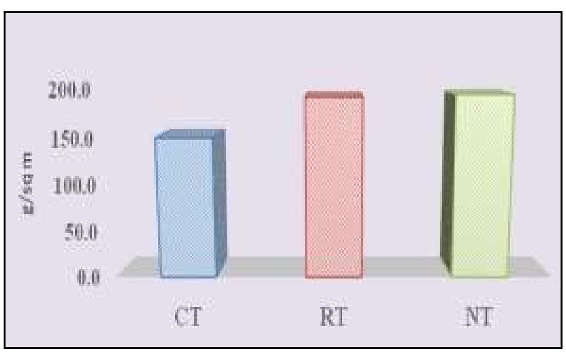


Fig. 2.6.1 Weed biomass under conservation agriculture

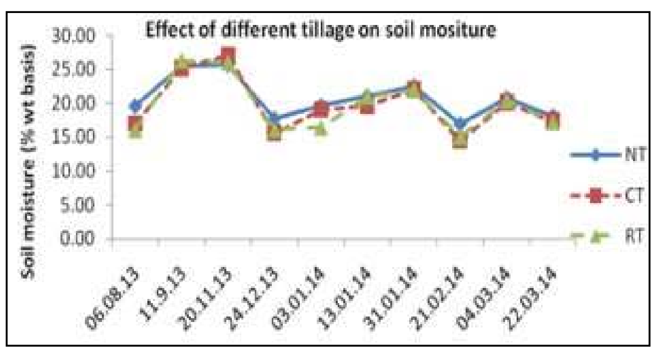


Fig. 2.6.2 Effect of different tillage systems on soil moisture

Soil moisture and temperature under different tillage practices

The temporal soil moisture (0-15 cm) data revealed that no-tillage recorded higher soil moisture compared to reduced tillage and conventional tillage. However, both reduced tillage and conventional tillage treatment behaved in similar fashion (Fig 2.6.2). Soil temperature recorded at 5 cm and 5-15 cm under conservation agriculture practices at standard time revealed that after first crop cycle, the soil temperature under different tillage systems behaved almost in a similar fashion. The data further revealed that there was no significant different between tillage system (Fig. 2.6.3 a, b).

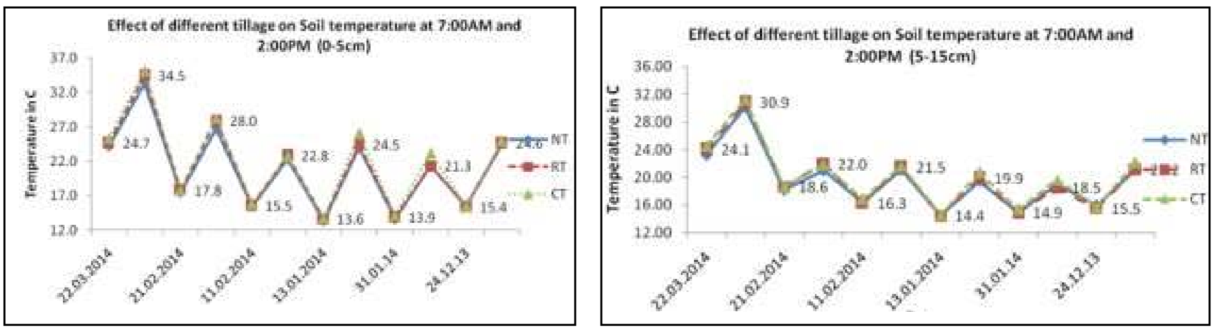


Fig. 2.6.3 a & b Soil temperature under different tillage system

Carbon stocks and pools under different tillage practices

Total organic carbon (TOC) data revealed that there was no significant difference observed under TOC. Carbon stocks data revealed 6.1-10.9% increase of carbon stocks under RT and NT over CT in 0-5 cm. However, tillage systems did not have significant effect on carbon stocks (Fig. 2.6.4). Carbon pool analysis was done after first crop cycle. Data also indicated increase in labile and less labile carbon pools were observed after 1st crop cycle.

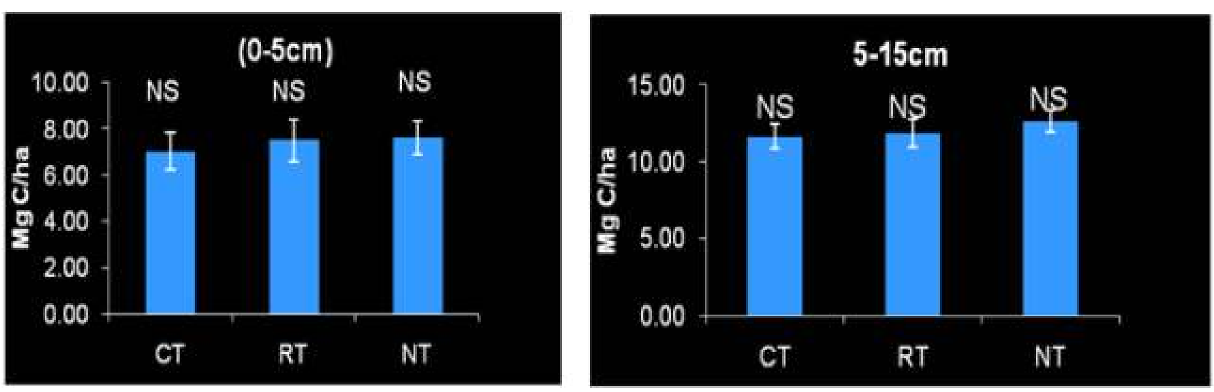


Fig. 2.6.4 Carbon stocks under conservation agriculture

Active carbon is a better indicator for the management practices. This portion of carbon is also known as labile fraction. Small change in labile fractions of soil organic carbon (SOC) may give an early indication of soil degradation or improvement in response to management practices. The active carbon estimated in soils under conservation agriculture experiment after completion of first crop cycle revealed that soils under pigeon pea based cropping system registered relatively higher active carbon (varied from 371 to 373 mg kg^{-1}) in 0-5cm compared to other cropping system. Among the tillage systems, no-tillage (383 mg kg^{-1}) and reduced tillage (360 mg kg^{-1}) recorded higher active carbon compared to conventional tillage (335 mg kg^{-1}) in 0-5 cm. Similar trend was observed for 5-15 cm soil depth (Fig. 2.6.5).

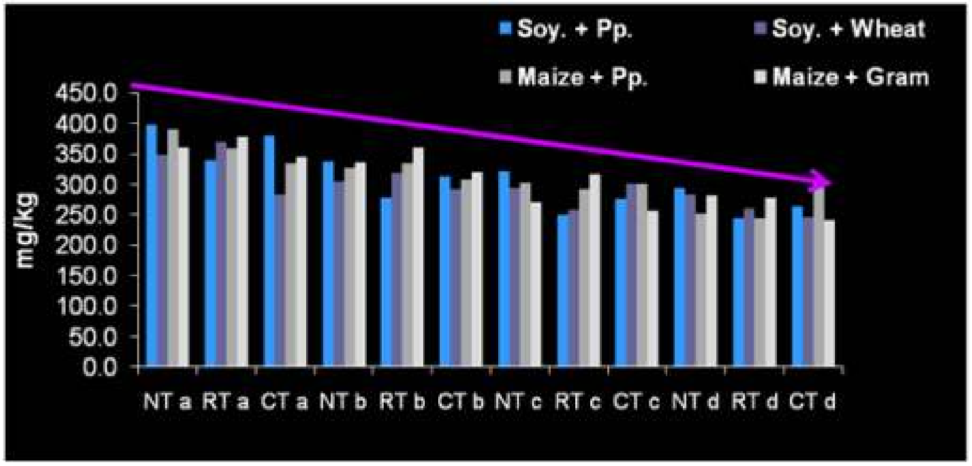


Fig. 2.6.5 Active carbon under conservation agriculture practices and cropping systems
a: 0-5cm, b:5-15, c:15-30, d:30-45 ; CT: Conventional Tillage, RT- Reduced Tillage, NT- No-tillage

2.6.3 Long term tillage and manure effect on nitrous oxide emission

Green house gas (GHG) emission under different tillage (reduced and no tillage) and manure management practices in 6th crop of soybean under soybean-wheat cropping systems was studied. GHG fluxes, soil temperature, moisture, soil nitrate and ammoniacal nitrogen were determined at frequent intervals throughout the cropping season. After six years of cropping cycle, reduced tillage (RT) resulted in higher emission of nitrous oxide immediately after sowing than no tillage (NT) (Fig. 2.6.6). However, during the initial crop growth period *i.e.* in July and August, across the manure management practices no tillage was found to have relatively higher nitrous oxide fluxes than reduced tillage. At later stage of crop growth RT was found to have significantly higher emissions than NT. Further, at harvest stage there was decrease in emission of N_2O compared to fluxes at sowing. Overall, NT had significantly higher N_2O emission as compared to RT. Over tillage treatments, the average nitrous oxide flux was higher initially in fully inorganic treatment (T_1) and at later stage of soybean, integrated nutrient management (T_2 to T_4) resulted in higher N_2O emission till harvest (Fig. 2.6.6).

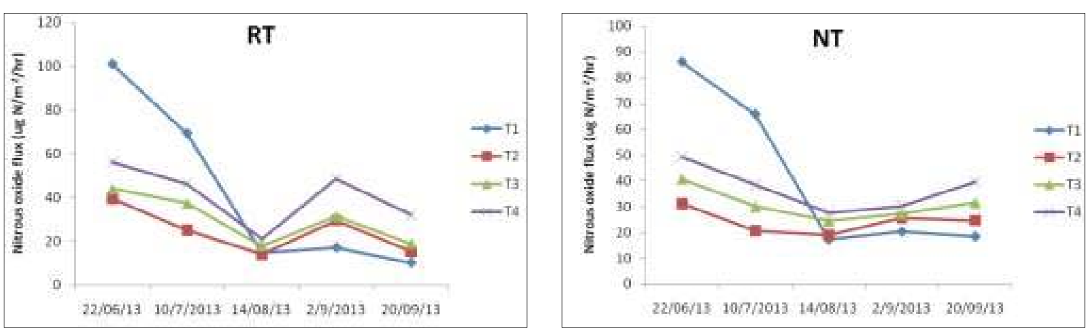


Fig. 2.6.6 Tillage and manure effect on nitrous oxide emission in soybean
RT (Reduced tillage); NT (No tillage); T_1 (NPK); T_2 (NPK + 0.5 Mg ha^{-1} FYM-C); T_3 (NPK + 1.0 Mg ha^{-1} FYM-C); T_4 (NPK + 2.0 Mg ha^{-1} FYM-C)

2.6.4 Quantifying the effect of climate change on soybean productivity using APSIM model

The rising atmospheric temperature, CO_2 concentration and uncertainties in rainfall associated with global warming may or may not have serious consequences on crop production. It is, therefore, important to have an assessment of the consequences of global warming on productivity of different crops. The changes in the simulated yield potential per unit area for soybean caused by changes in the temperature, CO_2 and rainfall over the period 1980-2010 for the Bhopal region was investigated. The simulations were performed for a widely cultivated soybean cultivar JS 335 which is based on procedure laid out by the coordinated climate-crop modelling pilot team (C3MP). The C3MP sensitivity tests are designed to efficiently sample the uncertainty space in projected temperature, water, and carbon dioxide changes in the 21^{st} century. By analyzing end-of-century outputs from the global climate model (GCM) outputs, the upper and lower bounds of each climate metric were developed (Table 2.6.3). These ranges include the projected extremes over the majority of agricultural lands. Although the final years of the 21st century have CO_2 higher than 900 ppm in representative concentration pathways (RCP 8.5), C3MP is focused on 30-year time slice climatologies. The end-of-century period has a central year CO_2 of 801ppm. Therefore, 900 ppm was selected as the upper bound for CO_2 in this study.

Table 2.6.3 Climate metric ranges for C3MP climate sensitivity experiments

Climate Metric	Lower Bound	Upper Bound
Temperature change (ΔT)	-1˚C	+8˚C
Precipitation change (ΔP)	-50%	+50%
Carbon Dioxide Concentration (CO_2)	330 ppm	900 ppm

Total ninety nine sensitivity simulation experiments using APSIM model were statistically fitted with an emulator to estimate mean yield (Y) and coefficient of variation (CV) response surfaces to the range of changes in temperature (T), rainfall (P) and CO_2. The following polynomial based emulators shown in Equations 1 and 2, were used for this purpose.

$$Y(CO_2, T, P) = a + b(T) + c(T)^2 + d(P) + e(P)^2 + f(CO_2) + g(CO_2)^2 + h(T*P) + i(T*CO_2) + j(P*CO_2) + k(T*P*CO_2). \quad \text{(Eq. 1)}$$

$$CV(CO_2, T, P) = a + b(T) + c(T)2 + d(P) + e(P)2 + f(CO_2) + g(CO_2)2 + h(T*P) + i(T*CO_2) + j(P*CO_2) + k(T*P*CO_2). \quad \text{(Eq. 2)}$$

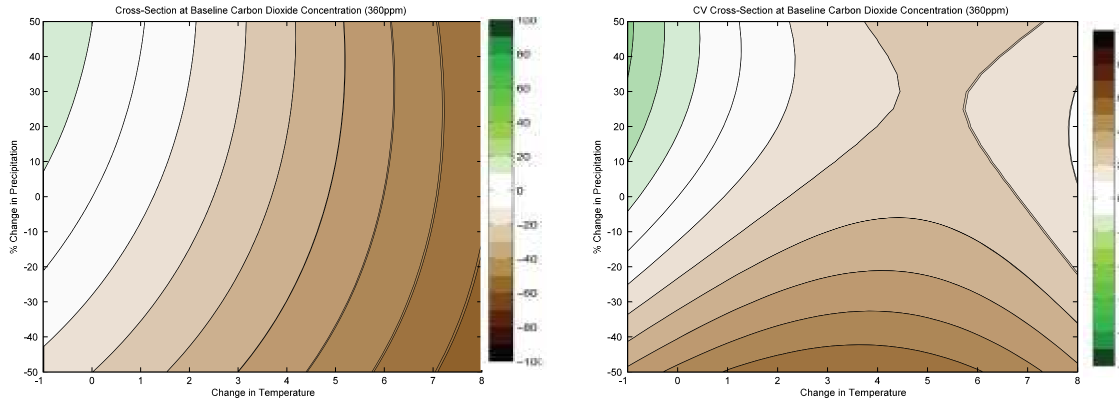


Fig. 2.6.7 Simulated (a) soybean grain yield and (b) coefficient of variation as affected with changes in temperature and precipitation at constant CO_2 concentration (360 ppm)

Results indicated that increase in temperature during soybean growing period decreases soybean yield while decrease in temperature from the current climate favours soybean yield (Fig. 2.6.7a). By increasing the temperature to 1.5°C will reduced the grain yield of soybean by 20%. Similarly reduction in rainfall does not favours soybean yield. Decreasing the temperature from the current climate by 1°C and increasing the rainfall by more than 10% favours the soybean yield most. Green colours in the Fig. 2.6.7a indicate a positive response of rainfall on soybean yield. While decrease in rainfall pattern with increase in temperature reduced soybean yield drastically. However, increase in temperature with increase in rainfall doesn't favour soybean growth. Increasing the temperature to 1.5°C along with increase in rainfall up to 50% during soybean growth reduces the soybean yield to the tune of 5 to 10% which can be considered a tolerable limit. Beyond 1.5°C increase in temperature, the increase in rainfall doesn't show any positive impact on soybean yield. Similarly the CV of the crop yield is presented in the Fig. 2.6.7b which indicates the variation in the data series used for soybean grain yield analysis.

In this study, increase in CO_2 concentration favours soybean growth when the temperature is reduced by 1°C from the current climate (Fig. 2.6.8a). However, with increase in CO_2 concentration the yield is masked by the adverse impact of rise in temperature on crop growth. Even increasing the temperature by 1°C and CO_2 concentration to double from the current stage, the yield decline in soybean is as high as 15% (Fig. 2.6.8a). The variability in the dataset can be seen in the Fig. 2.6.8b.

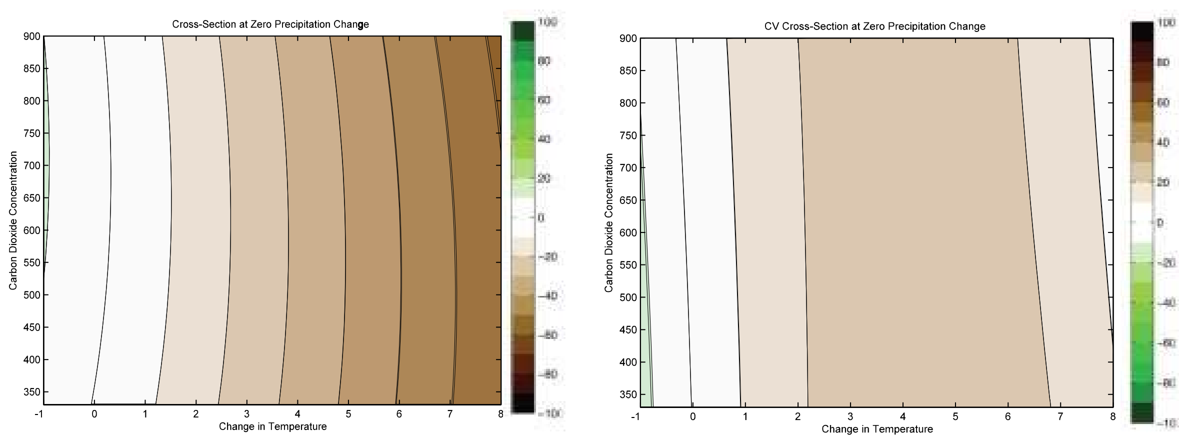


Fig. 2.6.8 Simulated (a) soybean grain yield and (b) coefficient of variation as affected with changes in temperature and CO_2 concentration, without changes in precipitation

2.6.5 Root system architecture of soybean crop

Root architecture refers to the spatial configuration of the root system, *i.e.* the explicit geometric deployment of root axes. The root architecture is fundamentally important for plant growth and survival because of its role in water and nutrient uptake. Thus, it is important to characterize root system architecture of field crops to understand its behaviour under changing soil environments. With this background, this study was carried out to characterize root system architecture of soybean cultivars *i.e.* JS-335 and JS-9560, in Vertisol of central India.

Soybean cultivars were grown for twenty days in acrylic tube of size 25 cm height and 5 cm diameter with five replicates. After twenty days, root systems were separated out from soil using 10% calogen solution. Total root lengths, mean root diameter, equivalent surface area, equivalent volume were measured using Delta-T imaging system and length and number of individual root axes and laterals i.e. primary and secondary root, number of nodes, and root angles were measured using scale and protractor. Results indicated that root length, diameter, surface area and volume were higher in JS-9560 compared to JS-335 (Table 2.6.4).

Table 2.6.4 General rooting parameters of two soybean cultivars

Parameter	Unit	JS-335	JS-9560
Root length	mm	2362 (17)	2664 (43)
Mean Diameter	mm	0.67 (0.16)	0.79 (0.26)
Equivalent surface area#	mm^2	3446 (303)	4499 (155)
Equivalent Volume#	mm^3	476 (88)	775 (53)

Value in parentheses indicates standard deviation # assuming perfectly cylindrical geometry of all roots.

Further, it was observed that number of nodes/plant in JS-9560 was significantly higher than JS-335 (Fig. 2.6.9). In general, laterals roots are emerged from nodes and higher the number of nodes higher will be the primary and secondary roots. In the present investigation number of primary as well as secondary roots were also significantly higher in JS-9560 compared to JS-335 (Fig 2.6.10 a & b). Root insertion angle is measure of root growth in lateral direction and indicates root responses against stress encountered by the roots in field. The primary and secondary root insertion angles were higher in JS-9560 compared to JS 335 (Table 2.6.5). This indicated that lateral spread was higher in JS-9560 and also this cultivar was more tolerant towards stress conditions.

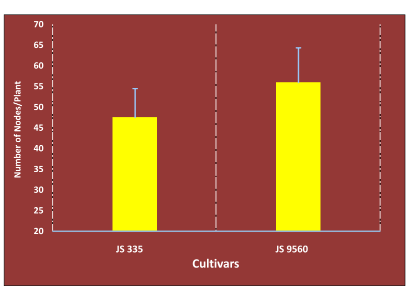


Fig. 2.6.9 Number of nodes/plant in two soybean cultivars

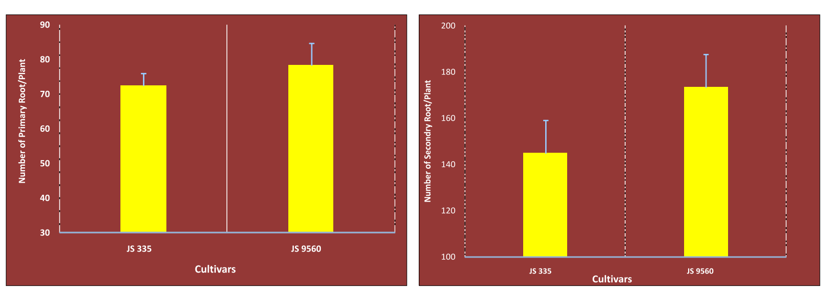


Fig. 2.6.10 Number of (a) primary and (b) secondary roots of two soybean cultivars

Table 2.6.5 Root insertion angles of two soybean cultivars

Parameter	JS 335	JS 9560
Primary root insertion angle (degree)	45	60
Secondary root insertion angle (degree)	45	50

2.6.6 Impact of crop covers on soil and Nutrient losses through run off in Vertisols

The study was carried out to assess the impact of crop covers on soil and nutrient losses through runoff in Vertisol. The treatments consisted of three sole crops (soybean, maize and pigeon pea) and three intercrops [soybean + maize (1:1); soybean + pigeon pea (2:1) and maize + pigeon pea (1:1)] with one cultivated fallow as a control with three replications under randomized block design. The crop was sown on 22 June, 2013 with optimum soil moisture content. During crop growth period, runoff and rainfall data were recorded. (Plate 2.10) During June to December months of year 2013, the total rainfall received at the experimental farm was 1418.4 mm. Total rainfall during crop period of year 2013 was 1352 mm. The rainfall received during June, July, August and September was 448.6, 486, 342.4 and 27.6 mm, respectively. The rainfall distribution was excess during June to August and therefore crops performance were not conducive specially for soybean and maize. Pigeon pea performed better due to sufficient soil moisture during vegetative growth. The week wise rainfall distributions during the crop growth period are mentioned in Fig. 2.6.11.

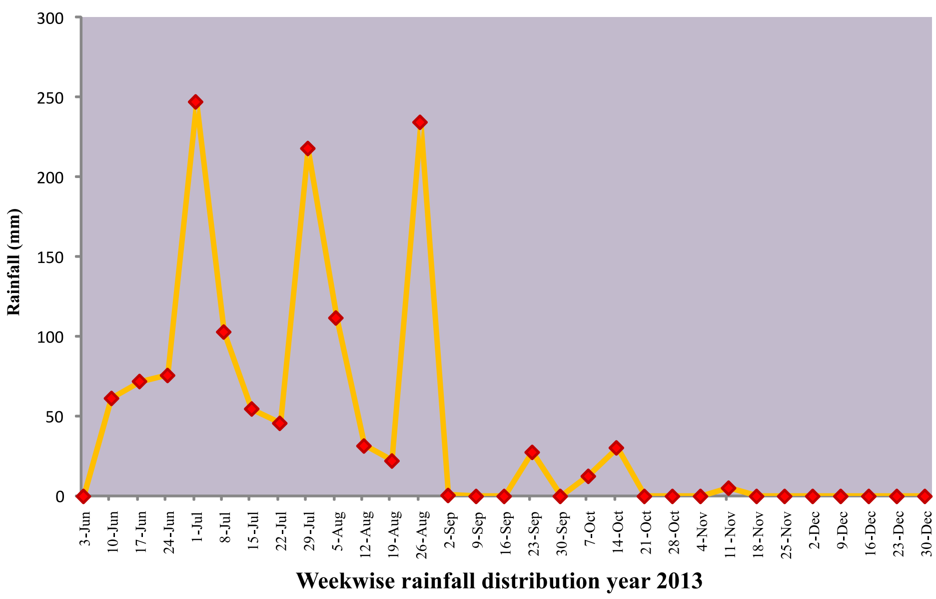


Fig. 2.6.11 Weekly rainfall distribution (mm) during crop growing period

Plate 2.10 Overall view of the field experiment

Runoff and soil loss

The runoff was recorded and runoff samples were collected after each storm for soil loss calculation. The runoff and soil loss varied from 336 to 479 mm and 3431 to 5557 kg ha^{-1}, respectively. The maximum runoff (479 mm) and soil loss (5557 kg ha^{-1}) was recorded under cultivated fallow over sole as well as intercrops. Among the sole crops, the highest runoff and soil loss was recorded under pigeon pea and the lowest was in soybean crop. In case of intercrops, the highest runoff and soil loss was in maize and pigeon pea (1:1) and the lowest in soybean + pigeon pea (2:1). The trend of runoff and soil loss was in the order: cultivated fallow > pigeon pea > maize > maize + pigeon pea > soybean + maize > soybean + pigeon pea > soybean. Among the sole crops, the per cent reduction of runoff and soil loss over cultivated follow was the highest under soybean and the lowest was under pigeon pea crop but in case of intercrops, soybean + pigeon pea (2:1) recorded the highest per cent reduction of runoff and soil loss and the lowest was in maize + pigeon pea (Table 2.6.6).

Table 2.6.6 Runoff and soil loss as influenced by crop covers during rainy season in 2013

Treatments	Run off (mm)	Run off (%)	Soil loss (kg ha^{-1})	Per cent reduction over cultivated fallow	
				Runoff	Soil loss
Soybean	336	25	3431	30	38
Maize	406	30	4259	15	23
Pigeon pea	446	33	4745	7	15
Soybean + Maize (1:1)	360	27	3785	25	32
Soybean + Pigeon pea (2:1)	345	26	3520	28	37
Maize + Pigeon pea (1:1)	377	28	3908	21	30
Cultivatedfallow	479	36	5557	--	--

Nutrients losses

The SOC and total NPK losses were the highest in cultivated fallow (Table 2.6.7). Among the sole crop treatments, the higher nutrients losses were recorded in sole pigeon pea followed by maize and the lowest in sole soybean and in case of intercrops, the maximum nutrient losses were recorded in maize + pigeon pea (1:1) followed by soybean + maize (1:1) and the lowest in soybean + pigeon pea (2:1).

Table 2.6.7 Nutrients losses (kg ha^{-1}) through runoff in different crop covers during rainy season in 2013

Treatments	SOC	Total N	Total P	Total K
Soybean	22.30	6.66	0.99	33.62
Maize	7.26	8.56	1.06	40.25
Pigeon pea	29.42	9.02	1.19	43.84
Soybean + Maize (1:1)	23.85	7.27	0.98	33.80
Soybean + Pigeon pea (2:1)	22.53	6.16	0.95	30.31
Maize + Pigeon pea(1:1)	24.62	7.74	0.98	33.34
Cultivated fallow	33.90	10.56	1.33	45.29

Crop and soybean equivalent yield (SEY)

This year crop growth suffered due to erratic heavy rainfall. The grain yield of soybean and maize was poor but pigeon pea seed yield was good. Among the sole crops, soybean equivalent yield (SEY) of pigeon pea was higher followed by maize. The lowest SEY was in soybean but in case of intercrops it was higher under maize + pigeon pea (1:1) followed by soybean + pigeon pea (2:1) and the lowest was in soybean + maize (1:1) based on minimum support price (MSP). The study indicated that pigeon pea in combination with maize recorded the highest soybean equivalent yield followed by pigeon pea and soybean + pigeon pea.

Theme III: Microbial Diversity and Genomics

2.7 Microbial Diversity and Biofertilizers

2.7.1 Diversity and metabolism of ammonium oxidizing bacteria and archaea in tropical Vertisol

Unlike bacteria, archaea communities have only recently been discovered as ubiquitous soil residents. However, their diversity and function in the complex soil environment is still not fully understood. An experiment was carried out to define the structure and function of bacteria and nitrifying archaea (Crenarchaeota), their interaction in the development of biogeochemical cycles in relation to the plant growth and ecosystem function. Nitrification rate was measured in the rhizosphere of soybean under different crop growth stages amended with different fertilizer. Potential nitrification rate remained high during vegetative growth phase of soybean. Fertilizer influenced nitrification was in the order of inorganic > integrated > organic > control treatment (Table 2.7.1).

Table 2.7.1 Potential nitrification rate in the rhizospheric soil of soybean during different growth stages and fertilizer management

Treatments	Potential Nitrification Rate (µg NO_3 produced g^{-1} soil day^{-1})		
	Vegetative (45 DAS)	Flowering (75 DAS)	Maturity (110 DAS)
Unamended control	0.24f	0.44cd	0.15g
Organic	0.38e	0.47c	0.14g
Inorganic	0.48c	0.82a	0.27f
Integrated	0.41de	0.62b	0.17g

DAS – Days after sowing; Tukeys HSD: 0.057 at α = 0.05, Df error: 24; Mean values with same letters are not significantly different

To explore the differential role of ammonium oxidizing bacteria (AOB) and ammonium oxidizing archaea (AOA) in nitrification during sequential reduction of terminal electron acceptors, nitrification rate was quantified under different redox processes. Potential nitrification rate (PNR) was in the range of 0.23 (un reduced soil) to 3.12 (Fe^{3+} reduction). PNR was high during Fe^{3+} reduction than other terminal electron accepting process. PNR was low during SO_4^{2-} reduction and methanogenic phase. Low PNR in response to SO_4^{2-} reduction was attributed to the reduced S moieties (S^{2-}). Sulfides are reported as inhibitor to several aerobic microbial groups. Terminal restriction fragment length polymorphism (T-RFLP) analysis revealed differential abundance (relative fluorescence) of nitrifying bacteria and Crenarchaea during terminal electron accepting process (TEAPs). Relative florescence of AOB was 12-15% and it remained unchanged during incubation. While, the relative fluorescence of Crenarchaea specific TRFs 56 and 247 was 8- 9.3% in unincubated soil increased to 18.5% and 11.60% during Fe^{3+} reduction. In general the relative fluorescence of Crenarchaea indicative TRFs were higher than AOB. Study indicated that Crenarchaea are actively involved in the nitrification process during sequential reduction in vertisol.

2.7.2 Microbial succession in rhizosphere of soybean

Microbial diversity in the rhizosphere of soybean was monitored by T-RFLP at different growth period. The major TRFs detected belonged to Delta proteobacteria, uncultured bacteria, uncultured Actinobacteria, Fusabacterium, Deltaproteobacteria/Geobacter, Acidobacteria, Azorhizobium/ Spingomonas, Streptomyces, Deltaproteobacteria-Shewanella,Verrumicrobiota, uncultured bacteria, Desulfobacterium/Methylosinus, Acidophilum, Clostridium acetobutylicum. TRF 82, 234, and 169 were predominant at early stage while TRF 42, 64, 106 proliferated at later stage of crop. Succession of different microbial groups by TRFLP analysis during plant growth is depicted in Figure 2.7.1.

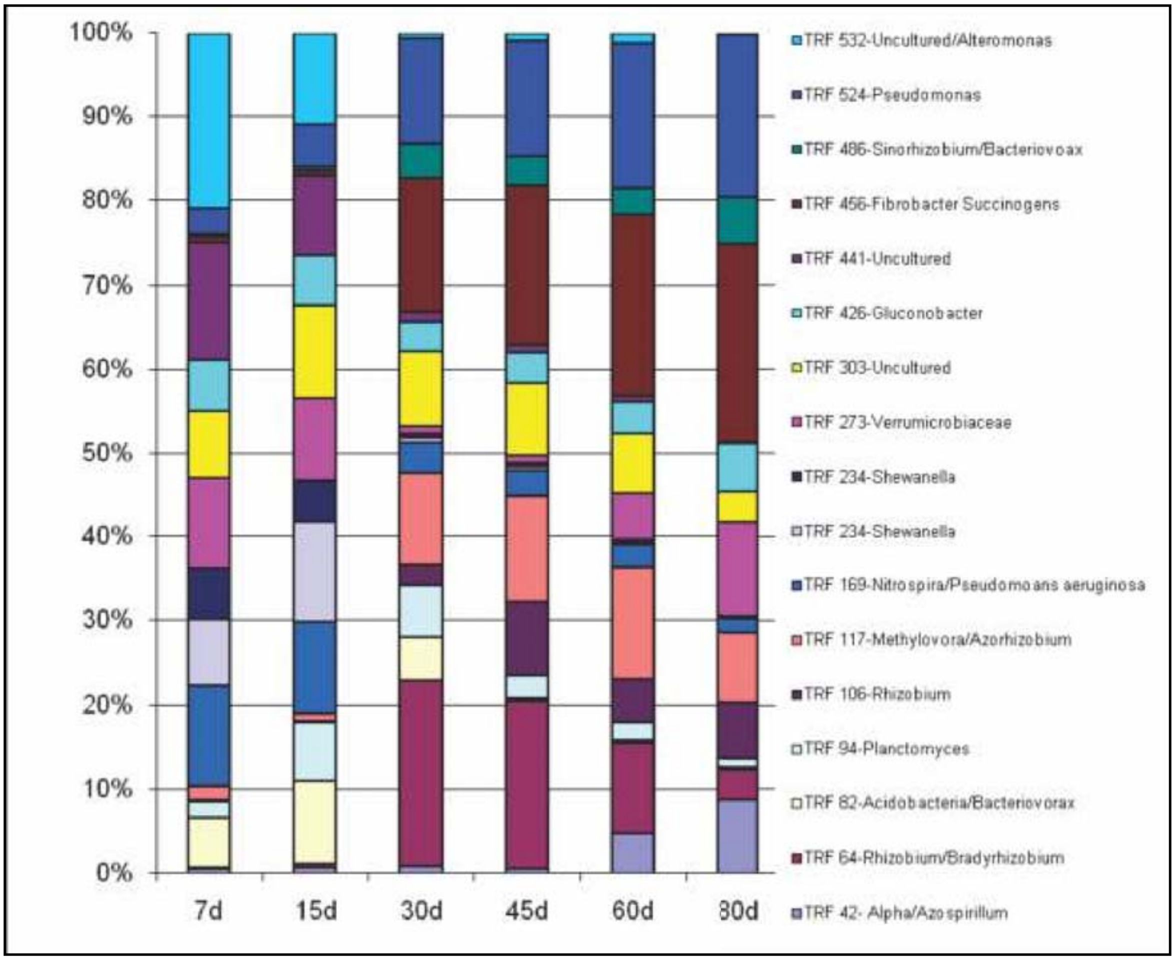


Fig. 2.7.1 Relative fluorescence of microbial community during different soybean growth stages (Growth stages (in days) in X axis, relative fluorescence (%) in Y axis)

2.7.3 Consequences of transgenic cotton on soil microbial diversity

The rhizosphere soil samples from Bt and non Bt cotton were analysed for microbial diversity of the beneficial microbes and soil enzyme activity. It was found that the diversity of beneficial microbes (cellulose decomposer, aerobic N fixers and total heterotrophs) was found more under Bt-cotton than non-Bt cotton. Soil enzymes such as dehydrogenase, fluorescin di-acetate and alkaline phosphatase activities were found 15, 23 and 6% respectively higher in Bt as compared to non Bt cotton soil. The glomalin protein content also was found higher (39-110 mg kg^{-1}) in Bt-cotton as compared to non-Bt-cotton (38-57 mg kg^{-1}) based cropping systems. The microbial counts under Bt cotton system ranged from 7.5-8.4 log cfu g^{-1} soil for heterotrophic bacterial population, 5.4-5.6 log cfu g^{-1} soil for aerobic nitrogen fixers, 2.5-3.1 log cfu g^{-1} soil for P solubilisers and 3.3 to 4.5 log cfu g^{-1} soil for cellulose decomposers were found higher compared to non Bt-cotton system where the counts (log cfu g^{-1} soil) were found 5.5-6.2 for heterotrophs, 5.1-5.3 for aerobic nitrogen fixers, 2.4-3.0 for P solubiliser and 3.3-4.3 for cellulose decomposers. In this study, the soil meta-genomics DNA was isolated using HiPurametagenomics kit and 16s *r* DNA has been amplified for analyzing microbial diversity. It was found that in Bt rhizosphere the bacterial diversity was higher than non-Bt rhizosphere.

2.7.4 Chemical and microbiological evaluation of biodynamic and organic preparations

The effect of foliar application of different organic and biodynamic preparation on wheat was studied in a pot culture experiment. Enumeration of phyllospheric microbial population (bacteria, fungi and N-fixers) at different interval of application of organic and biodynamic preparations was done. Total count of phyllospheric microbes was the highest in panchagavya, biodynamic and treatment receiving combination of all nutrient sources at 24 hrs of application which decreased as the time passed. Effect on leaf chlorophyll, and nitrate reductase (NR) activity (Fig. 2.7.2) was also estimated. Initially there was no difference in the chlorophyll content of the leaf but after 45 days of sowing (DAS) low chlorophyll content was found in control, panchagavya treatment and biodynamic treatment (Fig. 2.7.3). At 45 DAS NR activity was highest in T3 and T4 but after 85 DAS highest NR activity was recorded in T2 (chemical fertilizer) followed by T7 and T3 (Plate 2.11).

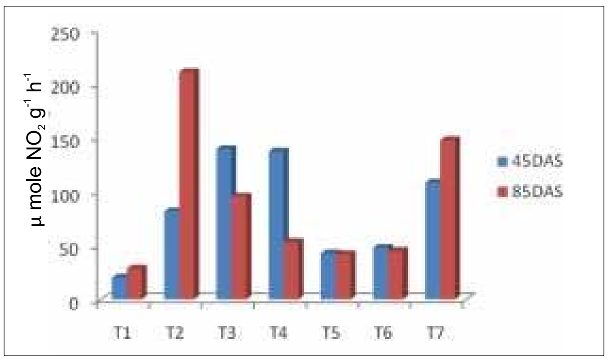


Fig. 2.7.2 Nitrate reductase activity in flag leaf of wheat at 45 and 85 DAS

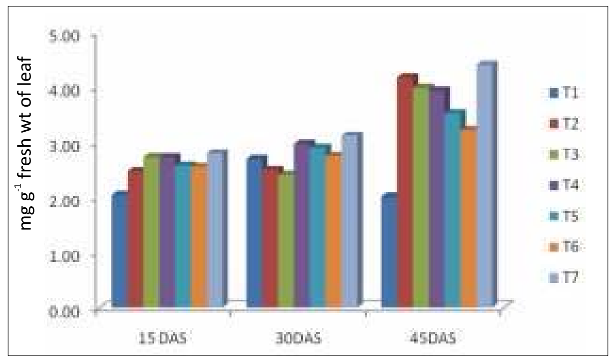


Fig. 2.7.3 Total leaf chlorophyll content in leaf of wheat at different time interval

Plate 2.11: Performance of wheat under different nutrient management practices.

T1: Control (No fertilizer or manure); T2: Chemical fertilizer; T3: Integrated nutrient management; T4: Organic nutrient management; T5: Biodynamic treatment; T6: Panchagavya T7: T3+T5+T6.

2.7.5 Rhizobia diversity and formulation

In Arid Zone

From Udaipur, Chittorgarh, Bhilwada, Kota and Sirohi regions, 158 rhizobial cultures were isolated from root nodules of chick pea, pea, lentil, methi, soybean, cowpea, green gram, black gram and groundnut. Majority of chick

2.7.5 Rhizobia diversity and formulation

In Arid Zone

From Udaipur, Chittorgarh, Bhilwada, Kota and Sirohi regions, 158 rhizobial cultures were isolated from root nodules of chick pea, pea, lentil, methi, soybean, cowpea, green gram, black gram and groundnut. Majority of chick pea rhizobia were able to grow upto 6% Na Cl concentration, however, some could grow up to 9 % NaCl. Rhizobia of `*methi'* could grow up to 6% NaCl (MPUAT, Udaipur).

The genomic DNA of 103 abiotic stress tolerant cluster bean (49) and pigeon pea (54) rhizobia were tested for *nod*C gene and authenticated as rhizobia. The 35 and 40 isolates of pigeon pea and cluster bean showed *nif*H gene amplification. Amplification of 16S rRNA gene with 27F and 1378R primers, followed by digestion with MspI and *Hae*III and ARDRA showed wide diversity. Dendrogram showed two major clusters and many sub-groups. Divergence among them started at 65% similarity coefficient. At 80% level of similarity coefficient, 18 different biotypes were formed in pigeon pea. On the basis of abiotic stress tolerance, biochemical and molecular characterization, six pigeon pea rhizobial isolates namely PPH-8E, PPR-2, PPB-26A, PPM-30A, PPM-33C and PPM-37A and three cluster bean rhizobial isolates viz., GB-36b, GB-26d and GH-2b were selected as most efficient rhizobial isolates (HAU, Hisar).

Sixty seven rhizobial isolates from nodules of cluster bean, moong bean,moth bean, cowpea from Churu, Sikar, Bikaner & Jodhpur districts of Rajasthan were characterized for stress tolerance**.** Some rhizobial isolates of moth bean, cluster bean, moong bean and cowpea were able to grow at 45^{0}C, and some could tolerate osmotic stress of 40% PEG. More than 50% of the above rhizobial isolates were able to grow in combined stress of drought and temperature but with decreased growth rate. Most of the rhizobia produced indole acetic acid (IAA) and excreted ammonia. Only few could synthesize siderophores or utilize Amino cyclopropane carboxylate (ACC) (22%) as sole source of nitrogen. Around 24% of the isolates were able to produce siderophores. P- solubilization index of the isolates was good (18), moderate(24) and poor (20). A total of 14 rhizobial isolates were found to have all the five characters i.e. IAA production (I), Siderophore production (S), P- solubilization (P), Ammonia excretion (Am) and ACC deaminase activity (Ac). 64 isolates were having at least one of these four PGPR characteristics (HAU, Hisar).

Rhizobia in Tal lands

Of 48 *Rhizobium* isolates from lentil, pea, lathyrus, chickpea and *bakla* from Tal land, 39 were fast growers. The site was mostly unfertilized having mono-cropping systems (RAU, Pusa).

Proteomics of Rhizobia in acid soils

Role of genes crucial in imparting tolerance to rhizobia in acid soils is under elucidation through proteomics. Various isolates from different legumes in Jharkhand were characterized. Proteomic analysis of *Rhizobium* isolates of black gram (*Vigna mungo*), Pea (*Pisum sativum* L.) and green gram (*Vigna radiata L.*) was carried out. Several important and Unique protein differences amongst the various *Rhizobium* isolates thought to impart acid tolerance were documented. The 16S rRNA sequences of three isolates were deposited in NCBI. The MALDI-TOF-TOF data for one of the unique proteins from black gram rhizobia expressed exclusively in the acid soils was obtained. The protein was identified *Chain A, Structure Of Periplasmic Binding Protein* (Accession Number: gi|88192851, Molecular weight: 33,300Da and Isoelectric Point: 7.80 respectively). The data generated by the MS analysis would surely be able to shed light on the roles of the genes, which are thought to play a crucial role in imparting tolerance to the acidic soil regime (BAU, Ranchi).

Dual purpose Rhizobium in Inceptisols

100 rhizobial isolates of chickpea, pea and lentil were screened for antagonistic behaviour against *Fusarium oxysporum* f. sp. *ciceri, Ascochyta rabiei, Botrytis cinerea* and *Macrophomina phaseolina.* Five isolates (CR 9, 16,

38, 50 and 64) of chickpea showed antagonistic activity against *Fusarium oxysporum* f. sp. *ciceri* while six isolates (CR 9, 16, 18, 19, 25 and 72) showed antagonistic activity against *Macrophomina phaseolina* (IARI, Delhi).

2.7.6 Arbuscular mycorrhizal fungi (AMF) colonization and bioinformatic analysis

Amaravathi

Six pure cultures of AMF were developed and single spore inoculation in green house conditions on maize host was done. Sporulation was triggered by manipulating temperature during growth period. In field crops, cotton root system was colonized to the greatest extent by AMF, 82% followed by sugarcane. In the top 20 cm soil depth AMF spore population was high when the fields were grown with black gram crop.

Solan

In mid and high-hills of soils Himachal Pradesh there was great variation in spore counts of native AMF in sweet cherry. The root colonization varied from 19-29%. Frequency of occurrence was in the order of *Glomus* (>75%) >*Acaulospora* and *Scutellospora* (10-12 %) >*Gigaspora* (about 5%).

2.7.7 Other microbial organisms

Rice Endophytes

In areas where traditional rice varieties, *viz.*, red, white and black Desariya grow together with stem nodulating *Aeschynomene* spp., an endophytic association with *Rhizobium* was detected in *chaur* land. The site was never fertilized with chemical fertilizers. Such endophytic rhizobia were observed in rhizospheric roots as well as nodal roots (RAU, Pusa).

PGPR for maize in Himalayan soils

In the rhizosphere of maize grown in low and mid-hills, of 98 bacterial isolates screened for PGP traits, 35 were P-solubilizers, 38 were siderophore producers and 18 were positive for HCN production and about 30 isolates showed antagonism against major soil borne pathogen *viz.,Rhizoctonia solani* and *Fusarium oxysporum*, the causative agents of banded leaf and sheath spot and ear rot disease, respectively in maize crop (YSPUHF, Solan).

Soil mesofauna

Amongst the soil mesofauna, *Collembola* are important indicators of soil health. Population of *Collembola* of collembolan were higher than other individual components of soil arthropods. Among four ecosystems, forest ecosystem favored the highest population of mesofauna (2606 m^{-2}). The conventional paddy cultivation reduced the population (874) in comparison to INM paddy (1398) and organic vegetables cultivated soils (1724 m^{-2}) (AAU, Jorhat).

2.7.8 Biofertlizer applications for different commodities

Actinomycetes Inoculants

Field evaluation of actinobacterial inoculants in dry zone at Maize Research Station, Vagarai in *rabi* season revealed that the inoculants performed better at 75% recommended dose of NPK fertilizers rather than 50 and 100% and A10 performed best in terms of plant height, number of cobs and cob weight. All the actinobacterial inoculants had a population range of 10^4cfu g^{-1} in soil and found enhanced levels in 75% NPK than 50 and 100% levels (TNAU, Coimbatore).

Bionutrient package for direct seeded rice

Microbial consortium (Cyanobacteria, *Azospirillum*, *Bacillus subtilis*, enriched mycostraw) was evaluated for direct seeded rice. Soaking of seeds in *Azospirillum* or *Bacillus* liquid culture or in combination resulted taller plants, increased number of grain per panicle and grain yields as compared to control or respective fertilizer level (RAU, Pusa).

Suppressive soils

Application of four DAPG-producing fluorescent pseudomonads enhanced the pod yield in groundnut cultivar TG37A significantly over uninoculated control. In summer 2014, maximum yield of 2328 kg ha^{-1} was obtained with *P. putida* DAPG3 (2098 kg ha^{-1} in uninoculated control, yield gain of 11%). However in *kharif* 2013 application of *P. aeruginosa* DAPG1, *P. putida* DAPG5, and *P. fluorescens* FP98 significantly enhanced pod yield by 14.9, 11.6 and 10.8%, respectively. Application of the DAPG-producing fluorescent pseudomonads suppressed the seedling mortality of groundnut cultivar cv. GG20 (susceptible to stem rot caused by *Sclerotium rolfsii*) from 60% in pathogen control to 25-40% in inoculated treatments. Maximum yield gain of 12.1% was achieved with the *P. putida* besides reduction in disease incidence (DGR, Junagadh).

Mixed rhizobium inoculation in blackgram

Rabi black gram field experiment for testing mixed rhizobial strains of BLG 165+BLG 168+BLG 175 along with other biofertilizers gave very good nodulation when applied in combination of other biofertilizer organisms like PSB, *Pseudomonas* and VAM (ANGRAU, Amaravathi).

Zinc mobilizers influence on Bt cotton

Zinc mobilizing microbial cultures *Trichoderma viride* and *Pseudomonas striata* showed upto 23 and 18% increase in seed cotton yield respectively as compared to RDF. They also increased the DTPA extractable zinc in soil by ~10%. Significant improvement in soil enzymes like acid phosphatase (26.6 and 23.9%), alkaline phosphatase (37.3 and 36.0%) and dehydrogenase activity (10.5 and 9.0%) was observed with these cultures (MAU Parbhani).

Biofertilizers for jute

In Jute (*var:Tarun*) and mesta (*var:* AMC108) INM treatment consisting of 50% NP and 100% K with biofertilizer (consortia of *Azospirillum, Azotobacter* and PSB) seed treatment gave the highest fibre yield of jute (2.23 t ha^{-1}). In mesta, the highest yield (1.98 t ha^{-1}) was observed with RDF which was at par with the INM (1.81 t ha^{-1})(AAU, Jorhat).

Jute crop grown at Kendrapara responded significantly (28.7%) to BFs application integrated with 100% soil test dose (yielding 2.99 Mg fibre ha^{-1}). Such response to BFs application further increased by 25.8% when its application was integrated with liming of soil (yielding 5.07 Mg fibre ha^{-1}). The BFs response was only 15.5 % when applied in isolation. Under all situations BFs application improved nutrient recovery by jute crop. The rice crop grown on residual fertility enriched with leaf litter of jute and RDF recorded on an average 11.0% higher grain yield in BFs integrated treatments along with higher nutrient recoveries (OUAT, Bhubaneswar).

Tropical vegetables

Bio inoculation with *Azotobacter*+ *Azospirillum*+ PSB over and above NPK + organics in pointed gourd yielded 21.7 Mg ha^{-1} and increase in the yield was 9.2%. Integrating liming of acid soil and BFs application (12 kg ha^{-1}) with recommended NPK & organics (yielding 28.7 Mg fruit ha^{-1}) improved the yield by 32%. Marketability of fruit improved (keeping quality) by 6-7 days due to BF application. The following crop of knol khol grown responded positively to BFs application by 8.5% over NPK + organic (18.9 Mg ha^{-1}). But BFs application with liming of acid soil improved the knob yield by further 18% and improved the recovery of added nutrients significantly (OUAT, Bhubaneswar).

Bitter gourd crop recorded 17.0, 11.1 and 10.0% positive response to BFs application when integrated with 50, 75 and 100% soil test based recommended dose of fertilizers with vermicompost, giving fruit yield of 2937, 3396 and 3683 kg ha^{-1} respectively. The economic benefit due to BFs application were Rs 4930, Rs 3770 and Rs 3530 ha^{-1} respectively over the investment of Rs 1000 ha^{-1} (OUAT, Bhubaneswar).

Biofertilizers for Chilli

Cultivation of hot chilli (*Capsicum Chinese* Jacq.) with organic inputs showed that enriched compost (10 t ha^{-1}) application gave the highest yield (2034 kg ha^{-1}) in the second year. The quality parameters of fruits like capsaicin (2.85%) and ascorbic acid (1.23 mg g^{-1}) were better over control. There was higher microbial biomass and enzyme activity with enriched compost application due to increase of soil organic carbon (1.22%) (AAU, Jorhat).

INM package for cauliflower

The conjoint use of PGPR (*Bacillus pumilus*) by seed treatment + seedling dip and 75% recommended doses of NP fertilizers increased curd yield by 24% besides saving 31 kg N ha^{-1} and 19 kg P_2O_5 ha^{-1} along with biocontrol against soil borne fungus *Fusarium spp*., *Rhizoctonia solani and Pythium spp.* The benefit to cost ratio of the package with biofertilizers was 5:1 (YSPUHF, Solan).

2.7.9 Actinomycetes diversity in arid and semi-arid soils and their PGPR ability

Actinomycetes of arid and semi-arid climatic zones in the rhizosphere soils of sorghum, pearl millet, pigeonpea, finger millet and groundnut in Karnataka; Anantpur in Andhra Pradesh and Jaisalmer, Rajasthan were characterized. The Shannon and Weaver diversity index (H) of all 41 actinomycete isolates (representing arid, semi arid and humid) was 3.54 and the species evenness (E) is 0.982, where as the diversity of actinomycetes was lower in the arid and semi arid soil i.e. 2.81, and the species evenness was 0.993.

The actinomycetes were characterized for gibberellic acid (GA) production, K mobilization and alkaline phosphatase activity. Among the 41 isolates tested, 16 produced GA which ranged from 21- 41.35 µg mL^{-1} of culture filtrate. The maximum GA production of 41.35 µg mL^{-1} of culture filtrate was observed in A28 which was isolated from semi arid soils of sorghum rhizosphere. All the isolates were examined for their ability to mobilize potassium on Alkesandrov medium. 15 isolates were able to mobilize potassium on Alkesandrov medium containing muscovite mica and it ranged from 3.7 to 6.3 µg mL^{-1} of culture filtrate. The maximum K mobilization was observed in A14 and A24 (6.3 µg μL^{-1}) isolated from sand dune soil and sorghum rhizosphere of humid soil. 32 isolates produced alkaline phosphatase which ranged from 46 to 460.9 (µg p-nitrophend released ml^{-1} broth h^{-1}). The maximum phosphatase activity was observed in A45 which was isolated from forest soil. Seventeen isolates of actinomycetes were field tested on maize (JM-216) in Vertisols along with FUI (fertilized 120:60:40, uninoculated) and UFUI (unfertilized uninoculated) controls.

2.7.10 Biofertilizer technology

Shelf life of biofertilizers

Addition of the bentonite (0.1%) resulted in 10-fold increase in population of *Azospirillum* and phosphobacteria in liquid formulations. However, the nitrogen fixing potential, IAA production and P-solubilizing ability of these organisms did not show any significant difference compared to control (without bentonite addition) (TNAU, Coimbatore).

Liquid biofertilizers

Complex liquid medium MGM3 could retain population of microbial consortium up to a period of six months whereas complex medium MGM8 could retain good population up to a period of nine months. On-farm trials with liquid biofertilizers on rice could save 25% of N and P in farmers' fields. In organic farming, application of liquid biofertilizers resulted in more grain yields in paddy at farmer's field (ANGRAU, Amaravathi).

Method of application in Bt and non-Bt cotton

Three years field trials on dry land Vertisols showed greater seed cotton yield in transgenic Bt (21.9 q ha^{-1}) as compared to non-Bt (19.3 q ha^{-1}). Dual inoculation of *Azotobacter* +PSB was significantly better than individual application and uninoculated control. Application of biofertilizers by mixing with moist compost after 15 days of crop germination by ring method was better is adoption to improve yield, nutrient uptake, soil fertility, microbial abundance and monetary returns (MAU, Parbhani).

2.7.11 Improved formulations of microbial inoculants and testing

Compatibility of PGPR and Rhizobium with Actinomycetes

To formulate a mixed consortium of the organisms, the compatibility of actinomycetes with PGPR and *Rhizobium* was checked. The PGPR *Bacillus megaterium* P3, *Bacillus subtilis* P10 and *Lysinibacillus fusiformis* P25 and soybean rhizobia-*Rhizobium* R10, R11, R32, R50 and R51, *Bradyrhizobium* R16, R33 and R34, chickpea rhizobia-*Rhizobium* R 40 and R56 were co-inoculated with 5 different strains of *Streptomyces* sp. (A1, A2, A6, A10 and A17) on humic acid vitamin agar, nutrient agar and tripticase soy agar. The results showed that all the 5 strains of *Streptomyces* were compatible with all the three PGPR strains P3, P10 and P25 when inoculated together. No chickpea *Rhizobium* strain was compatible with any of the *Streptomyces* strains. So it was concluded that consortia of Actinomycetes with PGPR can be prepared but not with chickpea rhizobia.

Compatibility among Actinomycetes

Compatibility among five different strains of *Streptomyces* sp. (A1, A2, A6, A10 and A17) was studied by co-inoculating the five strains on humic acid vitamin agar and starch casein agar. All the strains were compatible with one another and none of them inhibited each other.

High count Bacillus medium

In order to improve the quality of inoculants, modifications were made to nutrient broth to obtain high cell densities of *Bacillus* sp. Peptone was removed and in its place, glucose, K_2HPO_4 and $MgSO_4.7H_2O$ were added. Glucose is an easily utilizable carbon source and phosphate acts as source of P as well as increases the rate of glucose uptake. Concentration of yeast extract was increased so as to compensate for peptone and also decreased the C:N ratio of the medium which served to increase the cell counts. Calcium carbonate was added so as to protect the medium from pH fluctuations that is an important factor which limits cell counts. Two strains of *Bacillus* P10 and P25 were grown in nutrient broth as well as the modified broth for 48h at 28°C under continuous shaking at 125 RPM. After incubation, the cell counts were done using suitable dilutions on nutrient agar plates. The cell counts improved many fold (Table 1). A variant of yeast mannitol broth with glucose at a concentration of 10 g^{-1} and mannitol reduced to 5g L^{-1} instead of 10 g L^{-1} did not give any difference in counts of rhizobia.

Testing carrier based formulations of actinomycetes on maize

Field evaluation of 17 carrier based actinomycetes inoculants on maize (var. JM-216) in *kharif* 2013 in a Vertisol at Jabalpur showed that the best isolates A1, A2, A6, A10, A16 and A30 gave average yield of 3843 kg ha^{-1} (control yield 2279 kg ha^{-1}). Liquid formulations of the same isolates were also evaluated on chickpea (JG-16). Isolates A1, A2 and

A6 and A17 gave average yield of 2292 kg ha^{-1} over control (1389 kg ha^{-1}). Liquid formulations A10 and A17 individually and in mixed consortium (CRP) of *Rhizobium* (R40 and R56) and PGPR (P3, P10 and P25) strains were evaluated separately and in combination on chickpea. Combination of A10 + A17 + CRP gave the highest yield of chickpea (2972 kg ha^{-1}) which was 65% higher over uninoculated control (1805 kg ha^{-1}) (JNKVV, Jablpur).

2.8 Soil Genomics

2.8.1 Metagenomics of organic soils

Soil bacterial community structure and function in organic and chemical farming system was compared in soybean and maize through metagenomic analysis of the V3 region of 16S rDNA at four time periods- before sowing, seedling, vegetative, flowering and maturity stages of crop growth by using next generation sequencers. All the samples studied were rich in bacterial species (816 to 1047). Average number of species was 940 in organic and 884 in chemical farming in soybean. Differences in Shannon diversity index were minor. The reductions in species diversity were subtle rather than dramatic.

Based on 16S rRNA data, species belonging to *Rhizobium* and *Arthrobacter* were found to be in higher proportion under organic management. Clustering of protein coding genes at subsystem level 1 indicated that the genes involved in respiration, nitrogen fixation, stress response, resistance to heavy metal and production of antibiotics were found significantly higher proportion in organic soil of maize rhizosphere (UAS, Dharwad).

2.8.2 Long-term fertilization effect on N-transforming genes

In a 100 year old permanent manurial trial, the effects of organic (OM) and inorganic (IC) nutrient managements on bacterial communities were measured. The abundance of bacterial 16S rRNA, *nif H* and *amo A* genes was measured for two years using quantitative real-time PCR. The 16S rRNA and *nif H* genes were abundant in OM while the inorganic nutrient amendments increased the quantity of *amo A* gene. The OM plots had higher substrate-induced respiration (SIR) rates compared to IC and control unfertilized soils but the metabolic quotient (qCO_2) of the soil remained unaffected because of long-term nutrient management regimes. IC recorded higher nitrification potential (NP) compared to OM and control. The multivariate regression analysis revealed that MBC, SOC and SIR were the significant soil variables that drive the abundance of 16S rRNA and *nif H* genes, while for *amo A,* the variables were available N, SIR and NP. Long-term organic and inorganic nutrient management had strong influences on key bacterial genes and biochemical processes in semi-arid tropical Alfisol. The study underlined the importance of fertility management options *viz.*, organic amendments and balanced mineral fertilizers for improving or sustaining the biological properties of tropical soils (TNAU, Coimbatore).

2.8.3 Metagenomic characterization and spatio-temporal changes in microbes in the rhizoplane of bioenergy crop *Jatropha curcas*

Real time PCR quantification of nutrient cycling microbes in the rhizosphere of bioenergy crop

Functional microbial groups involved in nutrient transformation in the rhizosphere were quantified using quantitative real time PCR. Genomic DNA extracted from soil samples using extraction buffer (SDS, CTAB based) and phenol:$CHCl_3$ separation protocol. Real time PCR carried out using SYBR green targeting functional gene of eubacteria (16S rRNA), ammonium oxidizers (*amo A*), nitrogen fixers (*nif H*), P solubilizers, and denitrifiers (*nirK*). Preliminary results revealed that *Alp* gene (P solubilizer) varied from $5.8x10^4$ – $8.1x10^6$ genes g^{-1} soil, while the *amoA* ranged within $1.5x10^6$-$5.5x10^8$ gene copies g^{-1} soil. Data revealed differential abundance of functional genes indicating significance of microbial interaction in the rhizosphere of bioenergy crop *J. curcas*.

Metagenomic diversity of rhizospheric microbes associated with bioenergy crop

Diversity of bacteria and archaea in the rhizosphere of *J curcas* was estimated to define how the bioenergy crop

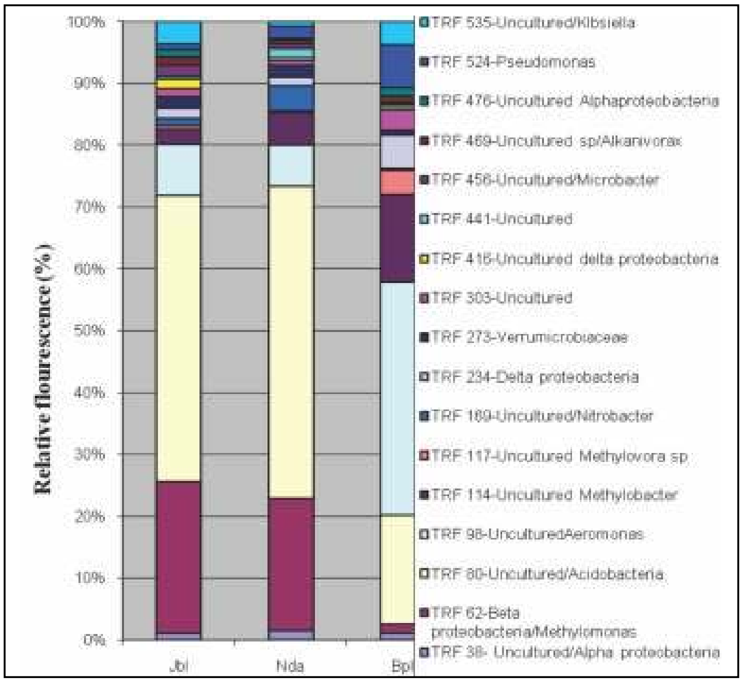


Fig.2.8.1 Metagenomic diversity of bacteria associated with rhizosphere of bioenergy crop. X axis represents sampling location and Y axis relative fluorescence (%) of different ribotypes.

Theme IV: Soil Pollution, Remediation and Environmental Security

2.9 Amelioration of Contaminated Soils

2.9.1 Removal of heavy metals from municipal solid waste composts through extraction-cum-wet sieving

Our previous study showed that composts manufactured in India from mixed wastes (MWC) and partially segregated wastes (PSWC) were unsuitable for land application due to low organic matter and high heavy metal content. (Fertilizer Control Order, 1985 Govt. India). Finer size (<0.5 mm) particles in MWC and PSWC contained higher concentrations of heavy metals (Fig. 2.9.1) in inorganic forms or were electrostatically held on the surfaces of organic and inorganic particles (Fig. 2.9.2).

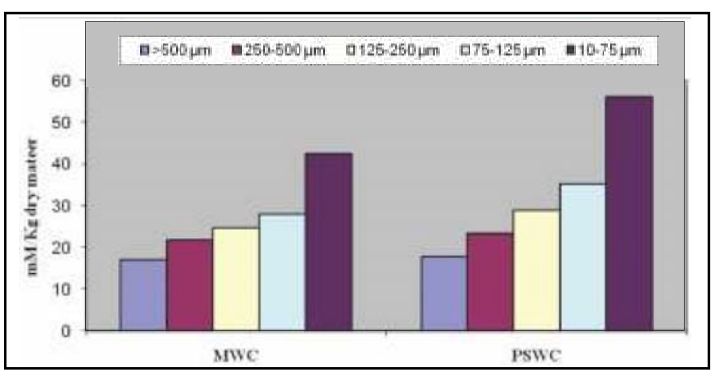


Fig. 2.9.1 Mean total heavy metals (Cd, Cu, Cr, Ni, Pb and Zn) present in different size fractions of composts prepared from municipal solid wastes

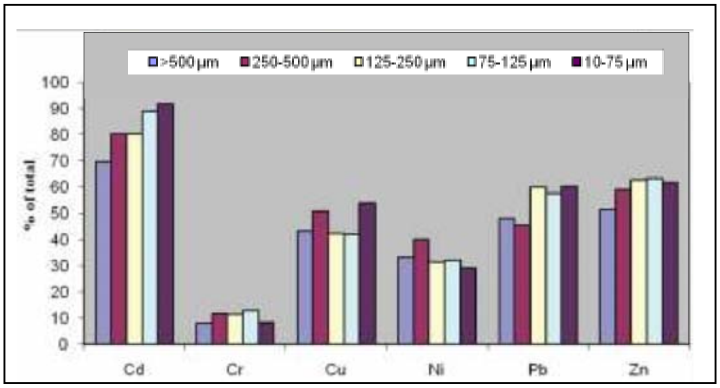


Fig. 2.9.2 Fraction of total heavy metals extracted by 0.5 N HCl from different size fractions of composts prepared from municipal solid wastes

An experiment was initiated to investigate the removal of heavy metals from municipal solid waste composts through extraction-cum-wet sieving. Fourteen compost samples from different cities, prepared from mixed wastes (unsegregated/ partially segregated) were selected for the study. Extractants compared were water, EDTA (0.05N), HCl (0.1N) and raw distillery spent-wash (RSW) containing 0.01N EDTA. Compost samples were treated with extractants (unstirred in 1:5 ratio) for 48 hours and thereafter, these were washed on 0.5 mm sieve to remove finer particles and extracted metals. The retained >0.5 mm MSW compost materials were dried in oven at 70ºC for 24 hours. Total heavy metal contents in the dried samples were determined by acid digestion method. Results showed that removal of finer particles with water reduced, on an average, Cu by 22%, Cd by 19%, Pb by 21%, Cr by 26%, Ni by 42%, Zn by 15% and As by 24%. Among the extractants, 0.05N EDTA was usually most efficient in removing Pb and Cr; whereas, RSW+0.01N EDTA was most efficient in removing Cu, Cd, Ni, Zn and As (Fig. 2.9.3). Extraction-wet sieving using efficient extractants (0.05N EDTA and RSW+0.01N EDTA) reduced different heavy metals on an average by about 34-58%, indicating that this method has considerable potential in lowering the magnitude of soil contamination potential from the regular use of MSW composts in agriculture.

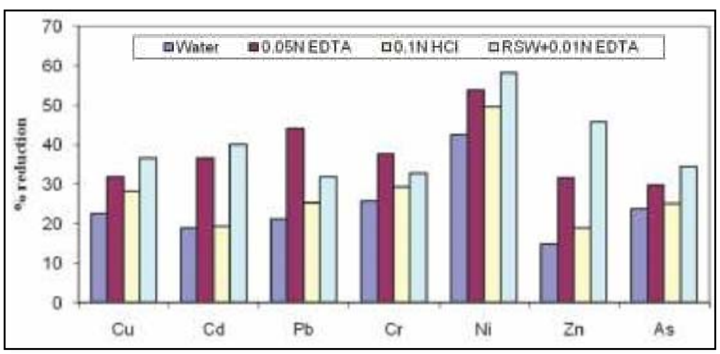


Fig. 2.9.3 Reduction in heavy metals contents in MSW composts using extraction-wet sieving

2.9.2 Bioavailable P fractions in water and sediment samples of Upper lake, Bhopal

The water samples were collected from (15 locations) where water enters from different source (Agriculture and Municipal water) to the Upper lake and analyzed for different P fractions. The results showed that the total phosphorus (TP) in the water sample (entry point) ranged from 0.30 to 0.73 mg L^{-1} (mean value of 0.47 mg L^{-1}) with minimum and maximum value from Kholukhedi (Agriculture source) and Bhadbada (domestic waste water), respectively. Among the P fractions, the bioavailable P fraction (total dissolved P-TDP) was the highest in the domestic wastewater, where the dominant P fraction in water samples from agriculture source was particulate P (PP).

Soil samples collected from the catchment area of Upper lake, Bhopal were analyzed for total and available P. The total P content of the soil samples ranged from 0.028 to 0.09% with a mean value of 0.041% while the available P ranged from 4.42 to 59.75 kg ha^{-1} with a mean value of 27.52 kg ha^{-1}. The geo-referenced sediment and water samples collected from 15 sampling points of Upper Lake, Bhopal were analyzed for different fractions of P (Table 2.9.1). The total P value in the pre monsoon stage water samples ranged from 0.23 to 0.46 mg L^{-1} with a mean value of 0.40 mg L^{-1}. The mean TDP, total reactive P (TRP), dissolved reactive P (DRP), dissolved organic P (DOP) and particulate P (PP) was 30.07%, 19.73%, 12.07%, 15.17% and 67.72% of TP, respectively. The total P in the sediment of pre monsoon stage samples ranged from 0.025 to 0.074% with a mean value of 0.049%. The mean sediment inorganic phosphorus (SIP) and the sediment organic phosphorus (SOP) was 70.75% and 29.43% of total phosphorus (TP), respectively. Among the inorganic P fractions in the sediment, Ca bound P was maximum and found to be in the range of 89.42 to 95.82% of total sediment inorganic P followed by Fe bound P (2.72 to 8.75%) and loosely sorbed P (LSP) (0.47 to 6.72%).

Table 2.9.1 Phosphorus fractions (% of TP) in water samples collected from different entry points of upper lake, Bhopal

Locations	Total P Fractions (%)				
	DRP	TRP	TDP	PP	DOP
Koh-e-fiza (City)	23.09	36.25	44.66	55.34	27.56
Shahid Nagar (City)	15.07	28.68	40.95	59.05	19.94
Lalgati (Ag)	6.25	12.17	30.82	69.18	11.17
Bairagarh (Idol)	20.92	29.92	35.56	64.44	25.92
Baisenkhedi (Ag)	4.21	6.32	26.05	73.95	9.08
Bhauri (Ag)	3.43	5.43	25.14	74.86	8.33
Jamoniya Cherra (Ag)	4.89	7.47	25.29	74.71	9.87
Kholukhedi (Ag)	10.28	13.91	24.44	75.56	15.26
Kolans Nala (Ag)	2.54	5.07	20.85	79.15	18.57
Mugaliya Chap (Ag)	4.25	6.37	23.11	76.89	9.24
Goregoan	3.69	5.96	23.26	76.74	5.84
Barkeranathu (Ag)	1.70	3.41	19.60	80.40	6.69
Bhadbada (Idol)	11.29	19.83	40.08	59.92	16.28
Prempura (City)	7.00	8.70	31.16	68.84	11.99
Bhadbhada lake sample	14.62	21.54	30.51	69.49	19.61
Minimum	1.70	3.41	19.60	55.34	5.84
Maximum	23.09	36.25	44.66	80.40	27.56
Average	8.88	14.07	29.43	70.57	14.36

Ag - Agriculture

2.9.3 Effect of chromium contamination on microbial activity and carbon mineralization rate

Use of chromium (Cr) contaminated tannery effluent for irrigation purpose reduces the crop yield and soil microbial activities. The soil microbial population plays a crucial role in plant nutrient transformation and its availability to plant. Keeping the above view, a study was conducted to evaluate the effect of Cr on carbon mineralization and microbial activity. Graded doses of Cr (0, 5, 10, 15, 20, 40, 80 and 100 ppm) were applied, and CO_2 evaluation was measured at 1, 2, 4, 7, 15, 30 and 45 days after incubation. Increase in the concentration of Cr (0 to 100 ppm), decreased the cumulative CO_2 evolution from 354.2 to 122.47 mg CO_2 100^{-1}g soil incubated upto 45 days. The initial CO_2 evaluation rate was higher and decreased with time in all the treatments. A drastic reduction was observed from 40 to 100 ppm Cr level. The study indicates that high concentration of Cr significantly reduced microbial activity and carbon mineralization rate in the soil.

2.9.4 Sewage water utilization for agriculture the farmers in Bhopal region

A survey was done to collect secondary data information from various sources (Central Pollution Control Board, MP Pollution Board and Bhopal Municipal Corporation) on municipal sewage water with respect to generation (volume) and treatment capacity; extent of area irrigated with sewage water, and its impact on crop productivity. It was observed that large areas of the city has no proper sewage network, either internal or trunk, and thereby raw sewage or septic tank outflow are discharged directly into open drains which ultimately flow to the water bodies (Patra Nala, Halali dam and Betwa River).

Under Bhopal Municipal Corporation, about $1/3^{rd}$ area has underground sewers in different catchments and in the remaining $2/3^{rd}$ areas, a large section of population discharge wastewater into open drains. The total wastewater generation in the Bhopal city is about 334.75 MLD *i.e.* million liter per day (CPCB 2009-10), against which the treatment capacity is only 22 MLD (7%) of total generation. This sewage water is being widely used by the farmers for crop production particularly for vegetable cultivation. Farmers from more than 45 villages are getting benefit of Patra Nala sewage water to meet their crop irrigation requirement. Farmers reported that with the use of sewage water, chemical fertilizer application is reduced to half and crop yield is increased as compared to the tube well irrigated crops. During survey, sewage water (33 samples) and soil samples (47 samples) were collected from different locations starting from lower lake to Halali dam at an interval of 1 to 2 km distance (Plate 2.12).

Plate 2.12 Collecton of sewage water and soil samples along with the main stream

2.9.5 Screening fungi *vis a vis* heavy metal toxicity

Six efficient mesophilic fungi have been identified from municipal solid waste compost, domestic sewage-sludge and industrial effluents. It was observed that the growth performance substantially decreased with higher concentration of heavy metals. However, *Aspergillus terrus, A heteromorphus, A. flavus and A.awamori* could not grow at 5-10 ppm of Cd and 25 ppm of Cr. All these fungi could tolerate Zn concentration up to 400 ppm in growth media.

The degree of biosorption of a metal ion on biosorbent has been found to be a function of the equilibrium metal ion concentration in solution at constant pH and temperature conditions. The single solution adsorption isotherm model of Freundlich model is basically empirical, and was used for heterogenous surfaces and the model is a useful means of data description. The Freundlich isotherm is computed as follows : $Q=KCe^{1/n}$ Where, Q is metal uptake capacity of biomass, or amount of metal ion biosorbed per unit biomass, K is biosorption equilibrium constant indicative of biosorptive uptake capacity, n is biosorption equilibrium constant and Ce is equlibrium metal ion concentration in solution after biosorption.

The basic data of Zn and Cr biosorption on different fungi were fitted into isotherm equation to explain the adsorption behavior of Zn and Cr (Table 2.9.2). The variation in equilibrium Zn and Cr concentration in different dead fungi were 1.2 to 18.5 mg L^{-1} and 0.4 to 18.1 mg L^{-1} observed at all levels of Zn and Cr application. The Cd adsorption isotherm curve of X/m *vs* Ce for different fungi X/m is the capacity of adsorption per gram of biomass and Ce is the equilibrium concentration. With increase in Cr levels the affinity of Cr for solution phase increased with increase in added Cr at higher levels, but the absolute affinity seems to be towards solution. There was comparatively smooth increase in adsorption rate up to 30 mg kg^{-1} biomass and beyond this level, the rate of adsorption decreased. The relative affinity of Zn at lower concentration was more for solid phase than the affinity for solution phase which was similar to that of Cr. Due to coverage of surface up to certain Zn level; it had more affinity for solution and later on with increase in further Zn levels, due to precipitation and or multilayer adsorption, the affinity for solid phase increased.

The adsorption parameters of Freundlich model for Cr, n and K value varied from 0.6 to 1.00 and 54.2 to 206.7, respectively and for Zn, n and K values were varied from 0.62 to 0.69 and 73.4 to 88.1, respectively. Higher values of K indicate higher biosoptive uptake capacity of metal ions. In this study K values were higher for *Aspergillus heteromophus* followed by *Trichoderma viride* for Zn and Cr. It was also observed that higher the "n" value, higher the metal adsorption binding affinities towards fungi cell. The Cr and Zn adsorption equation studied conformed to the Freundlich isotherm for fungi that adsorption of Zn is relatively higher than Cr.

Table 2.9.2 Freundlich biosorption constant of Cr and Zn sorption phenomenon

Organisms	Freundlich constant (Cr)			Freundlich constant (Zn)		
	K	n	R^2	K	n	R^2
Trichoderma viride	54.2	0.6	0.96	88.1	0.69	0.96
Aspergillus heteromophus	206.6	1.0	0.99	73.4	0.62	0.96

2.9.6 Heavy metal toxicity and trace metal contamination

In maize plants, a major fraction of almost all heavy metals (Cd, Co, Ni and Pb), except Cr were accumulated in roots and little was translocated variably to the upper plant parts. The accumulation of the elements in roots was as follows: Co (82%) > Pb (65%) > Cd (57%) > Ni (41%) > Cr (17%). The soils in the peri-urban areas of Nagpur and Aurangabad districts of Maharashtra continuously irrigated with sewage water showed higher average available sulphur (29.8 mg kg^{-1}) as compared to well water irrigated soil (17.4 mg kg^{-1}). Average DTPA-extractable micronutrients and heavy metals were also found higher in the soils irrigated with sewage effluent. The mean DTPA-Zn, Fe, Mn, Cu, Co, Cd, Pb and Cr in soil were found to be 3.12, 21.46, 26.43, 3.67, 0.769, 0.144, 1.85 and 0.595 mg kg^{-1}, respectively, while in well water irrigated areas it was found to be 0.63, 9.91, 15.50, 1.81, 0.050, 0.026, 0.32 and 0.238 mg kg^{-1}, respectively. The threshold toxic limits of Ni in buckwheat for 10 per cent reduction in relative yields were 25.4, 29.0 and 11.5 mg Ni kg^{-1} dry matter for soil which received 0, 2.23 and 4.46 g FYM kg^{-1} soil, respectively. Similarly threshold toxic limits for Cd in buckwheat were 6.0, 21.0 and 15.25 mg Cd kg^{-1} dry matter grown in soil which received 0, 2.23 and 4.46 g FYM kg^{-1} soil, respectively.

2.9.7 Assessment of Century plant (*Agave americana*) for remediation of chromium contaminated soils

An experiment was conducted to evaluate the potential of an ornamental non edible fibre yielding plant namely century plant (*Agave americana*) for the remediation of soils contaminated with Cr. Century plant was selected because it comes up well on dry soils which are otherwise unsuitable for cultivation. The plant was exposed to different levels of Cr (0, 25, 50,100 and 200 mg kg^{-1} soil) and mechanism of tolerance to Cr was studied (Plate 2.13). Also the phytotoxicity threshold concentration (PT_{50}) of soil and plant, and the characteristics of Cr accumulation *viz.,* partitioning of Cr and its uptake, bioconcentration factor (BCF), translocation factor (TF), translocation efficiency (TE %) *etc.* were assessed.

Plate 2.13 Effect of different levels of Cr on growth of century plant (*Agave americana*)

Agave americana tolerated up to 200 mg Cr kg^{-1} soil (Plate 2.13). But beyond 50 mg Cr kg^{-1} soil, there was no addition of new roots and leaves (Table 2.9.3) and there was a reduction in the dry weight of roots by 50%. The phytotoxicity threshold concentration ($PT_{50-leaf}$) defined as the concentration of Cr in plant tissue that corresponds to 50% growth retardation was found to be 88.5 mg kg^{-1} (Fig. 2.9.4). Similarly, $PT_{50-soil}$ defined as concentration of Cr in soils (added) where Cr causes 50% reduction in maximum yield, was calculated. Similar to $PT_{50-leaf,}$ in the present study, $PT_{50-soil}$ was also found to be in the same range i.*e,* 81 mg kg^{-1} (Fig. 2.9.6). The index of Cr tolerance decreased with increase in the level of applied Cr. Up to 50 mg Cr kg^{-1} soil, the index of tolerance was greater than 50 % and beyond that, it was < 50%. In general, the concentration of Cr in the plant tissues (roots and leaves) increased with increasing addition of Cr to the soil (Table 2.9.4). Significantly greater accumulation of Cr occurred in roots than in leaves. On an average the concentration of Cr was around seven times higher in roots than in leaves. The concentration of Cr in the roots ranged from 150 µg g^{-1}dry wt at Cr 25 mg kg^{-1} soil to 1318 µg g^{-1}dry wt at 200 mg kg^{-1} soil. The concentration of Cr in the leaves ranged from 22 µg g^{-1}dry wt at Cr 25 mg kg^{-1} soil to 179 µg g^{-1}dry wt at 200 mg kg^{-1} soil. The significant difference between root and shoot concentrations indicated an important restriction of the internal transport of Cr from roots to shoots. For an effective phytoextraction process, substantial amounts of the Cr taken up by the root must be translocated to the harvestable plant parts so that it can be completely removed from the contaminated site. Translocation factor (TF) indicates the efficiency of the plant in translocating the accumulated heavy metals from roots to shoots. TF of >1 shows that the accumulation of heavy metals in the shoots is higher than roots. In the present study, the TF values were found to be <1 and a linear decrease in TF values were observed (0.18-0.13) (Table 2.9.4 and Fig. 2.9.5). The study has clearly demonstrated that this plant could not be classified as a hyperaccumulator of Cr. Hence, it could not be considered for phytoextraction of Cr, however it could be considered as a potential plant species for phytostabilization of Cr contaminated soils.

Table 2.9.3 Effect of different levels of Cr on some physiological parameters in *Agave americana*

Treatment (mg Cr kg^{-1} soil)	Dry weight (g $plant^{-1}$)		Number of leaves/plant	Tolerance index (%)
	Root	Leaves		
0	3.75	16.88	18.30	-
25	3.43	14.65	17.00	87.6
50	1.87	10.12	11.30	58.1
100	1.63	7.02	8.00	41.6
200	1.59	7.21	8.00	42.7
CD (0.05)	0.89	2.27	0.70	-

Table 2.9.4 Partitioning, uptake, translocation factor and translocation of Cr in *Agave americana*

Treatment (mg Cr kg^{-1} soil)	Concentration of Cr in the tissue (µg g^{-1} DW)		Uptake of Cr (µg g^{-1} plant)			Cr removal	TF	TE	BCF
	Root	Leaves	Root	Leaves	Total	(%)			
25	122	22	417	327	745	0.47	0.18	44	4.88
50	253	40	473	364	890	0.24	0.16	41	5.06
100	567	87	924	417	1535	0.21	0.15	27	5.67
200	1318	179	1568	718	2286	0.16	0.13	31	6.59
CD (0.05)	128	19	253	144	259	0.12	0.02	-	

TF = Translocation Factor, TE= Translocation efficiency (%), BCF= Bio Concentration Factor

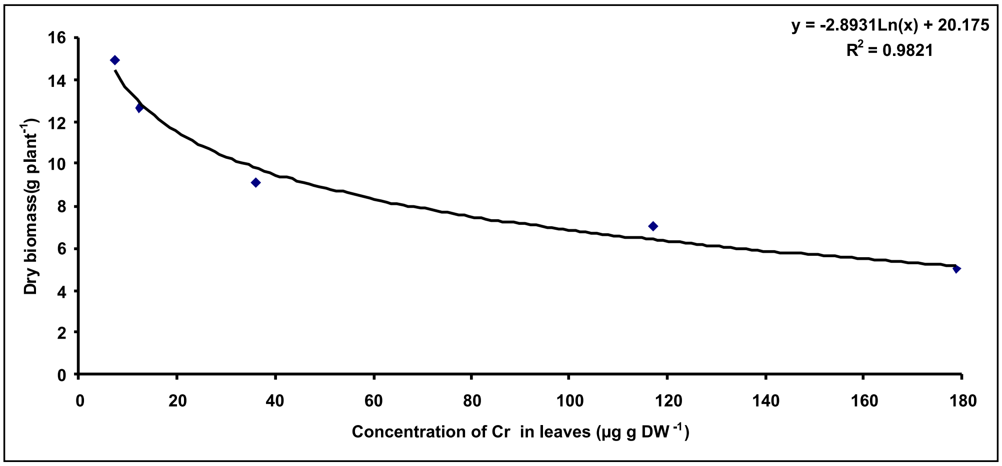


Fig. 2.9.4 **PT $_{50\text{-leaf}}$ in Agave *Americana***

(PT $_{50\text{-leaf}}$ is the concentration of Cr in the leaf tissue that cause 50% reduction in the dry weight of the leaf)

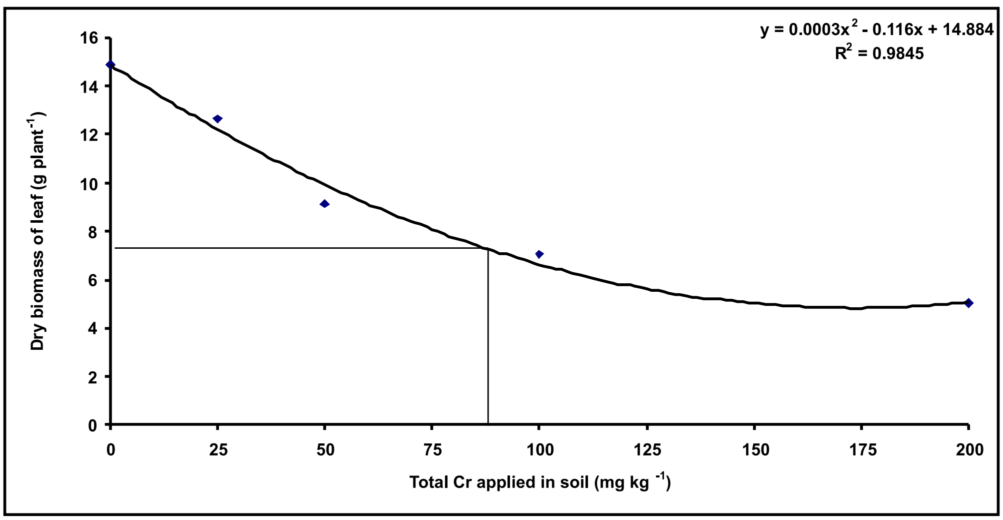


Fig. 2.9.5 **PT $_{50\text{-Soil}}$ in Agave *americana***

(PT $_{50\text{-Soil}}$ is the concentration of Cr in the soil that cause 50 % reduction in the dry weight of the leaf, PT= Phytotoxicity threshold concentration).

2.9.8 Herbicide persistence in soil

Half life and dissipation constant of Imazethapyr (Jabalpur)

The dissipation constant of imazethapyr was the highest in 100% NPK + FYM and the lowest in 100% N treatment. However, the half life period recorded was minimum in 100% NPK+FYM and maximum in 100% N alone. Further, imazethapyr content decreased with passage of time (Fig. 2.9.6 and 2.9.7). However, incorporation of FYM increased the persistence time because of sorption of herbicide, which is protected from microbial decomposition.

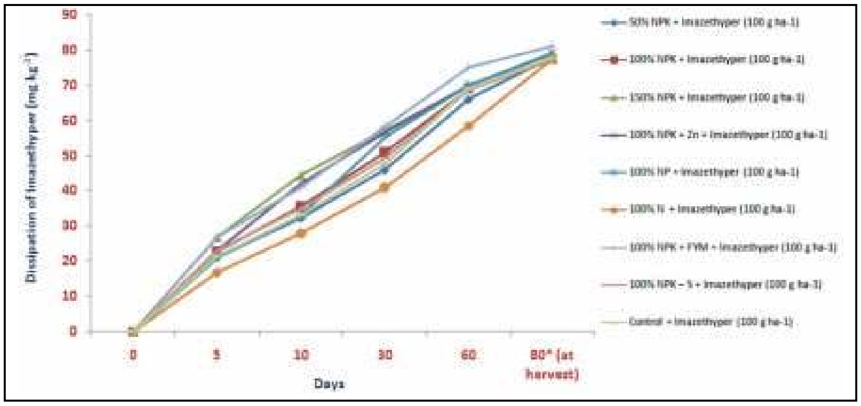


Fig. 2.9.6 Dissipation of Imazethapyr on soil at different interval

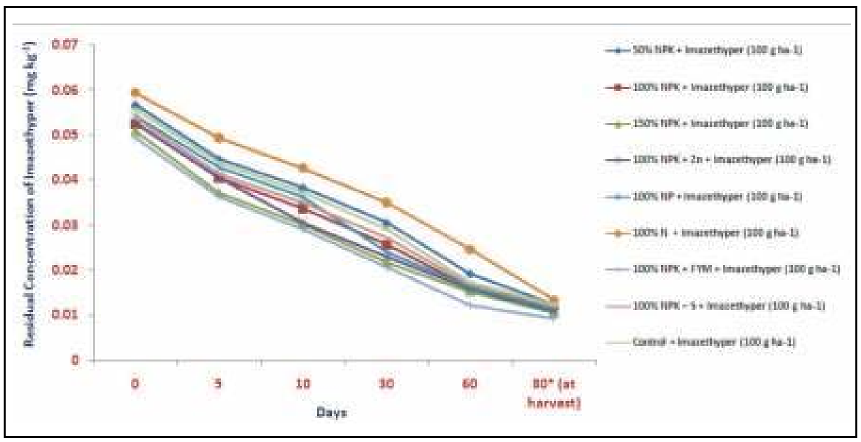


Fig. 2.9.7 Residue of Imazethapyr on soil at different interval (Jabalpur)

Degradation of herbicide (Barrackpore)

The effect of 2 pre-emergence (trifluralin and fluchloralin), 1 post-emergence herbicide (quizalofop ethyl) and 3 fungicides (carbendazim, mancozeb and copper oxychloride) applied on jute (*Chorchorus olitorius* L.) were studied for fibre yield, nutrient uptake and residual nutrient status and soil quality parameters. The enzyme activities (dehydrogenase, urease, fluorescein diacetate hydrolyzing activity and acid and alkaline phosphatase) in soil reduced significantly after 7 days of herbicide and fungicide application, while treatments having un-weeded control and hand weeding maintained the same status as compared to initial status. The microbial biomass carbon and basic soil respiration rate of the soil followed the same trend as that of enzyme activities during 3rd year. The enzyme activities, microbial biomass carbon content and basic soil respiration rate in herbicides and fungicides treated plots started recovering after 15 days of their application and recovered almost to the extent of their respective initial level. The recovery in microbial biomass carbon and other microbial properties may be due to adaptability of the microorganisms in utilizing these herbicides/fungicides as a source of carbon, resulting in increased microbial population and other enzymatic activities. Among the herbicides and fungicides, trifluralin 0.75 kg *a.i.ha*$^{-1}$ was the safest regarding soil quality next to hand weeding with higher fibre yield. Application of herbicides and fungicides had temporary detrimental effect on enzyme activities and other microbial properties of soil, which were replenished at the time of harvest of the crop. Although, hand-weeded plots maintained better microbial properties, but as the cost of cultivation is more under hand weeding, it can be substituted by pre-emergence herbicide trifluralin @ 0.75 kg *a.i.*ha^{-1} without affecting fibre yield and soil quality much but with less cost involvement.

Isoproturon in soil with drill sown finger millet crop (Bangalore)

The persistence of isoproturon in soils of experimental field in Bangalore revealed that the residue of isoproturon in soils ranged from 0.10 to 0.63 µg g^{-1} (Table 2.9.5). The rate of degradation is maximum in 100% NPK+ FYM+ lime treatment followed by 150% NPK treatment and 100% NPK+ FYM treatment and least degradation is observed in control followed by 50% NPK treatment. Though application of FYM and lime both have resulted increase in dissipation but small amount persisted for larger period, may be because of protective action of manure compared to NPK. The half life of isoproturon in the field ranged from 10.5 to 20.8 days (Table 2.9.6). Nutrient application had insignificant effect on half life. However, application of lime resulted in decline in half life of isoproturon which could be due to large activities of micro-organisms.

Table 2.9.5 Persistence of Isoproturon in soil under Long term fertilizer experiment on finger millet

Treatments	Residues (µg g^{-1}) at days after applications							
	0	3	5	10	20	30	40	60
Control	0.63	0.60	0.55	0.43	0.41	0.32	0.22	BDL
100% N	0.56	0.53	0.50	0.43	0.37	0.22	0.09	BDL
100% NP	0.58	0.41	0.36	0.21	0.18	0.07	BDL	BDL
100% NPK	0.58	0.43	0.34	0.27	0.19	0.06	BDL	BDL
100% NPK+ Lime	0.54	0.59	0.43	0.34	0.30	0.14	0.07	BDL
100% NPK+ FYM	0.61	0.53	0.51	0.36	0.27	0.09	BDL	BDL

BDL- Below detectable level, ND- Not detected

Table 2.9.6 First order kinetics of K and half life ($t_{1/2}$) of the soils collected from LTFE experiment (Dissipation of Isoproturon in soil)

Treatments	K day^{-1}	$t_{1/2}$ days	r^2
Control	0.0290	20.8	0.970
100% N	0.0417	16.6	0.913
100% NP	0.0638	18.8	0.914
100% NPK	0.0680	17.6	0.955
100% NPK+ Lime	0.0443	15.6	0.931
100% NPK+ FYM	0.0582	10.5	0.948
100% NPK+ FYM+ Lime	0.0701	9.9	0.970

2.9.9 Greenhouse gas (GHG) emission from composting systems and characterization of GHG regulating microbes

A study was carried out to investigate the impact of environmental parameters on CH_4 oxidation of farm yard manure (FYM). Composting at 50-60% MHC stimulated CH_4 consumption than at 30 and 80% moisture holding capacity (MHC) (Fig. 2.9.8). Similarly incubation experiment with different temperature revealed that FYM exhibited maximum CH_4 oxidation at 35°C (Fig. 2.9.9). To develop an environmental friendly microbial technology to reduce CH_4 emission from compost, methane oxidizing bacteria (methanotrophs) from FYM were isolated and enriched under laboratory conditions. These isolated cultures were tested for their efficiency in enhancing CH_4 oxidation potential of the compost. Methanotrophic bacteria (Fig. 2.9.10) were added in the range of 10^7-10^{10} cells (CFU) per gram of compost (FYM). Methanotrophic bacteria at 10^8 cells showed maximum oxidation (22 µg g^{-1} d^{-1}) while bacterial inoculation at higher rate did not show any significant increase in CH_4 oxidation rate (Fig. 2.9.11).

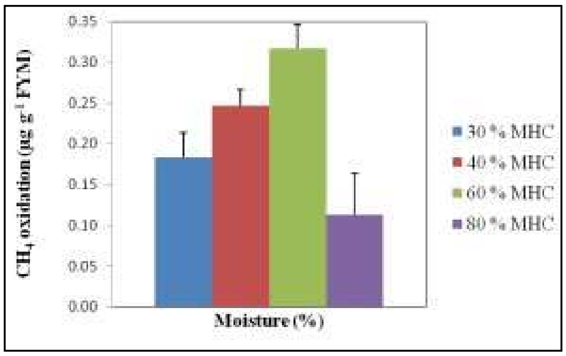


Fig. 2.9.8 **CH_4 oxidation in FYM as influenced by moisture holding capacity (MHC)**

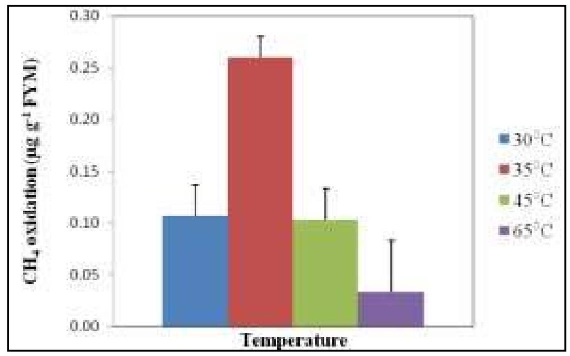


Fig. 2.9.9 **Influence of temperature on CH_4 oxidation in FYM.**

Fig. 2.9.10 **Methane oxidizing bacteria (Methanotrophs) isolated from compost (FYM).**

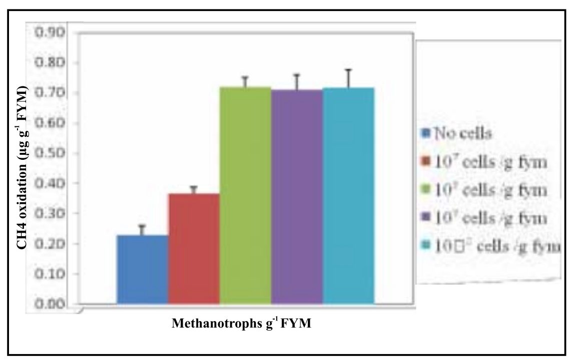


Fig. 2.9.11 **Influence of methanotrophs amendment on CH_4 oxidation rate of FYM.**

2.9.10 Biochar (BC) as an additive to compost for reducing Greenhouse gases (GHG)

In order to underpin the complex interaction of biochar (BC), composts and soil microbial process involved in GHG production and consumption was studied. Soil was amended with composts and BC at 80 kg N ha^{-1} and 10% w/w respectively. Three types of composts including vermicompost (VC), poultry manure (PM), and farm yard manure (FYM) and two sizes of BC (<0.25 mm, and 0.25-2.00 mm) were applied as single or in combination to soil. CO_2 production, CH_4 production, N_2O production and CH_4 oxidation was measured. Production of GHG followed the trend of CO_2>CH_4>N_2O. N_2O production from soil was in the range of 30 µg g^{-1} soil while BC amendment reduced N_2O production over control. Apparent rate constant k (µg CH_4 consumed g^{-1} soil d^{-1}) of CH_4 oxidation varied from 0.051 to 0.242 (Table 2.9.7). Amendment of BC enhanced k value in all treatments but their response was maximum in small size (<0.25 mm) BC fraction than large size (0.25 – 2.00 mm). CH_4 consumption significantly correlated ($p<0.0001$) with methanotrophic microbial population (Table 2.9.7) indicating the significant role of biochar in mitigating GHG emission from compost.

Table 2.9.7 Apparent rate constant of CH_4 oxidation and changes in the abundance of aerobic heterotrophs methane oxidizing bacteria in soil samples after complete headspace CH_4 oxidation

Treatment	BC size (mm)	Apparent rate constant k (µg CH_4 consumed g^{-1} soil d^{-1})	Aerobic Heterotrophs (CFU x 10^8 g^{-1} soil)	Methanotrophs (CFU x 10^6 g^{-1} soil)
Soil	-	0.051 ^{g}	1.33 ^{g}	6.00 ^{h}
Soil + VC	-	0.105 ^{de}	4.66 ^{fg}	15.00 ^{ef}
Soil + PM	-	0.072 ^{fg}	8.33 ^{def}	7.66 ^{gh}
Soil +FYM	-	0.093 ^{ef}	3.66 ^{fg}	12.00 ^{fg}
Soil + BC	<0.25	0.088 ^{ef}	11.00 ^{cde}	12.33 ^{fg}
Soil +VC + BC	<0.25	0.176 ^{b}	17.00 ^{c}	31.00 ^{b}
Soil + PM +BC	<0.25	0.242 ^{a}	53.00 ^{a}	45.00 ^{a}
Soil + FYM + BC	<0.25	0.150 ^{c}	15.00 ^{c}	26.67 ^{bc}
Soil + BC	0.25-2.00	0.125 ^{cd}	42.67 ^{b}	18.67 ^{de}
Soil +VC + BC	0.25-2.00	0.149 ^{c}	11.67 ^{cde}	19.33 ^{de}
Soil + PM +BC	0.25-2.00	0.147 ^{c}	13.33 ^{cd}	22.67 ^{cd}
Soil + FYM + BC	0.25-2.00	0.135 ^{cd}	6.66 ^{efg}	18.00 ^{de}
Tukeys HSD (=0.05, Df error = 24)		0.023	6.22	5.23

2.9.11 Greenhouse gases (GHG) emissions from static pit of poultry manure

Poultry manure of Parwalia village was characterized (Table 2.9.8) and correlated with GHG (N_2O, CH_4, CO_2) emissions. Sampling for GHG was carried in August - November 2013. N_2O emission was initially high with flux ranging from 2.05-29.15 mg m^{-3} d^{-1} (Fig. 2.9.12). CH_4 emission from poultry manure reached high at 30 days (Fig. 2.9.13). Decrease in CO_2 emission values over time indicates the maturity of compost. Greenhouse gas losses during composting of poultry manure in form of CH_4-C mg kg^{-1} was 0.37 and N_2O-N was 1.86 mg kg^{-1}. DNA was extracted to study the bacterial diversity during composting of poultry manure. High humics and protein content of the extracted DNA from poultry manure resulted PCR inhibition.

Table 2.9.8 Physico-chemical properties of poultry manure

Days of Sampling	NH_4-N (mg g^{-1})	SD	Volatile solids (%)	SD	Moisture (%)	SD	Total N (%)	SD
0	2.37	0.18	82.75	10.0	68	2.6	0.83	0.14
30	0.47	0.10	80.01	6.5	67	3.8	1.33	0.05
60	0.32	0.20	68.67	3.4	65	4.1	1.41	0.25
90			60.92	1.8	58	3.8	1.62	0.14

SD - Standard deviation

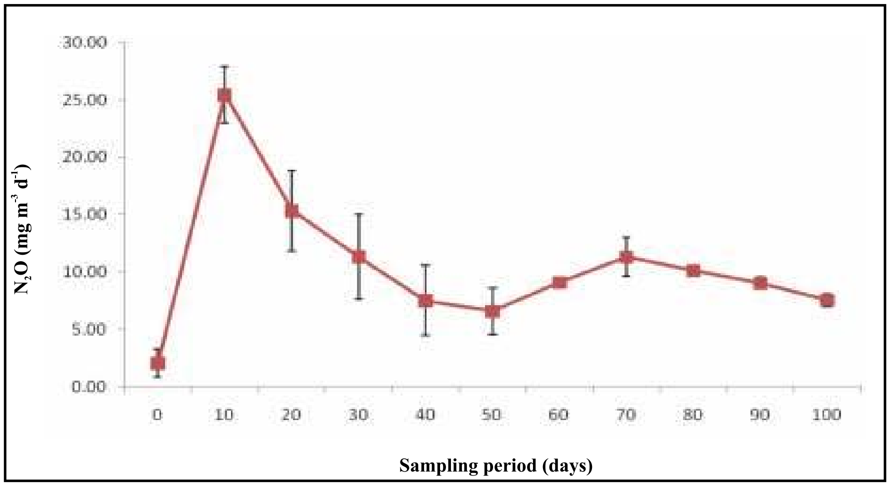


Fig. 2.9.12 Nitrous oxide (N_2O) emission from poultry manure (Pit).
Greenhouse gas was sampled using static chamber and analyzed in gas chromatograph with ECD. For all samples n=3, error bars are standard deviation.

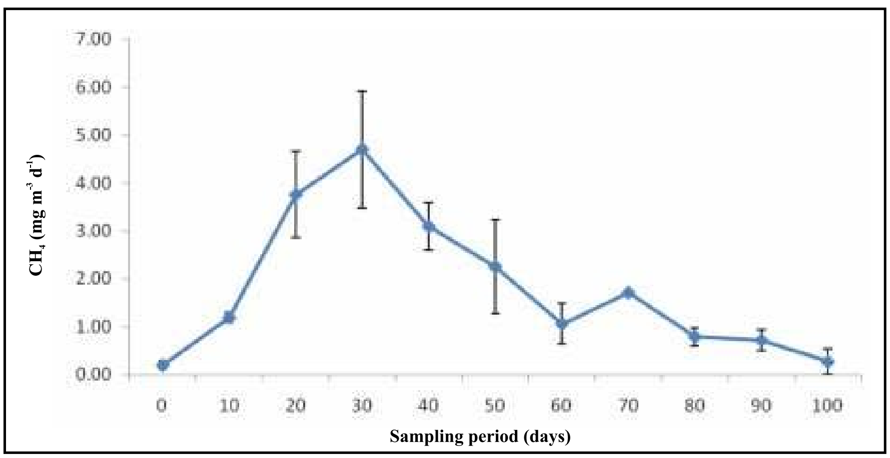


Fig. 2.9.13 Methane (CH_4) emission from poultry manure (Pit) during different sampling period.

3. TECHNOLOGY ASSESSED AND TRANSFERRED

3.1 Multi-location/verification follow up trials (STCR)

Barrackpore

Jute (JRO 128)

Follow up trials on jute (cv. JRO 128) in three locations under farmers' fields were conducted using the targeted yield equation developed at CRIJAF, Barrackpore through INM experiment (Table 3.1). The targeted yield of jute fibre (35 q ha^{-1}) was achieved with (–) 3.96 and (+) 0.16% yield deviation by the application of fertilizers as per soil test and targeted yield equation without and with FYM (Table 3.1). Similarly, the targets of 40 q ha^{-1} jute fibre yield was achieved with (–) 4.56 and (-) 1.53% yield deviations without and with application of FYM @ 5 t ha^{-1} in conjunction with NPK under soil test based INM treatment, respectively. The fibre yield (39.4 q ha^{-1}) under ST-TY+FYM treatment was recorded slightly lower than RDF (41.1 q ha^{-1}) but save 11.6, 30 and 30 kg N, P_2O_5 and K_2O, respectively over the RDF. Response ratio was found maximum in ST-TY (35 q ha^{-1}) followed by ST-TY (40 q ha^{-1}) treatment but B: C ratio was observed almost similar to RDF. Application of phosphorous in jute crop was avoided in ST-TY treatments where available soil-P was higher than the 10 kg P ha^{-1} (Critical limit for jute).

Table 3.1 Verification of IPNS fertilizers prescription equations of jute (JRO 128) in farmers' fields (mean value of three locations)

Treatment	Fertilizer doses (kg ha^{-1})			Fibre yield (q ha^{-1})	Response ratio (q ha^{-1})	Net return (Rs. ha^{-1})	Yield deviation (%)	B:C ratio
	N	P_2O_5	K_2O					
Control	-	-	-	26.4	-	20104	-	1.53
FP	23	50	50	31.5	4.2	28507	-	1.70
RDF	80	40	40	41.1	9.2	48648	-	2.17
ST-TY 35 q ha^{-1}	36	10	10	33.6	13.0	34621	(-) 3.96	1.88
ST–TY 35 q ha^{-1}+FYM	30	10	10	35.1	17.3	37943	(+) 0.16	1.97
ST-TY 40 q ha^{-1}	74	10	10	38.2	12.5	43748	(-) 4.56	2.09
ST–TY 40 q ha^{-1}+FYM	68	10	10	39.4	14.7	46556	(-) 1.53	2.16

TY - Targeted yield; FP - Farmers practices; ST-STCR dose

Rice (MTU 1010)

Three follow up trials on rice (cv. MTU 1010) were conducted in the *kharif* season in Nadia districts, West Bengal. From the result, it was observed that 40 and 50 q ha^{-1} targeted yield of rice grain has been achieved with (+) 1.39 and (–) 0.44% yield deviation, respectively whereas in soil test and targeted yield based INM treatment, the rice grain yield superceded the fixed target of 40 and 50 q ha^{-1} rice grain with (+) 5.56 and (+) 0.44% yield deviations (Table 3.2). Profit earned under ST-TY treatment with INM was found higher in comparison to RDF. Response ratio and B:C ratio was also found the highest in the ST-TY+FYM treated plot. Application of fertilizers as per soil test and targeted yield with INM could achieve the target which was superceded to the RDF and saved about 11.3, 22.0 and 8.0 kg N, P_2O_5 and K_2O kg ha^{-1}.

Table 3.2 Verification of IPNS fertilizer prescription equations of rice (MTU 1010) in farmers' fields (mean value of three locations)

Treatment	Fertilizer doses ($kg\ ha^{-1}$)			Grain yield ($q\ ha^{-1}$)	Resp. ratio ($q\ ha^{-1}$)	Net return ($Rs.\ ha^{-1}$)	Yield deviation (%)	B:C ratio
	N	P_2O_5	K_2O					
Control	-	-	-	25.8	-	4222	-	1.15
FP	60	50	50	42.9	10.8	21839	-	1.69
RDF	80	40	40	49.1	14.6	29612	-	1.93
ST-TY 40 $q\ ha^{-1}$	29	10	16	40.6	27.9	21381	(+) 1.39	1.73
ST–TY 40 $q\ ha^{-1}$+ FYM	26	10	15	42.2	33.3	23576	(+) 5.56	1.81
ST–TY 50 $q\ ha^{-1}$	72	20	36	47.8	17.6	28680	(–) 4.44	1.92
ST–TY 50 $q\ ha^{-1}$+ FYM	69	18	32	50.2	21.1	31969	(+) 0.44	2.04

ST - STCR dose ; TY - Targeted yeild ; FP - Farmers practices

Vegetable pea (Azad P 3)

Nine follow up trials on vegetable pea (cv. Azad P 3) were carried out in farmers' field using the targeted yield equations developed by CRIJAF. Means of nine locations revealed that the green pod yield of vegetable pea superceded the fixed target of 90 and 100 $q\ ha^{-1}$ with and without INM. The targeted yield (90 $q\ ha^{-1}$) of green pod of vegetable pea was achieved with (+) 2.3 and (+) 7.7% yield deviations whereas 100 $q\ ha^{-1}$ green pod was recorded with (+) 4.4 to (+) 11.4% yield deviation without and with INM, respectively (Table 3.3). Maximum net return was observed in INM treatment based on soil test and targeted yield. The highest response ratio and B: C ratio was recorded in soil test and targeted yield with INM treatment.

Table 3.3 Verification of IPNS fertilizers prescription equations of vegetable pea (Azad P-3) in farmers' fields (mean value of nine locations)

Treatment	Fertilizer doses ($kg\ ha^{-1}$)			Green pod yield ($q\ ha^{-1}$)	Response ratio ($q\ ha^{-1}$)	Net return ($Rs.\ ha^{-1}$)	Yield deviation (%)	B:C ratio
	N	P_2O_5	K_2O					
FP	15	30	20	64.5	0.0	19084.9	-	1.7
ST-TY 90 $q\ ha^{-1}$	73	15	59	92.1	20.8	36395.2	(+) 2.3	2.3
ST–TY 90 $q\ ha^{-1}$+FYM	59	11	48	96.9	30.1	40479.9	(+) 7.7	2.5
ST–TY 100 $q\ ha^{-1}$	95	21	72	104.4	22.8	44031.7	(+) 4.4	2.5
ST–TY 100 $q\ ha^{-1}$+FYM	81	17	62	111.4	31.5	49647.3	(+) 11.4	2.8

ST - STCR dose ; TY - Targeted yeild ; FP - Farmers practices

Jabalpur

The verification trials were conducted on garlic and chandrasur under IPNS mode, soybean and onion under STCR condition at Soil Science Research Farm, Jabalpur. Fertilizer recommendations based on soil test were done in accordance with the fertilizer adjustment equations as under:

Soybean	**Onion**
FN = 5.19 T - 0.48 SN FP_2O_5 = 5.20 T - 4.10 SP FK_2O = 3.90 T - 0.22 SK	FN = 9.11 T - 0.37 SN FP_2O_5 = 3.60 T - 0.75 SP FK_2O = 4.66 T - 0.13 SK
Garlic	**Chandrasur**
FN = 7.45 T - 0.67 SN - 0.80 ON FP_2O_5 = 2.73 T - 0.65 SP - 1.50 OP FK_2O = 5.74 T - 0.28 SK - 0.51 OK	FN = 8.03 T - 0.25 SN - 0.96 ON FP_2O_5 = 11.35 T - 3.11 SP - 0.65 OP FK_2O = 16.45 T - 0.37 SK - 1.54 OK

The performance of various treatments and their economics is presented in Table 3.4 and 3.5.

Table 3.4 Verification trials (on-farm): Percent deviation in yield from affixed target

Crop / Variety	Treatment	Yield (q ha^{-1})		Percent deviation
		Grain/Bulb	Straw/Haulm	
Soybean (JS 97-52)	Control	15.8	37.0	
	GRD	19.4	46.1	
	STCR dose (T.Y. 25 q ha^{-1})	25.6	49.2	(+) 2.40
	STCR dose (T.Y. 30 q ha^{-1})	27.5	55.5	(-) 8.33
	STCR dose (T.Y. 35 q ha^{-1})	32.1	60.3	(-) 8.29
	CD *(p = 0.05)*	2.98	3.94	
Chandrasur (HI-4)	Control	4.94	43.29	
	GRD	8.65	58.45	
	STCR dose (T.Y. 10 q ha^{-1}*)	10.21	53.64	(+) 2.10
	STCR dose (T.Y. 12 q ha^{-1}*)	11.67	56.89	(-) 2.75
	STCR dose (T.Y. 14 q ha^{-1}*)	12.92	61.15	(-) 7.71
	CD *(p = 0.05)*	2.10	8.62	
Garlic (G- 323)	Control	28.0	14.3	
	GRD	36.1	22.3	
	SRCR dose (T. Y. 30 q ha^{-1}*)	31.0	19.5	(+) 3.33
	STCR dose (T.Y. 40 q ha^{-1}*)	45.8	23.0	(+)14.50
	STCR dose (T.Y. 50 q ha^{-1}*)	52.5	24.4	(+) 5.00
	CD *(p = 0.05)*	5.46	3.67	
Onion (Agri-found light red)	Control	14.6	5.3	
	GRD	22.4	6.1	
	STCR dose (T.Y. 20 t ha^{-1}*)	20.9	7.4	(+) 4.50
	STCR dose (T.Y. 30 t ha^{-1}*)	29.8	8.0	(-) 0.67
	STCR dose (T.Y. 40 t ha^{-1}*)	36.7	8.9	(-) 8.25
	CD *(p = 0.05)*	**3.59**	**1.19**	

** indicates 5 t FYM ha^{-1}*

Table 3.5 Economics of verification trials (on-farm)

Treatment	Nutrient applied (kg ha^{-1})			Response (kg ha^{-1})	Cost of fertilizer (Rs. ha^{-1})	Cost of response (Rs. ha^{-1})	Profit (Rs. ha^{-1})	B:C ratio	Yard stick value
	N	P_2O_5	K_2O						
Soybean									
Control	0	0	0	-	-	-	-	-	-
GRD	20	60	20	360	3322	10800	7478	3.25	3.60
STCR dose (TY 25 q ha^{-1})	45	93	57	980	6096	29400	23304	3.82	5.03
STCR dose (TY 30 q ha^{-1})	71	119	77	1170	8089	35100	27011	3.34	4.38
STCR dose (TY 35 q ha^{-1})	97	145	96	1630	10052	48900	38848	3.86	4.82
Chandrasur									
Control	0	0	0	-	-	-	-	-	-
GRD	50	50	30	371	3581	25970	22389	6.25	2.85
STCR dose (TY 10 q ha^{-1}*)	18(31)	79(28)	46(39)	527	9854	36890	27036	2.74	2.19
STCR dose (TY 12 q ha^{-1}*)	34(31)	102(28)	79(39)	673	11984	47110	35126	2.93	2.15
STCR dose (TY 14 q ha^{-1}*)	50(31)	124(28)	112(39)	798	14073	55860	41787	2.97	2.08
Onion									
Control	0	0	0	-	-	-	-	-	-
GRD	80	60	80	7738	5854	92856	87002	14.86	35.17
STCR dose (TY 20 t ha^{-1}*)	133	68	73	6300	6639	75600	68961	10.39	22.99
STCR dose (TY 30 t ha^{-1}*)	224	104	119	15213	10630	182556	171926	16.17	34.03
STCR dose (TY 40 t ha^{-1}*)	316	140	166	22075	14662	264900	250238	17.07	35.49
Garlic									
Control	0	0	0	-	-	-	-	-	-
GRD	80	60	80	805	5854	40250	34396	5.88	3.66
SRCR dose (TY 30 q ha^{-1}*)	119(31)	49(28)	107(39)	300	11689	15000	3311	0.28	0.80
STCR dose (TY 40 q ha^{-1}*)	194(31)	76(28)	165(39)	1775	15464	88750	73286	4.74	3.33
STCR dose (TY 50 q ha^{-1}*)	268(31)	103(28)	222(39)	2450	19197	122500	103303	5.38	3.55

** 5 t FYM ha^{-1} (31 kg N + 28 kg P_2O_5 + 39 kg K_2O); Existing Rates of inputs and outputs (Rs. kg^{-1}): Nutrients N = 12.5; P_2O_5 = 41.3; K_2O = 29.7; FYM = Rs. 1.0 and Economic produce: Soybean =30.0, Onion = 12.0, Chandrasur = 70.0, Garlic = 50.0*

Vellanikkara

The test verification trial on chilli (Ujwala) was undertaken at four locations in Palakkad district. The target of 10 t ha^{-1} was achieved and the maximum yield was observed for the STCR treatment. Following equations for chilli (*Ujwala*) was developed

N	1.92 T – 0.28 SN
P_2O_5	0.44 T – 1.71 SP
K_2O	0.53 T – 0.06 SK

The performance of various treatments is presented in Table 3.6 and Plates shown below :

Table 3.6 Benefit cost ratio analysis data of different treatments of test verification trials on chilli (average) at different locations in Palakkad district

Treatment	Details of treatment	Yield (t ha^{-1})	Labour, planting materials and other cost (Rs. ha^{-1})	Total cultivation cost (Rs. ha^{-1})	Benefit (Rs. ha^{-1})	Profit (Rs. ha^{-1})	B:C ratio
T1	Control	0.89	46417	46417	13333	-33083	0.00
T2	FP	11.63	69996	130336	174417	44080	1.34
T3	GRD	12.86	54029	95268	192875	97607	2.03
T4	STL recommendation	12.43	58485	98201	186500	88299	1.90
T5	STCR 1 - 10t yt/ha^{-1}	10.99	61363	66982	164875	97893	2.46
T6	STCR 2 - 12t yt/ha^{-1}	11.15	64798	70417	167208	96791	2.38
T7	STCR 3 - 14t yt/ha^{-1}	10.68	66654	72273	160250	87976	2.22
T8	STCR 4 - 16t yt/ha^{-1}	11.04	68697	74316	165583	91267	2.23

YT/ha : yield target per hectare

Test verification trial on chilli variety Ujwala at Mullakkal, Palakkad district

(a)

Test verification trial on chilli variety Ujwala at Malayampallam, Palakkad district

(b)

3.2 Long term STCR-IPNS demonstration

Pearl millet-wheat (New Delhi)

A field experiment on pearlmillet–wheat sequence started in *kharif*, 2003 on a Typic Haplustept soil at IARI farm New Delhi. The treatments included: T_1 - Organic alone, FYM @ 20 t ha^{-1} in each crop; T_2 - Soil test based integrated use of fertilizers with 10 t ha^{-1} of FYM for grain yield target of 25 q ha^{-1} of pearlmillet and 50 q ha^{-1} of wheat; T_3 - Soil test based use of fertilizers alone for grain yield target of 25 q ha^{-1} of pearl millet and 50 q ha^{-1} of wheat and T_4 - Control.

It was observed that T_2 treatment recorded the highest grain and straw yield (32.7 and 61.5 q ha^{-1}) of pearl millet which was 184 and 109 % higher over control. While treatments T_1 and chemical T_3 were statistically at par and significantly lower than (Table 3.7).

In case of wheat, the highest grain yield (52.3 q ha^{-1}) was recorded with treatment T_2. Significant differences were observed among the treatments with respect to grain and straw yield of wheat, while the lowest grain yield (20.8 q ha^{-1}) of wheat was observed with control treatment (T_4). The treatment (T_2) produced significantly higher grain and straw yields of both crops (pearlmillet and wheat) over all the treatments (Table 3.7). However, application of nutrients through chemical fertilizer showed superiority over treatment T_1 in respect of grain and straw yield of both the crops (pearlmillet and wheat). Fertility status (available N, P and K) after harvest of the both the crop under T_2 treatment were observed statistically higher over T_3 treatment and control T_4, while maximum values of available nitrogen and potassium were recorded with Organic alone treatment T_1 after harvest of both the crops (Table 3.8).

Table 3.7 Grain and straw yield of pearlmillet (Target grain yield 25 q ha^{-1}) and wheat (Target grain yield 50 q ha^{-1}) as influenced by STCR based fertilizer recommendations for targeted yield

Treatment	Pearlmillet (q ha^{-1})		Wheat (q ha^{-1})	
	Grain	Straw	Grain	Straw
Organic alone (T_1)	24.3	54.7	44.2	54.7
Integrated (T_2)	32.7	61.1	56.7	76.4
Chemical (T_3)	26.3	56.5	49.1	65.8
Control (T_4)	11.5	29.2	21.2	35.8
CD *(p=0.05)*	2.21	4.4	7.6	4.8

Table 3.8 Fertility status after harvest of pearl millet and wheat crop under long term experiment on pearl millet–wheat cropping sequence

Treatment	Available Nurtient (kg ha^{-1})					
	N	P	K	N	P	K
	After wheat			After pearlmillet		
Organic alone	221	28.4	244	190	26.4	195
Integrated	181	29.2	212	208	30.9	261
Chemical	219	27.9	241	175	28.4	219
Control	174	16.3	187	165	13.1	181
CD *(p=0.05)*	5.9	1.621	6.7	8.9	1.881	12.3

After completion of eight cropping cycles of pearl millet-wheat cropping cycles significantly higher content of total soil organic carbon (TOC), Walkely and Black carbon (WBC), labile organic carbon (LBC) and soil microbial biomass carbon (SMBC) in surface soil (0-15 cm) were observed in plots treated with FYM alone (T_1) and FYM+Fertilizer NPK (T_2) respectively, over the fertilizer NPK (T_3) and control (T_4). However, except LBC the content of all pools of organic carbon was significantly high in FYM alone (T_1) as compared to FYM+Fertilizer NPK (T_2). Similar trends for WBC and SMBC after eight cropping cycle (Table 3.9).

Table 3.9 Soil properties after harvest of pearl millet and wheat crop under long term experiment on pearl millet–wheat cropping sequence

Treatment	Physical properties						DTPA extractable micronutrients (mg kg^{1})				Biological properties	
	BD	WHC (%) (g cm^{-3})	IR (cm h^{-1})	pH (1:2.5)	EC (1:2.5) (dSm^{-1})	Org. C (g kg^{-1})	Zn	Fe	Cu	Mn	SMBC (µg g^{-1} dry soil)	DHA (µg TPF g^{-1} soil h^{-1})
Organic (T_1)	1.52	46.1	3.5	8.03	0.313	9.0	5.2	9.2	4.9	46.8	270.6	8.5
Integrated (T_2)	1.54	42.2	3.4	8.10	0.330	6.8	35	7.8	4.8	29.5	318.4	9.2
Chemical (T_3)	1.57	40.7	2.6	8.18	0.341	5.5	2.9	4.7	3.6	25.1	217.2	6.1
Control (T_4)	1.60	39.3	2.1	8.26	0.356	5.1	2.6	3.9	2.6	21.6	163.5	5.2
CD (p=0.05)	0.05	1.26	0.07	NS	0.05	0.59	0.20	1.73	0.94	3.05	7.49	0.47

Where, BD= Bulk density, IR= Infiltration rate, WHC = Water holding capacity, SMBC = Soil microbial biomass carbon, DHA = Dehydrogenating activity

Higher content of all the micronutrients have been observed in FYM alone and FYM + Fertilizer NPK treatments over fertilizer (NPK alone) and control treatments after eight cropping cycles. However, Fe content in control plots has decreased below critical limit (Table 3.9). Similarly, other soil quality parameters such as water holding capacity, infiltration rate and DHA content were found significantly higher in FYM alone and FYM + Fertilizer NPK treatments over fertilizer (NPK alone) and control treatments after eight cropping cycles except for bulk density for which reverse trend has been observed (Table 3.9).

Rice-Rice (Coimbatore)

The demonstration is being conducted since *kharif* 1998 in the Wetland farm of TNAU, Coimbatore (Typic Haplustalf, Noyyal series). The 29th crop was raised during *kharif* season with rice variety ADT 43 and the 30th crop was raised during *rabi* season with rice variety CO (R) 50. The treatments imposed were T_1 - Blanket recommendation T_2 -STCR - NPK alone for 6 t ha^{-1} for *kharif* rice and 5 t ha^{-1} for *rabi* rice T_3 - STCR - NPK alone for 7 t ha^{-1} for *kharif* rice and 6 t ha^{-1} for *rabi* rice T_4 - STCR - IPNS for 7 t ha^{-1} for *kharif* rice and 6 t ha^{-1} for *rabi* rice and T_5- Absolute control. The fertilizer doses were calculated based on the available nutrient status of initial soil samples using the fertilizer prescription equations as presented below:

Kharif	Rabi
FN = 4.39 T – 0.52 SN – 0.80 ON	FN = 4.63 T – 0.56 SN – 0.90 ON
FP_2O_5= 2.22 T – 3.63 SP – 0.98 OP	FP_2O_5= 1.98 T – 3.18 SP – 0.99 OP
FK_2O = 2.44 T – 0.39 SK – 0.72 O	FK_2O = 2.57 T– 0.42 SK – 0.67 OK

The grain yield of rice ADT 43 during *kharif* season ranged from 2.82 t ha^{-1} in control to 7.01 t ha^{-1} in STCR-IPNS 7 t ha^{-1} treatment (Table 3.10). In all the STCR treatments, the per cent achievement was more than 93 and the highest achievement of 100 per cent was recorded in T_4 treatment. The highest response ratio of 17.2 kg grain yield per kg of nutrient applied was recorded in T_4 treatment. The achievement of yield targets in T_3 were 93.7 and 97.1 per cent in *kharif* and *rabi*, respectively.

The grain yield in *rabi* rice ranged from 2.41 t ha^{-1} in control to 6.16 t ha^{-1} in T_4 treatment (Table 3.11). The highest response ratio of 20.7 kg grain yield per kg of nutrient applied was recorded in T_4 treatment. The achievement of yield target was more than 95 per cent in all the STCR treatments and the highest achievement (102.6 %) was observed in T_4 treatment. The achievement of yield targets in T_2 and T_3 treatments were 102.0 and 98.7 per cent, respectively.

Table 3.10 Grain yield, response ratio, per cent achievement and available nutrient status of post - harvest soil samples of *kharif* rice (29th crop)

Treatment	Grain yield (t ha^{-1})	Response ratio (kg kg^{-1})	Achievement (%)	Available nutrients (kg ha^{-1})			SOC (g kg^{-1})	pH	EC (dS m^{-1})
				N	P	K			
Blanket dose	5.60	11.1	-	230	20.8	465	6.4	4.40	0.50
STCR-NPK alone - 6 t ha^{-1}	5.62	13.2	93.7	235	22.2	492	7.4	8.27	0.54
STCR- NPK alone -7 t ha^{-1}	6.80	16.4	97.1	268	28.5	502	7.4	8.47	0.54
STCR-IPNS- 7 t ha^{-1}	7.01	17.2	17.2	288	30.2	550	8.2	8.30	0.60
Absolute control	2.82	-	-	180	15.8	415	5.2	8.38	0.50
CD (p=0.05)							4.6	8.15	0.48

Table 3.11 Grain yield, response ratio, per cent achievement and available nutrient status of post - harvest soil samples of rabi rrice (30th crop)

Treatment	Grain yield (t ha^{-1})	Response ratio (kg kg^{-1})	Achievement (%)	Available nutrients (kg ha^{-1})		
				N	P	K
Blanket	4.98	10.3	-	220	22.0	468
STCR -NPK alone - 6 t ha^{-1}	5.10	17.6	102.0	228	23.0	498
STCR - NPK alone -7 t ha^{-1}	5.92	19.4	98.7	255	29.4	505
STCR - IPNS - 7 t ha^{-1}	6.16	20.7	102.6	273	31.0	558
Absolute Control	2.41	-	-	172	17.5	410

Frontline demonstrations on oilseeds in Tamil Nadu

Front line demonstrations were conducted at 10 locations with oilseeds *viz*., groundnut, sunflower and gingelly in Southern, North -Western and Western zones of Tamil Nadu as detailed below:

Groundnut

Three demonstrations were conducted one each at Southern, North-Western and Western zones of Tamil Nadu with JL 24, VRI 2 and CO 6 varieties, respectively. The treatments included were control, blanket recommendation, STCR –NPK- 25 q ha^{-1} and STCR - IPNS – 25 q ha^{-1} and farmer's practice. The soil was red non-calcareous and sandy clay loam in texture. Based on the initial available N, P & K status, the fertiliser N, P_2O_5 and K_2O doses were calculated for STCR treatments. For STCR-IPNS treatment, FYM @12.5 t ha^{-1} was applied and the contribution of NPK from FYM was accounted and the remaining doses were applied through NPK fertilisers. Using the yield data, per cent achievement and response ratio were computed.

The range values for fertiliser doses, initial soil test values and mean values for yield, per cent achievement and RR are furnished in Table 3.12. The pod yield of groundnut varied between 1190 kg ha^{-1} in absolute control and 2560 kg ha^{-1} in STCR-IPNS-25 q ha^{-1}. The highest mean response ratio (RR) of 8.59 kg kg^{-1} was recorded in STCR-IPNS followed by STCR-NPK alone (7.67 kg kg^{-1}), blanket (5.03 kg kg^{-1}) and farmer's practice (4.64 kg kg^{-1}). The increase in yield due to STCR-IPNS over blanket and farmer's practice was 31.5 and 46 per cent, respectively. Therefore, the results clearly proved the superiority of STCR-IPNS over blanket and farmer's practice.

Table 3.12 Range and mean values for groundnut (3 locations)

Treatment	Fertiliser doses (kg ha^{-1})			Mean Dry pod yield (kg ha^{-1})	Mean Achievement (%)	Mean RR (kg kg^{-1})
	N	P_2O_5	K_2O			
Control	0	0	0	1190	-	-
Blanket	25	50	75	1947	-	5.03
STCR -NPK alone-25 q ha^{-1}	31.50***	50	38**-131***	2413	96.5	7.67
STCR -IPNS* 25 q ha^{-1}	13**	25**-88***	38**-91***	2560	102.4	8.59
Farmer's practice	23-50	25.68	40**-50***	1753	-	4.64

** FYM @ 12.5 t ha^{-1}; ** maintenance dose; *** maximum dose*

Sunflower

In Southern zone of Tamil Nadu, frontline demonstrations were conducted with sunflower in four locations *viz.*, Vakkampatti, Kallipatti, Alakuvarpatti and S. Pudur in Dindigul districts on sandy clay loam soils with hybrid sunbreed-275 variety. The treatments included were control, blanket recommendation, STCR -NPK alone – 20 q ha^{-1} and STCR – IPNS-20 q ha^{-1} and farmer's practice. Based on the initial soil available N, P & K status, the fertiliser N, P_2O_5 and K_2O doses were calculated for STCR treatments. For STCR-IPNS treatment, FYM @12.5 t ha^{-1} was applied and the contribution of NPK from FYM was accounted and the remaining doses were applied through NPK fertilisers. The range values for fertiliser doses, initial soil test values and mean values for yield, per cent achievement and response ratio (RR) are presented in Table 3.13. The mean seed yield of sunflower varied between 851 kg ha^{-1} (absolute control) and 2050 kg ha^{-1} (STCR-IPNS-20 q ha^{-1}). The highest mean RR of 6.38 kg kg^{-1} was recorded in STCR-IPNS followed by STCR-NPK alone (5.89 kg kg^{-1}), blanket (3.72 kg kg^{-1}) and farmer's practice (3.47 kg kg^{-1}). The increase due to STCR-IPNS over blanket and farmer's practice was 25.6 and 51.0 per cent, respectively.

Table 3.13 Range and mean values for sunflower (4 locations)

Treatment	Fertiliser doses applied (kg ha^{-1})			Mean dry pod yield (kg ha^{-1})	Mean Achievement (%)	Mean RR (kg kg^{-1})
	N	P_2O_5	K_2O			
Control	0	0	0	851	-	-
Blanket	60	90	60	1633	-	3.72
STCR -NPK alone-20 q ha^{-1}	79**-102***	56**-75***	30	1960	98.0	5.89
STCR -IPNS* 20 q ha^{-1}	27**-50***	45**-53***	30	2050	102.5	6.38
Farmer's practice	40**-69***	45**-50***	40**-50***	1358	-	3.42

** FYM @ 12.5 t ha^{-1} ; ** maintenance dose ; *** maximum dose*

Gingelly

In Southern zone of Tamil Nadu, three front line demonstrations were conducted with gingelly at Thoppupatti, K.N.Patti and Alakuvarpatti in Dindigul districts on sandy loam and sandy clay loam soils with TMV 7 and TMV 1 varieties. The treatments include control, blanket recommendation, STCR - NPK alone -10 q ha^{-1} and STCR–IPNS-10 q ha^{-1}. Based on the initial soil available N, P & K status, the fertiliser N, P & K doses were calculated for STCR treatments. For STCR - IPNS treatment, FYM @12.5 t ha^{-1} was applied. The mean seed yield of gingelly varied between 433 kg ha^{-1} (absolute control) and 1007 kg ha^{-1} (STCR-IPNS-10 q ha^{-1}) (Table 3.14). The highest mean RR of 5.82 kg kg^{-1} was recorded in STCR-IPNS followed by STCR-NPK alone (5.14 kg kg^{-1}), blanket (3.58 kg kg^{-1}) and farmer's practice (3.38 kg kg^{-1}). The increase in yield due to STCR- IPNS over blanket and farmer's practice was 39.2 and 56.5 per cent, respectively. Therefore, the results clearly proved the superiority of STCR-IPNS over blanket and farmer's practice.

Table 3.14 Range and mean values for groundnut (3 locations)

Treatment	Fertiliser doses applied (kg ha^{-1})			Mean dry pod yield (kg ha^{-1})	Mean Achievement (%)	Mean RR (kg kg^{-1})
	N	P_2O_5	K_2O			
Control	0	0	0	433	-	-
Blanket	35	23	23	723	-	3.58
STCR-NPK alone-10 q ha^{-1}	35**-70**	18**-45***	12**-46***	943	94.3	5.15
STCR-IPNS* 10 q ha^{-1}	18**-46***	12**-13***	12**-31***	1007	100.7	5.82
Farmer's practice	20-30	15-30	15-20	643	-	3.38

** FYM @ 12.5 t ha^{-1} ; ** maintenance dose ; *** maximum dose*

(a) Groundnut *(b) Sunflower* *(c) Gingelly*

Front line demonstratioon on a) groundnut, b) Sunflower and c) Gingelly in Tamil Nadu

3.3 Production & supply of Biofertilizers and Demonstrations Production and supply of Biofertilizer

- About 61991, 34450, 87548, 32999 and 764 packets of *Rhizobium, Azotobacter/Azospirillum*, PSB, *Trichoderma* and soil based BGA respectively were produced and supplied to farmers amounting to Rs. 50 lakhs (JNKVV, Jabalpur).
- Biofertilizer sale was 7.95 lakhs. The demand for liquid biofertilizers by the farmers with drip irrigation facility for the crops like cotton, turmeric, sugarcane, sweet orange and pomegranate increased in comparison to previous years (MAU Parbhani).
- Powder formulations of biofertilizers (89.4 mt) as well as liquid formations (13.9 mt) worth Rs. 56.5 lakhs were produced (ANGRAU, Amaravathi).

Demonstrations

- Demonstrations on upland rice variety CR Dhan 40 showed that application of AMF inoculum (soil application) and *Azotobacter* (seed application) resulted in 30.6% and 17.4% increase in grain yield respectively in Jharkhand (CRURRS, Hazaribagh).

- Microbial consortium (Cyanobacteria, *Azospirillum*, *Bacillus subtilis*, enriched mycostraw) was evaluated for under participatory mode in submerged rice.The grain yield increased from 9.7-18.5% in comparison to farmers' practice (RAU, Pusa).
- The lively hood improvement experiment conducted in coastal acid saline soils of the state, adopting bioinoculation of various crops through *Azolla*, BGA, *Azotobacto*r, *Azospirillum and* PSB could increase the yield of principal crops (rice, greengram, blackgram, sunflower, sesamum and vegetables) by 12.1 to 15.6 per cent with monetary benefit due to BFs application with a cast of Rs 11970 $ha^{-1}yr^{-1}$. On an average there was 30% savings in chemical fertilizers application due to adoption of bioinoculation programme (OUAT, Bhubaneswar).
- The tribal area programme conducted in the three villages namely: Ghantamal, Chainpadar and Tolbrahamani of Kalahandi district on cotton (12 nos), cauliflowers (8 nos), cabbage (10 nos), capsicum (5 nos) ,broccoli (8 nos), field pea (6 nos), tomato (8 nos) and sunflower (6 nos) recorded the BFs responses ranging from 7.8 to 15.9 per cent on various crops, gaining economic benefit ranging from Rs 4900 to Rs 23000 ha^{-1} due to the biofertilizer application (OUAT, Bhubaneswar).

3.4 Research Farm Demonstration on Resource Conservation Technologies

To popularize indispensable resource conservation technology among farmers of Central India, the Institute demonstrated the following packages of treatments at the institute research farm with respect to: a) Reduced Tillage (RT) + BBF + Maize – Chick Pea; b) No Tillage (NT) + BBF + Maize – Chick Pea; c) Reduced Tillage (RT) + BBF + Soybean – Wheat ; d) No Tillage (NT) + BBF + Soybean – Wheat; e) Reduced Tillage (RT) + BBF + (Soybean + Pigeon Pea, 3:2) and f) No Tillage (NT) + BBF + (Soybean + Pigeon Pea, 3:2). In these demonstrations both tillage practices, broad bed and furrow system were followed. In No-tillage sowing was carried out by slit-drill whereas, in reduced tillage sowing was done by tropi-culter after ploughing by duck foot cultivator. Numerous farmers visited these demonstrations during crop growth period.

On farm demonstrations on wheat and gram at IISS

3.5 Demonstrations in Kisan Mela / Farmers' Fair at Betul (MP)

The Institute exhibited demonstration of its technologies in the Agriculture Fair-cum- 'Bharat Nirman Jan Suchna Abhiyan sponsored by the Press Information Bureau (PIB), Government of India at Krishi Upaj Mandi, Betul (MP) during 25-27th August, 2013. The Institute received fourth position for the Interaction and stall for depicting scientific information on agricultural technologies and transmitting them to the farmers. The award was given away by Honourable Shri Vinod Dagar, Ex MLA, Betul and other dignitaries at Betul Farmers Fair on 27th August, 2013.

3.6 Field Day Organized under TSP-AICRP (STCR)

State	Villages	No. of farmers	Date	Theme
Odisha	Rukunapur and Balibandh	60	07 March, 2014	Importance of soil test based fertilizer application
Chhattisgarh	Aturgaon, Bhagdeva, Baade Bendri, Narayanpur, Sulenga and Karlakha	50	09 March, 2014	Importance of soil test based fertilizer application
Jharkhand	Nagarabera	40	11 January, 2014	Soil testing and importance of soil test based fertilizer application
West Bengal	Adhghara and Haranghata	26	18-20 November, 2013	Soil testing and importance of soil test based fertilizer application
Tamil Nadu	Sadivayalpathi	50	21 July, 2013	Soil testing and importance of soil test based fertilizer application






3.7 Farmers'/Agriculture Officer/Students Visits

Large number of farmers/scientists/agriculture officers /extension workers/ students visited the institute and were provided the information on technologies generated by the institute particularly on organic farming, vermi-composting, phospho-sulpho-nitro-composting, soil sampling and integrated nutrient management. The detail of visits is presented below :

Farmers/ Extension workers visit to the Institute

S. No.	Department	Number of participants	Period
1.	Soil testing and Improved Agriculture Technology scheme, Distt Damoh (MP)	80 Progressive farmers	14/08/2013
2.	Bhopal ATMA,	100 Progressive farmers	30/08/2013
3.	Dharampuri Madhya Pradesh (under ATMA project).	30 Progressive farmers	13/09/2013
4.	Farmer Welfare and Agriculture Development Distt-Shyopur, (MP)	30 Progressive farmers	17/09/2013
5.	Vaishali Nagar Distt Damoh (MP) (under IWMP-II)	38 Progressive farmers	30/09/2013
6.	Farmer Welfare and Agriculture Development Distt-Damoh (MP) under IWMP-III	50 Progressive farmers	01/10/2013
7.	Project Directorate, Sagar (MP) (under ATMA Project)	30 Farmers	07/10/2013
8.	Project Directorate, ATMA, Agriculture Department Ajmer, Rajasthan	45 Progressive farmers	24/12/2013
9.	Project Directorate ATMA, Distt Vidisha (MP)	40 Progressive farmers	07/01/2014
10.	Project Directorate ATMA, Distt -Khargone (MP)	25 Progressive farmers	17/01/2014
12.	Training Centre Indore (MP)	30 Officers	24/01/2014
13.	B. Sc. /M. Sc. Chemistry Students from Institute of Excellence In Higher Education, Bhopal	55 Students	01/02/2014
14.	Agriculture Extension & Training Centre Bhopal (MP)	30 Officers	05/02/2014
15.	Project Directorate, ATMA, Jalour, Rajasthan	50 Farmers	08/2/2014
16.	Project Directorate, ATMA, Tonk Rajasthan	48 Farmers	09/02/2014
17	Project Directo rate, ATMA, Jhalawar, Rajasthan	50 Farmers	09/2/2014
18	Sawai Madhupur Distt. Rajasthan under ATMA, project	45 Farmers	11/02/2014
19	Project Directorate, ATMA, Bharatpur, Rajasthan	45 Farmers	12/02/2014
20	Agriculture Extension & Training Centre Pawarkheda, Hoshangabad (MP)	30 Officers	19/02/2014
21	Agriculture Extension & Training Centre Satrati, Distt - Khargone (MP)	35 Officers	22/02/2014
22	Project Director ATMA Distt. Khargone, (MP)	20 Farmers	9/01/2014
23	University of Horticultural Science, Bagalkot, College of Horticulture, Bagalkot Karnataka	45 B. Sc. Students	26/02/2014
24	Project Director, Farmer Welfare & Agriculture Development, ATMA, Distt. Mansour (MP)	20 Farmer	01/03/2014
25	Organic Farming Promotion Group, Phanda Block, Distt Bhopal	20 Farmers	06/03/2014
26	Vidhya Peeth Institute of Science and Technology, Bhopal (MP)	50 Students of Civil Engineering	06/03/2014

3.8 Trainings organized

Following training were organized on "Organic farming and soil health" for the farmers of the M.P. on various issues

Sponsoring department/ organization	No. of participants	Duration
Farmer Welfare and Agriculture Development under ATMA, Distt. Hoshangabad, Madhya Pradesh.	25 farmers	9-13, January, 2014
Farmer Welfare and Agriculture Development under ATMA, Distt. Morena, Madhya Pradesh.	30 farmers	10-14, March, 2014
Farmer Welfare and Agriculture Development under ATMA, Distt. Morena, Madhya Pradesh.	30 farmers	24-28, March, 2014

4. EDUCATION AND TRAINING

4.1.1 Training attended in India

Participant	Programme	Organization	Duration
Drs. A. Subba Rao, A. K. Biswas, Sanjay Srivastava, B. L. Lakaria, R. Elanchezhian, N. K. Lenka, S. Neenu and I. Rashmi	Training-cum-Workshop on "Soil Fertility Management"	Jointly organized by IISS, Bhopal and ZPD, Jabalpur	3-4 May, 2013
Dr. Nishant K. Sinha	Summer school (21 days) on "Machinery for Natural Resources Management and Technologies"	PAU, Ludhiana	29 August-18 September, 2013
Dr. J. Somasundaram and Mr. M. Mohanty	International advance training course on "Conservation Agriculture for Gateway for Sustainable Agriculture"	CIMMYT-BISA-PAU, Ludhiana	17-31 October, 2013
Drs. B.P. Meena and Shinogi K.C.	21 days training programme on "Advances in Experimental Designs for Development of Technologies in Agriculture"	IASRI, New Delhi	23 October - 12 November, 2013
Dr. B.P. Meena	MTC on "Improving Nutrient Use Efficiency through Agronomical Measures for Major Crops of India"	IISS, Bhopal	12-19 November, 2013
Drs. A. K. Shukla, M. C. Manna, A.K. Biswas and R. S. Chaudhary	10 days training programme on "Management Development Programme on Leadership Development (pre-RMP cadre)"	NAARM, Hyderabad	26 November - 7 December, 2013

Drs. N. K. Lenka, S. R. Mohanty, R.H. Wanjari, J. K. Thakur, Vasudev Meena, H. Das, M. L. Dotaniya, Sangeeta Lenka, A. K. Vishwakarma, K. Bharati, Asha Sahu, I. Rashmi, Shinogi K.C., Nishant K. Sinha, Ms. Seema Sahu and Mr. S. Siddiqui	NAIP sponsored training program on "Data Analysis using SAS"	IISS, Bhopal and IASRI, New Delhi	9-13 December, 2013
Dr. Ritesh Saha	National Training on "Project Formulation, Risk Assessment, Scientific Report Writing and Presentation"	IARI, New Delhi	9-13 December, 2013
Dr. K. Ramesh	CAFTA training on "Organic Farming Approaches and Applications"	TNAU, Coimbatore	22 January-11 February, 2014
Dr. S. Rajendiran	Winter training (21 days) on "Management of Soil Health and Degraded Lands for Sustainable Agriculture"	RVSKVV, Gwalior	14 February - 6 March, 2014
Dr. Neenu S.	National training on "Sensors and Actuators for Precision Farming"	CIAE, Bhopal	3-12 March, 2014
Dr. R. Elanchezhian	National training programme on "Application of Nanotechnology in Agriculture"	CAZRI, Jodhpur	10-19 March, 2014

4.1.2 Foreign Training /Visit

Dr. Asit Mandal

International training on "Bioremediation of Phenanthrene in Mixed Contaminated Soils Assisted by Modified Clay Minerals" sponsored by the National Agricultural Innovation Project of the Indian Council of Agricultural Research at the Centre for Environmental Risk Assessment and Remediation (CERAR), University of South Australia, Adelaide, Australia under the supervision of Dr. Ravi Naidu, distinguished professor of Soil Science during 2nd September to 30th November 2013.

International training at University of South Australia, Adelaide, Australia

Dr. Pramod Jha

International training in the area of "Carbon Trading/Carbon Sequestration/Climate Change" under HRD programme of NAIP-ICAR at Carbon Management and Sequestration Centre, School of Environment and Natural Resources, The Ohio State University, USA under the supervision of Dr. Rattan Lal, Distinguished Professor of Soil Science during 20 December, 2013 to 15 March, 2014.

International training on Carbon Trading/Carbon Sequestration/Climate Change at Ohio State University, USA

Dr. Sanjay Srivastava

Visited Burkina Faso and Togo in Africa, as a member of official delegation, led by Additional Secretary, DARE and Secretary, ICAR 1-7 during December, 2013 in connection with setting up of different projects under Indo African Forum Summit (IAFS-II). Also presented the project on "Establishing Soil, Water and Tissue Testing Laboratory" before agriculture minister of Burkina Faso on 3rd December, 2013.

4.2 Short term Training Organized for Students/Scientists

Name of Student and Degree Programme	Name of College / Institution	Duration in months	Name of Scientist	Training Programme
Ms. Minakshee Sawankar (M.Sc.)	Institute of Excellence in Higher Education, Bhopal (MP)	6	Drs. R. Elanchezhian, P. Jha and A. K. Biswas	Plant growth and yield parameter and nutrient uptake dynamics with slow release fertilizers
Ms. Hafsa (M.Sc.)	Institute of Excellence in Higher Education, Bhopal (MP)	6	Drs. K. Ramesh and A. K. Biswas	Studies on zeolite-organic manure interactions
Mrs. Snehita Chauhan (Ph. D.)	Berktull ah University Bhopal	3	Dr. M C Manna	Isolation, identification and screening of P-solibilizers under different habits of central India
Mr. D. H. Phalke (Ph. D.)	MPKV, Rahuri, Maharashtra	12	Dr. M C Manna	*In-situ* recycling of sugarcane residue and its industrial wastes for enhancing soil and crop productivity
Ms. Prachi Parsai (M. Sc.)	Banasthali University, Rajasthan	6	Dr. Kollah Bharati	Synergistic effect of biochar and compost on greenhouse gas production and feedback response in tropical Vertisols
Ms. Parul Rajput (M. Tech)	Rajiv G andhi Technological University, Bhopal	6	Dr. Santosh R. Mohanty	Response of soil microbial methane monooxygeanse (pMMO) to environmental nanoparticle contaminants

Name of Student and Degree Programme	Name of College / Institution	Duration in months	Name of Scientist	Training Programme
Ms. Pooja Sharma (M. Sc.)	Institute of Excellence College, Bhopal	6	Dr. J. K. Thakur	Evaluation of soil microbial activities under different nutrient management practices
Mrs. Indu Sen (M. Sc.)	Rajeev Gandhi College, Trilanga, Bhopal (Barkatullah University, M.P.)	6	Dr. Asha Sahu	Impact of sewage irrigation on heavy metal accumulation in soil and plants
Dr. D. Vasu (ARS attachment)	NBSS&LUP	3	Dr. A.K. Biswas	Effect of biochar on carbon and nitrogen mineralisation in different soils

4.3 Research guidance for degree programmes

Name of Student	Name of College/Institute/University	Degree	Name of Co-guide
Mrs. Pooja Singh	Mahatama Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna, M.P.	Ph. D.	Dr. A.K. Shukla
Mrs. Anita Singh	Regional Institute of Education, Barkatullah University, Shamla Hills, Bhopal, Madhya Pradesh	Ph. D.	Dr. A.K. Biswas
Mr. Satish Bhagwatrao Aher	Ramakrishna Mission Vivekananda University, Howrah, W.B.	Ph. D.	Dr. Brij Lal Lakaria
Mr. Ponam Singh	JNKVV, Jabalpur	M. Sc.	Dr. S. Srivastava
Sh. Salikram Malviya	JNKVV, Jabalpur	M. Sc.	Dr. J. Somasundaram
Ms. Babita Porwal	RVSKVV, Gwalior	M. Sc.	Dr. S. Srivastava
Mr. Prakash Patidar	RVSKVV, Gwalior	M. Sc.	Dr. Brij Lal Lakaria
Mr. Vinod Kushwaha	RVSKVV, Gwalior	M. Sc.	Dr. K.M. Hati
Sh. Kamlesh Malakar	JNKVV, Jabalpur	M. Sc.	Dr. Ritesh Saha
Mr. Punam Chandra Thakur	RVSKVV, Gwalior	M. Sc.	Dr. Pramod Jha
Sh. Kalu Chaudhary	JNKVV, Jabalpur	M. Sc.	Dr. Manorajan Mohanty
Ms. Rakhi Yadav	RVSKVV, Gwalior	M. Sc.	Dr. S.R. Mohanty

5. AWARDS, HONOURS AND RECOGNITIONS

Awards

Drs. A. Subba Rao, Ajay, B. L. Lakaria, Sangeeta Lenka, J. K. Thakur and S. Rajendiran

- Best annual report award of ICAR for the year 2013-14.

Drs. Muneshwar Singh, Sammi Reddy, M. Mohnaty and A. Subba Rao

- FAI Golden Jubilee Award for excellence for "Development of Best Fertilizer Management Practices" for the year 2013.

Dr. N. K. Lenka

- Indian Society of Soil Science (ISSS) Golden Jubilee Commemoration Young Scientist award for the year 2013.
- Indian Association of Soil and Water Conservationists Young Scientist award for the year 2013.

Dr. Ritesh Saha

- Associate NAAS fellowship for the year 2014 onwards for scientific research contribution in natural resource management



Drs. Santosh R. Mohanty and K. Bharti

- Fellow of "Association for the Advancement of Biodiversity Sciences" (FABSc) of India 2013.

Dr A. K. Vishwakarma

- Distinguished scientist award by Society for Extension Education and Management in Agriculture

Best poster/Oral presentation/Article awards

Dr A. K. Shukla

- Sri Ram Fertilizer Award for third best article in *Khad Patrika.*

Drs. I. Rashmi, A. K. Biswas, V. R. R. Parma and A. Subba Rao

- Best poster award for "Soil phosphorus sorption and release from agricultural land-environmental concern" at 18th convention of Indian Geological Congress & International Symposium on "Minerals and Mining in India-The way forward, inclusive of cooperative mineral –based industries in SAARC countries" held during 27-29 April 2013 at MPCOST, Bhopal, Madhya Pradesh.
- Award for oral presentation on "Phosphorus adsorption capacity in soybean growing soils of Madhya Pradesh" at Agro Summit on 'Changing Scenario of Agriculture in Madhya Pradesh: Prospects and Challenges' held during 1- 2 September 2013 at Bhopal, M.P.

Recognitions

Dr. D. L. N. Rao

- Member RAC, National Bureau of Agriculturally Important Microorganisms, Mau (U.P.)

Dr. Pradip Dey

- Vice President, Indian Society of Agrophysics, New Delhi.
- Guest of Honour in the Workshop on *Balanaced Fertilization in crops with special Reference to Potassium*, organized by International Potash Institute, Dept. of Soil Science & Agril. Chemistry, ANGRAU and Hyderabad Chapter– ISSS at ANGRAU, Hyderabad, on 16 December, 2013.
- Editor, *Research Journal of Environmental and Earth Sciences* (ISSN 0051-1335).
- Panelist in the Panel Discussion on "Challenges and Opportunities for Nutrient Management in Maize Systems", In: *Nutrient Expert Launch Meeting,* organised by IPNI and CIMMYT, held at NASC Complex, New Delhi on 20 June, 2013.
- Panelist in the Brain storming session on "*Soil Testing and Fertilizer Use*" on 24 January, 2014.

Dr. A.K. Biswas

- Editor, *The Journal of Indian Society of Soil Science*, New Delhi.
- Councillor, The Indian Society of Soil Science for the biennium 2014-15.
- President, Bhopal Chapter of ISSS for the biennium 2014-15.

Drs. A. K. Biswas and Sanjay Srivastava

- Co-convenors of the brainstorming session on "Efficient Utilization of Phosphorus"

  held at NAAS, New Delhi on 8 November, 2013.

Drs. N.K. Lenka and S. Lenka

- Co-convener, and rapporteur in the NAAS Brainstorming session on "Carbon Economy in Indian Agriculture" at NAAS, NASC Complex, New Delhi on 1 February, 2014.

Drs. Pradeep Dey, A. K. Biswas, Sanjay Srivastava, Brij Lal Lakaria and N.K. Lenka

- Chairman/Rapporteur in the Training-cum-Workshop on "Soil Fertility Management" (Jointly organized by IISS, Bhopal and ZPD, Jabalpur) at IISS, Bhopal during 3-4 May, 2013.

Dr. Ritesh Saha

- Joint Secretary, National Executive Council of Indian Society of Agrophysics (ISAP) for the term 20013-15.

Dr. A. K. Vishwakarma

- Expert member for the recruitment of Scientist at KVK, Raisen.
- Member of screening committee for the recruitment of Programme Coordinator at KVK, Raisen.

Mr. Shahab Siddiqui

- Best Technical Support Award of AICRP-MSN during 27th AICRP-MSN workshop at PDKV, Akola.

6. LINKAGES AND COLLABORATIONS IN INDIA AND ABROAD

The institute has strengthened linkages with ICAR institute and SAUs located throughout the country, the international agencies, and the extension & development agencies. Linkages have been further strengthened by organizing workshops/ meetings of AICRP projects and NAIP projects in which scientists of co-operating centers located at SAUs or ICAR institutes have participated. Efforts have also been made to strengthen research collaborative activities with SAUs through guidance of PG/Ph.D students by the institute scientists. The institute has already signed MOU with Jawaharlal Nehru Krishi Vishwavidyalaya (JNKVV), Japalpur, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya (RVSKVV), Gwalior, Indira Gandhi Krishi Vishwavidyalaya (IGKV) Raipur, Swami Keshwanand Rajasthan Agricultural Univesity (SKRAU), Rajasthan, Mahatma Phule Krishi Vidyapeeth (MPKV) Akola, Maharashtra; Mahatma Gandhi Chitrakot Gramodaya Vishwavidyalaya, Chitrakoot, Satna and RKDF, University, Gandhi Nagar, Bhopal.

The IISS has also encouraged interactions by exchanging its Annual Reports with about 194 ICAR Institutes/SAUs. The Annual Reports of other Institutions are also being received in the library for the reference of scientists and for exploration of further collaboration in research projects. The three AICRPs and one Network Project on Biofertilizers at IISS, Bhopal have 58 cooperating centres spread over in almost all the SAUs. The institute has collaboration for three NAIP projects with other ICAR institutes. A network project on organic farming is also in progress with its headquarters at PDFSR, Modipuram.

Co-operating Centers of AICRPs/Networks located at IISS, Bhopal

S.No.	All India Coordinated Research Projects Experiments	No. of co-operating centres		
		ICAR	SAUs/SGUs	Total
1.	AICRP on Long Term Fertilizer Experiments (LTFE) Hyderabad, Raipur, New Delhi, Junagarh, Palampur, Ranchi, Bangaluru, Pattambi, Jabalpur, Akola, Parbhani, Bhubaneshwar, Ludhiana, Udaipur, Coimbatore, Pantnagar, Barrakpore.	3	14	17
2.	AICRP for Investigation on Crop Response Correlation (STCR): Hyderabad, Pusa, Raipur, New Delhi, Hisar, Palampur, Bangaluru, Vellanikkara, Jabalpur, Rahuri, Bhubaneshwar, Ludhiana, Bikaner, Coimbatore, Pantnagar, Kalyani, Barrackpore.	2	15	17
3.	AICRP on Micro and Secondary Nutrients and Pollutants in Soil and Plants: Hyderabad, Pusa, Anand, Hisar, Jabalpur, Akola, Bhubaneshwar, Ludhiana, Coimbatore, Pantnagar, Lucknow, Jorhat, Kalyani, Ranchi, Palampuyr, Kanpur.	0	16	16
4.	All India Network Project on Soil Biodeversity-Biofertilizers (BNF): Jorhat, New Delhi, Hisar, Jabalpur, Parbhani, Amarawathi, Bhubaneshwar, Junagarh, Coimbatore, Pusa, Solan. Ranchi, Udaipur, Hazaribagh, Dharwad, Delhi.	3	13	16
	Total	**8**	**58**	**66**

7. LIST OF PUBLICATIONS

7.1 Research Paper

National

Ansari PG and Rao DLN (2014) Differentiating Indigenous Soybean Bradyrhizobium and *Rhizobium* spp. of Indian Soils. *Indian Journal of Microbiology* 1-6. DOI 10.1007/s 12088-013-0430-z.

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Meena BP, Kumar Ashok, Shivadhar and Sangeeta Paul (2013) Nutrient uptake and quality of popcorn-potato sequence as influenced by sources and levels of nutrients. *Pusa Agri Sciences* 36: 45-53.

Neenu S, Ramesh K, Ramana S, Biswas AK and Subba Rao A (2014) Growth and yield of different varieties of

Chickpea as influenced by phosphorus nutrition under rainfed conditions of Vertisols. *International Journal of Bio-resource and Stress Management* **5**(1): 053-057.

Pande VC, Kurothe RS, Singh HB, TiwariSP, Kumar G, Rao BK, Vishwakarma AK and Bagdi GL (2013) Economic assessment of soil erosion damage on smallholder farms in marginal lands of mahi ravines in Gujarat. *Agricultural Economics Research Review* 26 (1): 63-71.

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8. LIST OF APPROVED ON-GOING PROJECTS

Programme I: Soil Health and Input Use Efficiency

A) Institute Projects

1. Long-term evaluation of integrated plant nutrient supply modules for sustainable productivity in Vertisols

   Muneshwar Singh, A. K. Biswas (Executive PI), A. B. Singh, R. S. Chaudhary and B. P. Meena

2. Study on nanoporous zeolites for soil and crop management

   K. Ramesh and I. Rashmi

3. Studies on soil resilience in relation to soil organic matter in selected soils

   N. K. Lenka, Sangeeta Lenka, Brij Lal Lakaria and Asit Mandal

4. Development of phosphorus saturation indices for selected Indian soils

   I. Rashmi and Neenu, S.

5. Biofortification of grain sorghum and finger millet varieties with zinc through agronomic measures.

   Ajay, A.K. Shukla and J.K. Saha

6. Biochar on soil properties and crop performance

   Brij Lal Lakaria, Pramod Jha, A.K. Biswas, K.M. Hati, J. K. Thakur, M Vassanda Coumar, A. K. Dubey (CIAE) And S. Gangil (CIAE)

7. Impact of crop covers on soil and nutrient losses through runoff in Vertisols.

   R. K. Singh, J. Somasundaram and I. Rashmi

8. Characterizing rooting behaviours, soil water patterns and nutrient uptake of soybean-chickpea under different tillage and water regimes in Vertisols

   N. K. Sinha, M. Mohanty, Ritesh Saha and I. Rashmi

9. Soil resilience and its indicators under some major soil orders of India.

   Ritesh Saha, K.M. Hati, Pramod Jha, M. Mohanty and R.S. Chaudhary

10. Integrated assessment of some IISS technologies in enhancing agro-ecosystems productivity and livelihood sustainability

    Shinogi K.C., Sanjay Srivastava, A.B. Singh, D.L.N. Rao, Radha T.K. B.P. Meena, N.K. Sinha and Hiranmoy Das

11. Nano particle delivery and internalization in plant systems for improving nutrient use efficiency

    R. Elanchezian, A.K. Biswas, Tapan Adhikari, K. Ramesh, S. Kundu, A.K. Shukla and A. Subba Rao

12. Soil quality assessment for enhancing crop productivity in some tribal districts of Madhya Pradesh

    Rajendiran S., M. L. Dotaniya, M. Vassanda Coumar, N. K. Sinha, Sanjay Srivastava, A. K. Tripathi and S. Kundu

13. Evaluating rock phosphates for their suitability for direct application

    Sanjay Srivastava, K. Ramesh, A.K. Tripathi, I. Rashmi and Pradip Dey

14. Evaluation of modified urea materials and agronomic interventions for enhancing nitrogen use efficiency and sustaining crop productivity
B.P. Meena, K. Ramesh, Neenu, S. and R. Elanchezhian

15. Efficacy of soil sampling strategies for describing spatial variability of soil attributes
Neenu S., Sanjay Srivastava and Hironmoy Das

16. Changing climatic factors' influence on the nutrient acquisition, utilization and recovery by soybean and wheat/gram germplasm lines/ genotypes on black soils of Central India
Neenu S., K. Ramesh, S. Ramana, J. Somasundaram and I. Rashmi

17. Detection of water and nitrogen stress and prediction of yield of soybean and maize using hyper-spectral reflectance and vegetation indices
K. M. Hati and R. K. Singh

18. Participatory assessment of qualitative parameters for categorizing different degrees of soil quality to enhance the soil health and productivity
R. S. Chaudhary, J. Somasundaram, Santosh R. Mohanty and A. B. Singh

B) Externally Funded Projects

19. Understanding the mechanism of variation in status of a few nutritionally important micronutrients in some important food crops and the mechanism of micronutrient enrichment in plant parts (NAIP project)
A.K. Shukla, Muneshwar Singh and Tapan Adhikari

20. Nano-technology for enhanced utilization of native-phosphosrus by plants and higher moisture retention in arid soils (NAIP)
Tapan Adhikari, A. K. Biswas and S. Kundu

21. GPS and GIS based model soil fertility maps for selected districts for precise fertilizer recommendations to the farmers of India
A. Subba Rao, Pradip Dey (Executive PI), A. K. Shukla, Muneshwar Singh, Sanjay Srivastava, R. H. Wanjari and Hiranmoy Das

22. Network project on organic farming
A. B. Singh, K. Ramesh, Brij Lal Lakaria, S. Ramana and J.K. Thakur

Programme II: Conservation Agriculture and Carbon Sequestration vis-à-vis Climate Change

A) Institute Projects

23. Soil carbon saturation and stabilization in some soils in India
Pramod Jha, Brij Lal Lakaria, Ritesh Saha, S.R. Mohanty, A.K. Biswas and Muneshwar Singh

24. Evaluating conservation tillage on various sequences/rotations for stabilizing crops productivity under erratic climatic conditions in black soils of Central India
J. Somasundaram, R. S. Chaudhary, Neenu S and Ajay

25. Assessing impacts of climate change on different cropping systems in Central India and evaluating adaptation studies through crop simulation models

M. Mohanty, K.M. Hati, N.K. Sinha, Sangeeta Lenka, Pramod Jha, Neenu S., R. S. Choudhary , R. Elanchezhian and A. Subba Rao

26. Tillage and manure interactive effects on soil aggregate dynamics, soil organic carbon accumulation and by pass flow in Vertisols

Sangeeta Lenka, M. C. Manna, Brij Lal Lakaria, R. K. Singh and R. C. Singh (CIAE)

B) Externally Funded Projects

27. Evaluating conservation agriculture for stabilizing crop productivity and carbon sequestration by resilient cropping systems/sequences under aberrant climatic conditions in black soils of Central India

J. Somasundaram, R. S. Chaudhary, M. Vassanda Coumar, K. M. Hati, A. Subba Rao, Pramod Jha, K. Ramesh and Ajay

28. Quantifying green house gases (GHGs) emissions in soybean-wheat cropping system of M.P. (MPCOST)

Sangeeta Lenka, N.K. Lenka, S. Kundu and A. Subba Rao

Programme III – Soil Microbial Diversity and Biotechnology

A) Institute Projects

29. Structural and functional diversity of microbes in soil and rhizosphere

Santosh R. Mohanty, M.C. Manna and Muneshwar Singh

30. Consequences of transgenic cotton on soil microbial diversity

Asit Mandal, J. K. Thakur, Asha Sahu and M.C. Manna

31. Actinomycetes diversity in Decan plateau, hot, arid region and semi arid eco-sub-region (AER 3 and 6) and evaluation of their PGPR activity

Radha T.K. and D.L.N. Rao

32. Developing technique for acceleration of decomposition process using thermophilic organisms

Asha Sahu, U. B. Singh (NBAIM), J.K. Thakur, V. K Bhargav (CIAE), H.L. Kushwaha (CIAE), Asit Mandal, M.C. Manna and and A. Subba Rao

33. Chemical and microbiological evaluation of biodynamic and organic preparations

J. K. Thakur, Asha Sahu, Asit Mandal and A. B. Singh.

34. Greenhouse gas (GHG) emission from composting systems and characterization of GHG regulating microbes

K. Bharati, J.K. Saha, S.R. Mohanty and Shinogi K.C.

35. Biodegradation of pesticides under changing climate and metagenomic profiling of functional microbes

K. Bharati, Radha, T. K. and Santosh R. Mohanty

B) Externally Funded Projects

36. Metagenomic characterization and spatio-temporal changes in the prevalence of microbes involved in nutrient cycling in the rhizoplane of bioenergy crops (DST)

Santhosh R. Mohanty, Asit Mandal and K. Bharati

37. Novel bio-filtration method using selected mesophilic fungi for removal of heavy metals from municipal solid waste in Madhya Pradesh (MPCOST)
M.C. Manna, Asit Mandal, Asha Sahu, J. K. Thakur, S. Ramana and A. Subba Rao

Programme IV: Soil Pollution, Remediation and Environmental Security

A) Institute Projects

38. Phyto-extraction of Cr by some floriculture plants
S. Ramana, A.K. Biswas and Ajay

39. Non point sources of phosphorus loading to upper lake, Bhopal
M. Vassanda Coumar, M. L. Dotaniya, Vasudev Meena, J. Somasundaram and J.K. Saha

40. Interaction among tannery effluents constituents on heavy metals uptake by spinach
M. L. Dotaniya, J. K. Saha, S. Rajendiran, M. Vassanda Coumar and S. Kundu

41. Impact of long term use of sewage water irrigation on soil and crop quality in Bhopal region of Madhya Pradesh
Vasudev Meena, M. L. Dotaniya, Vassanda Coumar, S. Rajendiran, Asha Sahu and S. Kundu

9. CONSULTANCY, CONTRACTUAL SERVICES, PATENT, COMMERCIALISATION OF TECHNOLOGY

S.No.	Title	Project Team	Sponsorer
1	Evaluation of plant nutrition product (NP-1) for nutrient use efficiency in cereal crops	R. Elanchezhian, A.K. Biswas, K Ramesh, N.K. Lenka and A. Subba Rao	M/s Nagarjuna Fertilizers and Chemical Ltd., Hyderabad
2	Effect of urea pistilles on productivity and nutrient use efficiency in some soils of India	Pramod Jha, B.L. Lakaria, A.K. Biswas, Pradip Day, A. Subba Rao, B. Kumar (Ranchi) and S.R. Singh (Barrackpore)	M/s Sandvik Asia Pvt. Ltd., Pune.
3	Investigations on the safe use of sludge in agricultural land generated from effluent from plant of a soft drink	J.K. Saha, A. Subba Rao, S. Kundu and Vassanda Coumar	M/s Coca Cola India Pvt. Ltd.
4.	Testing a new slow release 14-7-14 NPK fertilizer for its efficiency nder field conditions	Sanjay Srivastava, K. Ramesh, P. Dey, A.K. Biswas and A. Subba Rao	PRII, Gurgaon
5.	Development of customized feature solution to promote balaneed fertilizations in selective agriculturally important states of India towards crop productivity and farm profitability	Drs. Pradip Dey, S. Srivastava, A.K. Shukla, H. Das, B. Lakaria, A.K. Biswas and A. Subba Rao.	NFCL, Hyderabad

10. INSTITUTE COMMITTEES

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Dr. A.K. Biswas	Member Secretary
All Scientists	Member

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Post Aduyal, The- PAONI, Distt. Bhandara (Maharashtra) Pin 441802	Member
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Pr. Scientist & National Fellow (Soil Chemistry/Fertility/Microbiology) Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad – 500 059 (A.P)	Member
Dr. A.K. Shukla	
Project Coordinator (MSN), Indian Institute of Soil Science, Bhopal (M.P)	Member
Dr. D.K. Painuli	
Pr. Scientist (Soil Physics), Central Arid Zone Research Institute, Jodhpur 342 003	Member
Dr. Obi Reddy	
Sr. Scientist (GIS), National Bureau of Soil Survey and Land Use Planning Nagpur – 440 033 (MS)	Member
Sh. Rajesh Dubey	
AF&AO, Indian Institute of Soil Science, Bhopal (M.P)	Member
Sh. V.K. Derashri	
Administrative Officer, IISS, Bhopal	Member Secretary

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Research Advisory Committee

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Potash Research Institute of India and Advisor, NRM Technology	
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Kanpur -208002	
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Baramati, Pune , Maharashtra- 413133	
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Indian Institute of Soil Science	Member
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Dr. R.S. Chaudhary, HOD (Soil Physics)	Technical Expert
Dr. P.C. Bhargale, HOD, TTD, CIAE	Outside Expert
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Dr. A.K. Biswas, HOD (Soil Chemistry & Fertility)	Member
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Dr, R.S. Chaudhary, HOD (Soil Physics)	Member
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Dr. Shinogi K.C., Scientist	Member
Ms. Geeta Yadav, Private Secretary	Member

Results – Framework Documentation (RFD) Cell

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Sh. P.S. Sunil Kumar, AAO	Member

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Director	Chairman
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Dr. M.L. Dotaniya, Scientist	Member
Dr. Nishant K. Sinha, Scientist	Member
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Dr. Sanjay Srivastava, Pr. Scientist	Incharge

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Dr. M. Vassanda Coumar, Scientist	Member
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Sh. Anurag, Security Supervisor	Member

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Ms. T.K. Radha, Scientist	Member

Dr. I. Rashmi, Scientist	Member
Dr. Asha Sahu, Scientist	Member
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Ms. Kirti Singh Bais, Personal Assistant	Member
Ms. Babita Tiwari, Assistant	Member
Ms. Kavita Bai, SS Gr. III	Member

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Sh. Harish Kumar Barmaiya, SSS	Supporting Staff
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Mr. Jagan Nath Gaur	Lab Attendent

Training Hostel

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Mr. Hiranmoy Das, Scientist	Incharge
Dr. B.P. Meena, Scientist	Alternative I/c
Sh. Saurabh Kumar, Assistant	Care Taker
Sh. Vinod Choudhary	Technical assistant

11. PARTICIPATION OF SCIENTISTS IN CONFERENCES / SYMPOSIA/ SEMINARS/ WORKSHOPS/ MEETINGS

Name	Programme	Venue	Period
Dr. A.K. Shukla	Agricultural Summit meeting	ICAR Research Complex for Eastern Region, Patna	5-6 April, 2013
Drs. A. B. Singh, N.K. Lenka, R.K. Singh, Ritesh Saha and N.K. Sinha	Workshop-cum- training on GPS and GIS based Soil Fertility Maps for Precise Fertilizer recommendations	IISS, Bhopal	11-12 April, 2013
Dr. K. Ramesh	USIEF workshop on Building Partnerships	Ahmedabad	11-12 April, 2013
Dr. D.L.N. Rao	Review meeting of National Fund for Basic, Strategic and Frontier Application Research in Agriculture (NFBSFARA) project	DOR, Hyderabad	13 April, 2013
All scientists	The Silver Jubilee seminar of IISS	IISS, Bhopal	15-16 April, 2013
Dr. J. Somasundaram	NICRA Review meeting of CGC	CRIDA, Hyderabad	25-26 April, 2013
Dr. A.B. Singh	Annual Group meeting of Network Project on Organic Farming	ICAR Research Complex for NEH Region, Sikkim Centre Tadong, Gangtok	26-27 April, 2013
Dr. I. Rashmi	International symposium on minerals and Mining in India-The Way Forward, Inclusive of Cooperative Mineral–based Industries in SAARC Countries	MPCOST, Bhopal	27-29 April, 2013
Dr. Pradip Dey	National seminar on Soil Fertility, Degradation and Contamination	BSKKV, Dapoli	9 May, 2013
Dr. A.K. Biswas	2nd Brainstorming meeting on CRP on Conservation Agriculture	NASC, New Delhi	10-11 May, 2013
Dr. A.K. Shukla	International conference on Impact of Technological Tools on Food Security under Global Warming Scenario	SVPUAT, Meerut	10-12 May, 2013
Dr. S. Srivastava	Meeting to discuss the fate of basic slag generated in huge amount from iron and steel industry	CRIDA, Hyderabad	8 June, 2013

Name	Programme	Venue	Period
Dr. J. Somasundaram	Annual workshop of NICRA Project	IARI, New Delhi	18-19 June, 2013
Dr. A.K. Shukla	Launching workshop on Nutrient Experts DSS	NASC, New Delhi	19-21 June, 2013
Dr. Pradip Dey	Nutrient Expert Launch meeting	NASC , New Delhi	20 June, 2013
Dr. A.K. Shukla	7th CAC meeting of NAIP Project	IIHR, Bengaluru	28-29 June, 2013
Dr. S. Srivastava	Meeting to discuss the Customized Fertilizer Formulations Suitability	Krishi Bhavan, New Delhi	5 July, 2013
Dr. D.L.N. Rao	Brainstorming session on Role of Root Endophytes in Agricultural Productivity	NASC, New Delhi	5 July, 2013
Dr. R. Elanchezhian	National workshop on Climate Controlled Green houses for Agricultural Research	CDAC, Chandigarh	11 July, 2013
Dr. D.L.N. Rao	Brainstorming Session on Bioinformatics in Agriculture	NASC, New Delhi	12 July, 2013
Dr. S. Srivastava	ICAR meeting on Establishing Soil-Water-Tissue Testing Lab in various parts of Kenya	NASC, New Delhi	19 July, 2013
Dr. Muneshwar Singh	Round table discussion on 'Balanced Fertilization'	New Delhi	21-22 July, 2013
Dr. D.L.N. Rao	Review meeting of National Fund for Basic, Strategic and Frontier Application Research in Agriculture (NFBSFARA) Project	NASC, New Delhi	22 July, 2013
Dr. I. Rashmi	International conference on Innovative Trends in Natural/ Applied Sciences and Energy Technology for Sustainable Development (ITNASSD - 2013)	JNU, New Delhi	27-28 July, 2013
Dr. K. Ramesh	NAIP training workshop on Scientific Report Writing and Presentation	NAARM, Hyderabad	30 July-3 August, 2013

Name	Programme	Venue	Period
Dr. R.H. Wanjari and Mr. Vinod Chaudhary	Agriculture fair-cum-Bharat Nirman Jan Suchna Abhiyan	Krishi Upaj Mandi, Betul	25-27 August, 2013
Dr. Muneshwar Singh	Project Coordinators Meeting	NASC, New Delhi	28-31 August, 2013
Dr. A.K. Biswas	CRP on Conservation Agriculture	NASC, New Delhi	29-30 August, 2013
Dr. R.S.Chaudhary	Brainstorming session on Enhancing Water Use Efficiency in Yamuna basin	NASC, New Delhi	30 August, 2013
Drs. I. Rashmi and K.C. Shinogi	National seminar on Changing Scenario of Agriculture in Madhya Pradesh: Prospects and Challenges	Ravindra Bhavan, Bhopal	1-2 September, 2013
Dr. K. Ramesh	International conference on Strategies to Drive Organic Sector Forward: For Sustainability & for Markets	Trivandrum, Kerala	5-6 September, 2013
Dr. A.K. Biswas	Travelling seminar on CA organized by CIMMYT- India	Travelling Seminar	16-25 September, 2013
Dr. S. Srivastava	Installation cum training workshop under NAIP Project Strengthening Statistical Computing at NARS for Nodal Officers	IASRI, New Delhi	17-18 September, 2013
Dr. Pradip Dey	Agriculture Leadership Summit conducted by Agriculture Today Group	NASC, New Delhi	19 September, 2013
Dr. S. Srivastava	Online application development using PHP & MySQL	IIFM, Bhopal	23–27 September, 2013
Dr. Pramod Jha	National workshop on National Fund for Basic, Strategic and Frontier Application Research (NFBSFARA) in Agriculture	CIFE, Mumbai	27-28 September, 2013
Dr. R.S. Chaudhary	Technical session cum retailers meeting	Shriram Fertilizers and Chemicals, Bhopal	7 October, 2013

Name	Programme	Venue	Period
Dr. S. Srivastava	Innovative Partnership on the occasion of foundation day of Agrinnovate India Ltd.	NAASC, New Delhi	19 October, 2013
Drs. A. Subba Rao, S. Kundu, J.K. Saha, A.B.Singh, Tapan Adhikari, B.L. Lakara R. Elanchezhian, R.H. Wanjari, N.K. Lenka, R. K. Singh, Ritesh Saha, K. Ramesh, Pramod Jha, S. Lenka, M. Vassanda Coumar, M. L. Dotaniya, N.K. Sinha, I. Rashmi and S. Rajendiran	78th Annual Convention of Indian Society of Soil Science	CAZRI, Jodhpur	23-26 October, 2013
Dr. S. Srivastava	Technical committee meeting To Examine the Method of Sampling of Imported Fertilizer	Krishi Bhavan, New Delhi	29 October, 2013
Drs. Muneshwar Singh, A.K. Biswas, Pradip Dey, J.K. Saha S. Srivastava, R. Elanchezhian and M. Vassanda Coumar	Brainstorming session on Efficient use of Phosphorus	NAASC, New Delhi	7-8 November, 2013
Drs. J.K. Thakur and N.K. Sinha	Science fiesta	Regional Science Centre, Bhopal	10-12 November, 2013
Drs. Pradip Dey and N.K. Lenka	International conference on Climate Change and Implication for Food Security and Nutrition	Bengaluru	15-16 November, 2013
Dr. K. Ramesh	DST Brain storming session on Agrometeorological Research for Food Security in India	AAU, Jorhat	15-16 November, 2013
Dr. S. Srivastava	International meeting and presentation on Establishment of Soil Water Tissue Testing Laboratory in Burkina Faso (Africa)	Krishi Bhavan, New Delhi	18 November, 2013

Name	Programme	Venue	Period
Dr. K. Ramesh	International Conference on Role of Plant Biochemistry and Biotechnology in Food and Nutritional Security	Sri Venkateswara University, Tirupati	11-14 December, 2013
Dr. R. Elanchezhian	National conference of Plant Physiology on Current trends in Plant Biology Research	DGR, Junagadh	13-16 December, 2013
Dr. A. B. Singh	14th National Agriculture Vigyan Sangosthi	CIFE, Mumbai	14-16 December, 2013
Dr. Pradip Dey	Workshop on Balanced Fertilization in Crops with Special Reference to Potassium	ANGRAU, Hyderabad	16 December, 2013
Dr. A.K. Shukla	Workshop of AICRPS on Vegetable crops	NASC, New Delhi	16-18 December 20131
Dr. Pradip Dey	Consultative workshop on Nutrient Expert for Cereal Systems	NASC, New Delhi	9 December, 2013
Dr. J. Somasundaram	NICRA Review meeting of CGC	CRIDA, Hyderabad	21-22 December, 2013
Drs. A.K. Shukla and Pradip Dey	Conference of Vice-Chancellors and Directors	NIASM, Baramati	18-21 January, 2014
Dr. Pradip Dey	Conference of ICAR Directors	NRC for Grapes, Pune	20 January, 2014.
Dr. D.L.N. Rao	Group meeting of AICRP on Fruits	BSKKV, Dapoli	22-23 January, 2014
Dr. Pradip Dey	Brain storming session on Soil Testing and Fertilizer Use	ANGRAU, Hyderabad	24 January, 2014
Dr. S. Srivastava	Training cum workshop on Technology Management for Researchers	NAARM, Hyderabad	27-31 January, 2014
Drs. A. Subba Rao, N.K. Lenka, J. Somasundaram and S. Lenka	Brain storming session on Carbon Economy in Indian Agriculture	NASC, New Delhi	1 February, 2014

Name	Programme	Venue	Period
Drs. R.K. Singh and M. L. Dotaniya	2nd International conference on Agriculture & Horticultural Sciences	Hotel Radison Blue, Hyderabad	3-5 February, 2014
Drs. J.K. Saha and Tapan Adhikari	101th Indian Science Congress	University of Jammu, Jammu	3-7 February, 2014
All scientists	Workshop on Management of Intellectual Property Rights in Public Research	IISS, Bhopal	7 February, 2014
Dr. A. K. Vishwakarma	National conference on Emerging Problems and Recent Advances in Applied Science Basic to Molecular Approaches	Ch. Charan Singh University, Meerut	8-9 February, 2014
Drs. A.B. Singh, S. Srivastava, R.H. Wanjari and R.K. Singh	Krishi Vasant National Agriculture Fair-2014	CICR, Nagpur	9-13 February, 2014
Dr. A. K. Vishwakarma	Meeting on Weed Control	DWSR, Jabalpur	12-14 February, 2014
Dr. Pradip Dey	KRISHI 21 – conference on Diversification Led Agricultural Transformation towards Greener Economy	NASC, New Delhi	14 February, 2014
Dr. A. K. Vishwakarma	Biennial conference of ISWS on Emerging Challenges in Weed Management	DWSR, Jabalpur	15-17 February, 2014
Drs. D.L.N. Rao, A. B. Singh, R.H.Wanjari, J. Somasundaram, K. Ramesh, Neenu, S. and N.K. Sinha	SOYCON-2014, International Soybean Research Conference	DSR, Indore	22-24 February, 2014
Drs. R.S. Chaudhary, K.M. Hati and N.K. Sinha	Workshop on Aquifer Mapping and Management	Central Ground Water Board, Bhopal	25-26 February, 2014

Name	Programme	Venue	Period
All scientists	National Level Consultation Meeting on Soil Health Assessment	IISS, Bhopal	26 February, 2014
Dr. S. Ramana	National Seminar on Protected Cultivation Technologies for Vegetable Cultivation	CIAE, Bhopal	26-27 February, 2014
Dr. Pradip Dey	International Conference on Potassium Nutrition and Crop Quality	BAU, Ranchi	4 March, 2014
Dr. A.K. Shukla and Mr. Pankaj K. Tiwari	27th Biennial workshop of AICRP-MSN	PDKV, Akola	8 March, 2014
Dr. D.L.N. Rao	Workshop of AICRP on Micro and Secondary Nutrients and Pollutant Elements in Agriculture	PDKV, Akola	7-9 March, 2014
Drs. R. S. Chaudhary, K.M. Hati and N.K. Sinha	Workshop on Groundwater Conservation and Management with Peoples Participation in Madhya Pradesh	Central Ground Water Board, Bhopal	14 March, 2014
Dr. A.K. Shukla	Terminal meeting of NAIP Project C-4	ICAR, New Delhi	18-20 March, 2014
Dr. N.K. Lenka	National Conference on Farmers First for Conserving Soil and Water Resources	The Institute of Engineers, Dehradun	22-24 March, 2014
Drs. Neenu S., Asit Mandal and J.K. Thakur	National Seminar on Innovations in Science and Technology for Inclusive Development	MPCOST, Bhopal	26-27 March, 2014

12. WORKSHOPS, SEMINARS, SUMMER/WINTER SCHOOLS AND OTHER EVENTS ORGANIZED AT THE INSTITUTE

Meeting/Seminars/Workshops Organised at IISS

Institute Research Council Meeting

During the year 2013-14, Institute Research Council (IRC) met twice on 18-20 & 26 July, 2013 and 28-30 & 9 April, 2014 under the Chairmanship of Dr. A. Subba Rao for reviewing the progress of on-going research projects. In these meetings the Chairman stressed to maintain a database of projects for being accountable for the public investment in research. He further added that we need to work as per Vision-2050. The Chairman expected new perspective in research with efficient/inefficient cultivars with respect to nutrient use efficiency, need for the development of GAP/BMPs, and soil health assessment and monitoring in some bench mark sites in production systems across agroecological region. The institute has to concentrate its all energy and manpower to flagship programmes identified for the XIIth plan, and there has to be a proportionate deployment of manpower to generate useful data on those key theme areas. He further added that all the scientists involved in soil resilience aspects should frame a new project to get in depth and detailed information on soil resilience. All green house gas emission projects are needed to have standardized procedures for measurement of greenhouse gas emission and calculations. PIs of these projects should come out with the protocol for measurement and calculation. New issues like nano technology, precision agriculture, genomics should also be considered and it is also important to frame new research works different from other institutes with respect to nutrient use efficiency and soil health. He also pointed out the issues like the clarity in the real picture of total soil health a scenario of the country. Further, studies on rhizosphere conditions, up scaling of Bio- and phytoremediation technologies, and conservation agriculture need our attention. In these two meetings the progress of both institute and externally funded projects were discussed in details. All projects of the Institute were brought under four main thematic areas.

Research Advisory Committee Meeting

The 20th meeting of Research Advisory Committee (RAC) was held during 14th December, 2013 under the Chairmanship of Dr. V.S. Tomar, Vice-Chancellor, JNKVV, Jabalpur. In his introductory remarks, the Chairman pointed out that scientists should have strong affinity for our profession and we should provide the vision to the country in respect of soil science research. In the recent past a lot of information related to soil fertility and other aspects of soil science has been generated which is of international standard but foaled to translate it into useful technologies. Therefore, we need to work hard for designing our agro-technologies suitable to farmers' needs. There is known perception amongst the people that problem of soils cannot be solved through plant breeding and bio-technological means, and will have to highlight this perception with our best knowledge of soil science and practical ways of solving the problems of soils. The institute has a good size of young scientists and we need to work hard to harness the talent and to provide leadership in the domain of soil science. The chairman also emphasized that in spite of large number of research projects completed and currently under operation in this institute, we are not able to show our impact and therefore requested all the scientists to assess their research output and try to convert them into meaningful farmers' friendly technologies. The chairman pointed out that soil micro-biological research is going to be an important means of tackling the problem of soil health and we should strengthen our research efforts in this direction.

Institute Management Comittee Meeting (IMC)

The 37th Meeting of IMC was held on 11 June, 2013 under the chairmanship of Dr. A Subba Rao, Director, IISS, Bhopal. During this meeting IMC recommended to purchase some of the proposed items.

Training / short course conducted

Programme	Course Director/ Co-ordinator(s)	Duration	Sponsorer
Training programme on "Soil Testing for Primary, Secondary and Micronutrient"	Drs. A.K. Biswas and B.L. Lakaria	12-15, 18-21 and 26-29 June, 2013	Government of Madhya Pradesh
National training programme on "Climate change, Carbon Sequestration and Carbon Credits"	Drs. S. Lenka, N. K. Lenka and Mr. M. Mohanty	23 August to 5 September, 2013	NAIP
MTC on "Improving Nutrient Use Efficiency through Agronomic Measures for Major Crops of India"	Drs. K. Ramesh, A.K. Biswas and B.L. Lakaria	12-19 November, 2013	Ministry of Agriculture, Govt. of India, New Delhi
MTC on "Assessment of Soil Health for Higher Productivity"	Drs. S. Kundu and M. Vassanda Coumar	3-10 December, 2013	Ministry of Agriculture, Govt. of India, New Delhi
Training Programme on "Data Analysis Using SAS" in collaboration with IASRI, New Delhi	Drs. S. Rajedra Prasad, S. Srivastava and J. Somasundaram	9-13 December, 2013	NAIP
Training Programme on "Soil Health Management – Training on Leaf and Soil Analysis"	Drs. A.K. Biswas, B.L. Lakaria and I. Rashmi	16-20 December, 2013, 14-18 January, and 10-14 February, 2014	State Department of Agriculture, Government of Kerala




Participants of different training programmes

- Workshop cum training programme on 'Soil Fertility Mapping' was organized during 11-12 April, 2013
- Training-cum-Workshop on Soil Fertility Management for KVK personnels of M.P. Chhattishgarh and Odisha was organized in collaboration with Zonal Project Directorate, Zone- VII, Jabalpur during on 3- 4 May, 2013
- Workshop on Management of Intellectual Property Rights in Public Research was organized for scientists and research scholars on 7 February, 2014


Workshop on Management of Intellectual Property Rights in Public Research

Independence Day

The 67th '*Independence Day*' was celebrated on 15 August, 2013 in the Institute premises. Events like race for children and musical chair for men and women were arranged. The programme was concluded with the distribution of prizes to the winners by Mrs. Subba Rao and Dr. A. Subba Rao, Director, IISS, Bhopal.

Prize distribution to the winners on the Independence Day celebrations

New Year Day

The Staff Recreation Club (SRC) organized a 'New Year Day' celebration on 1 January, 2014. The staff members wished each other for the 'Happy and Prosperous New Year 2014'. The honourable patron SRC, Dr. A. Subba Rao, Director of the Institute wishes everybody and requested for setting higher scientific targets and output to get name and fame to the Institution.

New Year Day Celebrations

Republic Day

The Institute celebrated 65th '*Republic Day'* with enthusiasm. All the staff members of IISS participated in various events with thrill and great enthusiasm. Activities include racing and drawing for children, musical chair for men and women. The programme was concluded with the distribution of prizes to the winners.

Plate .Republic Day celebrations

Womens' Day

International women's day was celebrated at IISS with great fervour and gaiety. Different competitions were organized for women staff and spouse of IISS staff. There were active participation of women in all competitions such as rangoli, antakshari and musical chair. The chief guest of the function, Dr. Sonia Gupta, Professor, Hospitality, at Leeds Metropolitan University U.K., India Campus at Bhopal addressed the gathering on women's rights and related issues. She also highlighted that, the status and position of women have improved over years. However, the figures of female foeticide have also gone up. Dr. Sangeeta Lenka, chairman women cell highlighted the importance of celebrating women's day function on 8 March every year. Guest of honour was Smt. Bhulaxmi Devi. At the end, prizes were distributed to winners of different competitions.

Womens' Day Celebrations

Agricultural Education Day

Indian Institute of Soil Science, Bhopal celebrated Agriculture Education Day' on 17 December, 2013 at nearby Parvalia village with more than 70 farmers along with state Govt. officials and local beneficiaries. Chief Guest Dr. A. Subba Rao, Director, IISS, Bhopal addressed the participants on the 'Importance of Conservation Agriculture'. He emphasized the importance of conservation tillage, residue management and crop diversification. Dr. Muneshwar Singh, PC (LTFE) highlighted the importance of natural resources like soil and water for the coming years and its judicious use for livelihood security. Dr. R.S. Chaudhary, Head, Soil Physics division explained the basics of conservation agriculture. Several activities including field demonstration of various conservation agriculture machineries like zero till seed drill, laser land leveler, strip drill seed drill and permanent BBF followed by interaction session with the farmers and subject matter specialists were organized. Field demonstrations were jointly organized by IISS and CIAE scientists and staffs. All the farmers enthusiastically participated in interaction and other sessions.

Agricultural Education Day activities

13. DISTINGUISHED VISITORS

- Following dignitaries participated in the Silver Jubilee Seminar organized on 15 April, 2013 and Foundation day celebrations on 16 April, 2013:

  Dr. C.L. Acharya, Former Director, IISS, Bhopal

  Dr. N.N. Goswami, Ex-Vice Chancellor, CSUAT, Kanpur

  Dr. S.S. Khanna, Ex-Advisor, Planning Commission, Govt. Of India

  Dr. N.S. Pasricha, Former Director, PRII, Ludhiana

  Dr. T.K. Adhya, Ex-Director, CRRI, Cuttack, Orissa

  Dr. N.P. Kurian, Director, Centre for Earth Science Studies, Thiruvananthapuram

- Sh. Charan Das Mahant, Union Minister of State for Agriculture and Food Processing, inaugurated Soil Biodiversity laboratory on 15 April, 2013
- World Bank team visited during 13-14 August, 2013 for review of ongoing NAIP
- Dr. A.K. Sikka, DDG (NRM) & Dr. S. K. Chaudhari, ADG (S&WM) visited during 25-27 February, 2014, for the "National Level Consultation Meeting on Soil Health Assessment"
- Dr. Rattan Lal, Distinguished Professor, Ohio State University, Columbus and former President, Soil Science Society of America, visited during 10-12 March, 2014

14. PERSONNELS

Joining

Sh. Pankaj Kumar Tiwari joined as Scientist on 11 April, 2013

Dr. Anand Kumar Vishwakarma, joined on 1 August, 2013 as Senior Scientist through direct selection in the scale Rs. 37400+ RGP 9000

Promotion

Dr. N. K. Lenka, Senior Scientist was promoted under CAS from Senior Scientist to Principal Scientist *w.e.f.* 30 September, 2012.

Dr. Santosh Ranjan Mohanty, Sr. Scientist was promoted under CAS in the scale of Rs. 37400 + RGP 9000 *w.e.f.* 18 June, 2012.

Dr. Promod Jha, Sr. Scientist was promoted under CAS in the scale of Rs. 37400 + RGP 9000 *w.e.f.* 17 July, 2012.

Dr. Kollah Bharati, Sr. Scientist was promoted under CAS in the scale of Rs. 37400 + RGP 9000 *w.e.f.* 29 October, 2012.

Dr. Neenu S., Scientist was promoted under CAS in the scale of Rs. 15700 + RGP 7000 *w.e.f.* 21 April, 2013.

Dr. Asit Mandal, Scientist was promoted under CAS in the scale of Rs. 15700 + RGP 7000 *w.e.f.* 23 June, 2013.

Dr. M. Vassanda Coumar, Scientist was promoted under CAS in the scale of Rs. 15700 + RGP 7000 *w.e.f.* 4 November, 2013.

Smt. Seema Sahu, Sr. Tech. Officer was promoted to Assistant Chief Technical Officer *w.e.f.* 1 April 2012.

Sh. D. R. Darwai, Sr. Technical Assistant was promoted to Technical Officer *w.e.f.* 23 January, 2013.

Sh. Pramod Kumar Chouhan, Sr. Technical Assistant was promoted to Technical Officer *w.e.f.* 5 February, 2013.

Superannuation

Sh. G. D. Dubey, F&AO retired from ICAR service on 30 September, 2013

Sh. V. B. Andurkar, Farm Superintendent retired from ICAR service on 31 October, 2013

15. INFRASTRUCTURE DEVELOPMENT

15.1 Instruments/Equipments purchased

Equipments such as Protein Analyzer, Image Analyzer, Digital Research Microscope, Refrigerated Centrifuge, Surface area and Porosity Analyzer, BET Instrument, Digital Soil Penetrometer with Data Logger, Soil Moisture Meter (TDR) with complete accessories, Multimedia Projector, 5KVA UPS, Printers, Desktop Computers, Server, Laptops, Printers & HDDs, Fire Extinguisher, Flame Photometer, Quartz Double Distillation Unit and Stainless Steel-304 grade fabricated filters were purchased during the year.

15.2 Library Developments

The library is well maintained with facilities of document such as lending service, reference service, reprographic services etc. The library has procured the Library Automation Software TLS, in which the bibliographic data of the books were imported from the existing software. The Library also exchanges the institute publication with the other ICAR Institute, SAUs and renowned Scientists in the field of Soil Science.

The institute library has been further strengthened with following new additions.

Document	Additions during 2013-14	Total
Books	43	2577
Bound Journal	0	2508
Annual Report	124	2017
Foreign journals subscribed	32	32
Indian journals subscribed	30	30

15.3 Miscellaneous Works completed

Renovation of library floor	Rs.	12,12,900/-
Renovation of screen House	Rs.	9,97,530/-
Replacement of cable	Rs.	5,30,250/-

15.4 Farm development

- Red gram (Asha) was raised successfully in the farm with an average productivity of 9.79 q ha^{-1} (area 3.78 ha with a production 37.02 q) in spite of poor crop of soybean due to incessant rains during the kharif season. Thus red gram emerges as a profitable crop for the shifting weather pattern at Bhopal.

- Maize was raised in an area of 3.10 ha and the production was 23.53 q.
- With the help of the underground irrigation system, commissioned with cost of Rs. 16 lakhs, *rabi* season crops were raised to successfully to cultivate 12.85 ha various crops – especially gram in 10.25 ha. Besides this all the *rabi* experiments of the institute were provided irrigation with the pond water.
- Levelling of fields was carried out and an additional one hecatrae was brought under cultivation.
- **Conservation agriculture practices for Arhar (Mechanical weeding for broad bed furrow planted red gram for conservation agriculture *vis-à-vis* organic farming**

  Mechanical weeding for broad bed furrow planted red gram for conservation agriculture was tested for the subsequent year with partial success due to heavy down pours. The technology encompasases a tractor based mechanical weeding technology adjusting the spacing of the cultivator tynes at 90 cm. The original 9 tyned cultivator was modified to three tynes. The first and second weeding can be done mechanically at 25-30 and 60 days after sowing when the plants reach to a height of 1.5 feet. It saves extensive labour requirement. Effective completion of weeding operations in the short operational window in the rainfed regions of the country.

A view of the field after weeding

- **Model organic farm – management options (strip row intercropping for Rainfed farming and conservation agriculture *vis-à-vis* organic farming)**

  Strip row intercropping for rainfed farming and conservation agriculture was extended to another 2 ha area in the farm with changes in the *rabi* season crops. It has been proven beyond doubt that red gram has delivered assured returns. To ensure fullest utilization of the season, a strip row inter cropping has been developed with red gram, soybean and/or maize.

15.5 Sports facilities

- Basket ball court was developed with a cost of ~ ₹ 70,000 through purchase of goal posts.
- Volleyball court was developed with a cost of ~ ₹ 67,000 by replacing 1.5 feet soil with *murram* and yellow soil.

Annexure-I

DETAILS OF MANPOWER

Name of the Staff	Designation	Discipline	Date of Joining ICAR	Date of Joining IISS
DIRECTOR'S CELL				
Dr. A. Subba Rao	Director	Soil Chemistry/Fertility/ Microbiology	27.07.1989	27.07.1989
Sh. Thomas Joseph	PS	Office Staff	18.09.1989	18.09.1989
Smt. Yojana Meshram	PA	Office Staff	12.05.1997	12.05.1997
Sh. Bhoi Lal Uikey	Lab Attendant	Skilled Supporting Staff	13.11.1995	13.11.1995
DIVISION OF SOIL PHYSICS				
Dr. R.S. Chaudhary	Head & Pr. Scientist	Soil Physics/Soil & Water Conservation	10.11.1993	09.12.1999
Dr. K.M. Hati	Pr. Scientist	Soil Physics/Soil & Water Conservation	27.12.1996	27.12.1996
Dr. Rakesh Kumar Singh	Sr. Scientist	Soil Physics/Soil & Water Conservation	25.01.1993	16.10.2002
Dr. Ritesh Saha	Sr. Scientist	Soil Physics/Soil & Water Conservation	26.11.1999	24.08.2009
Dr. J. Somasundaram	Sr. Scientist	Soil Physics/Soil & Water Conservation	12.11.2001	22.12.2008
Dr. Anand Kumar Vishvakarma	Sr. Scientist	Agronomy	16/04/2013	01/08/2013
Sh. M. Mohanty	Scientist	Soil Physics/Soil & Water Conservation	10.11.1999	10.11.1999
Dr. Sangeeta Lenka	Scientist	Soil Physics/Soil & Water Conservation	08.01.2007	18.05.2007
Dr. Nishant K. Sinha	Scientist	Agriculture Physics	20.04.2010	27.08.2010
Sh. R.K. Mandloi	T 7-8	Asstt. Chief Technical Officer (ACTO)	19.06.1989	19.06.1989
Sh. Darashram	Lab attendant	Skilled Supporting Staff	15.03.1990	15.03.1990
DIVISION OF SOIL CHEMISTRY AND FERTILITY				
Dr. A.K.Biswas	Head & Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	21.01.1992	11.01.1993
Dr. Sanjay Srivastava	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	22.03.1996	02.09.1996

Dr. Brij Lal Lakaria	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	01.10.1997	15.01.2007
Dr. R. Elanchezhian	Pr. Scientist	Plant Physiology	09.11.1998	17. 02.2012
Dr. N. K. Lenka	Pr. Scientist	Soil Physics/Soil & Water Conservation	30.11.2000	09.10.2009
Dr. K. Ramesh	Sr. Scientist	Agronomy	04.09.2008	04.09.2008
Dr. Pramod Jha	Sr. Scientist	Soil Chemistry/Fertility/ Microbiology	16.04.2003	17.07.2009
Dr. Neenu, S.	Scientist	Soil Chemistry/ Fertility/ Microbiology	21.04.2009	27.08.2009
Dr. I. Rashmi	Scientist	Soil Chemistry/Fertility Microbiology	21.04.2009	27.08.2009
Dr. J.S. Virgine Tenshia	Scientist	Soil Chemistry/Fertility/ Microbiology	28.05.2010	28.05.2010
Dr. Bharat Prakash Meena	Scientist	Agronomy	15.09.2011	22.12.2011
Sh. Deepak Kaul	T-7-8	Asstt. Chief Technical Officer (ACTO)	29.12.1988	29.12.1988
Sh. Khilan Singh Raghuvanshi	T-4	Sr. Technical Assistant	29.12.1988	29.12.1988
Sh. Bha war Singh Yadav	Messenger	Skilled Supporting Staff	01.09.1993	23.01.1999
DIVISION OF SOIL BIOLOGY				
Dr. M.C. Manna	Head & Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	21.01.1992	11.01.1993
Dr. A.B. Singh	Pr. Scientist	Biochemistry	22.03.1999	22.03.1999
Dr. A.K. Tripathi	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	05.08.1991	25.07.1992
Dr. S. Ramana	Pr. Scientist	Plant Physiology	06.02.1997	06.02.1997
Dr. S.R. Mohanty	Sr. Scientist	Soil Chemistry/Fertility/ Microbiology	18.06.2009	18.06.2009
Dr. Kollah Bharati	Sr. Scientist	Microbiology -Plant Science	29.10.2009	05.04.2011
Dr. Asit Mandal	Scientist	Soil Chemistry/Fertility / Microbiology	23.06.2009	30.10.2009
Dr. J . K. Thakur	Scientist	Agricultural Microbiology	20.04.2010	27.08.2010
Dr. Asha Sahu	Scientist	Soil Chemistry/Fertility Microbiology	03.05.2010	03.05.2010
Sh. Vinod Babu Pal	T-6	Sr. Technical officer	15.02.1993	15.02.1993

Sh. Vinod Choudhary	T-3	Technical Assistant	14.06.1989	14.06.1989
Sh. Ram Bharose	Lab attendant	Skilled Supporting Staff	20.03.1990	20.03.1990
DIVISION OF ENVIRONMENTAL SOIL SCIENCE				
Dr. J.K. Saha	Head & Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	21.01.1992	02.01.1993
Dr. S. Kundu	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	22.07.1986	03.07.2007
Dr. Ajay	Pr. Scientist	Plant Physiology	12.04.1993	31.08.1999
Dr. Tapan Adhikari	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	22.03.1996	07.11.1996
Dr. M.Vassanda Coumar	Scientist	Soil Chemistry/Fertility/ Microbiology	04.11.2009	15.03.2010
Dr. Mohan Lal Dotaniya	Scientist	Soil Chemistry/Fertility	20.04.2010	28.08.2010
Dr. Rajendiran S.	Scientist	Soil Chemistry/Fertility/ Microbiology	02.09.2010	10.01.2011
Sh. Vasudev Meena	Scientist	Agronomy	15.09.2011	23.12.2011
Smt. Seema Sahu	T-7-8	Asstt. Chief Technical Officer (ACTO)	14.04.1987	24.01.1989
Sh. Sanjay Kumar Kori	Steno. GR.III	Office Staff	03.01.2012	03.01.2012
Sh. Sant Kumar Rai	T-2	Sr. Technician	15.06.1989	15.06.1989
Sh. Kalicharan	Lab attendant	Skilled Supporting Staff	10.06.1999	10.06.1999
AICRP-LTFE				
Dr. Muneswar Singh	Project Co - ordinator	Soil Chemistry/Fertility/ Microbiology	11.07.1989	11.07.1989
Dr. R.H. Wanjari	Sr. Scientist	Agronomy	07.01.1999	07.01.1999
Sh. Sunny Kumar	Steno. GR.III	Office Staff	21.12.2011	21.12.2011
Sh. Arun Kumar Mis hra	Lab attendant	Skilled Supporting Staff	01.09.1993	10.06.1999
AICRP-MSN				
Dr. Arvind Kumar Shukla	Project Co - ordinator	Soil Chemistry/Fertility/ Microbiology	05.07.1996	31.03.2011
Sh. Pankaj Kumar Tiwari	Scientist	Soil Chemistry/Fertility/ Microbiology	01.01.2013	11.04.2013
Sh. Sahab Siddiqui	T-6	Sr. Technical Officer	05.10.1992	05.10.1992
Sh. Jai Singh	T-5	Technical Officer	22.05.1990.	22.05.1990
Sh. Venny joy	PA	Office Staff	14.02.1991	23.03.1998

Sh. Harish Kumar	Lab attendant	Skilled Supporting Staff	14.03.1990	14.03.1990
AICRP-STCR				
Dr. Pradip Dey	Project Co - ordinator	Soil Chemistry/Fertility/ Microbiology	03.06.1993	01.02.2012
Sh. Abhishek Rathore*	Scientist	Agricultural Stat istics	16.12.2002	16.12.2002
Sh. Hironmay Das	Scientist	Agriculture Statistics	15.09.2011	23.12.2011
Mrs. Kirti Singh Baise	PA	Office Staff	05.05.1997	18.02.2002
Sh. Sanjay N Gharde	Lab attendant	Skilled Supporting Staff	15.06.1999	15.06.1999
AINP-BIOFERTILIZERS				
Dr. D.L.N. Rao	Network Coordinator (Biofertilizer)	Agricultural Microbiology	29.07.1978	25.06.1998
Ms. Radha, T.K.	Scientist	Agricultural Microbiology	10.02.2009	20.06.2009
Sh. Arun Bhojraj Mate	Lab attendant	Skilled Supporting Staff	15.06.1999	15.06.1999
PME CELL				
Dr. Brij Lal Lakaria	Pr. Scientist	Officer In-Charge	01.10.1997	15.01.2007
Dr. Shinogi, K.C.	Scientist	Agril. Extension	27.04.2011	25.09.2011
Mrs. Geeta Yadav	PS	Office Staff	26.12.1995	26.12.1995
ITMU UNIT				
Dr. Sanjay Srivastava	Pr. Scientist	Officer In-Charge	22.03.1996	02.09.1996
Dr. Shinogi, K.C.	Scientist	Agricultural Extension	27.04.2011	05.09.2011
AKMU				
Dr. J. Somasundaram	Sr. Scientist	Controlling Officer	12.11.2001	22.12.2008
STATISTICS AND COMPUTER APPLICATION SECTION				
Dr. Kollah Bharati	Sr. Scientist	In-Charge	29.10.2009	05.04.2011
Mrs. Kavita Bai	Safaiwala	Skilled Supporting Staff	20.12.1988	20.12.1988
LIBRARY SECTION				
Dr. Ritesh Saha	Sr. Scientist	Controlling Officer	26.11.1999	24.08.2009
Mrs. Nirmal a Mahajan	T-6	Sr. Technical Officer	15.03.1993	15.03.1993
Sh. Pramod Kumar Chouhan	T-5	Technical Officer	15.02.1993	15.02.1993
Sh. Janak Singh Mehra	Khalasi	Skilled Supporting Staff	08.09.1997	08.09.1997
CENTRAL LAB				
Dr. S.R. Mohanty	Sr. Scientist	Offic er In-Charge	18.06.2009	18.06.2009
Sh. Vinod Babu Pal	T-6	Sr. Technical officer	15.02.1993	15.02.1993
Sh. Jagan Nath Gaur	Lab attendant	Skilled Supporting Staff	20.07.1992	20.07.1992

REFERRAL LAB				
Dr. Pradip Dey	Project Co-ordinator	Officer In-Charge	03.06.1993	01.02.2012
FARM SECTION				
Dr. K. Ramesh	Sr. Scientist	Officer In-Charge	04.09.2008	04.09.2008
Sh. C.T. Wankhede	T-5	Sr. Tech. Asstt. (Tractor Mechanic)	03.08.1992	03.08.1992
Sh. D.R. Darwai	T-5	Technical Officer (Field Assistant_	23.01.1993	23.01.1993
Sh. Om Prakash Shukla	T-4	Tractor Mechanic	22.04.1989	22.04.1989
Sh. Bhagwat Prasad	Beldar	Skilled Supporting Staff	24.01.1992	24.01.1992
Sh. Pramod Kumar Raut	Beldar	Skilled Supporting Staff	21.07.1992	21.07.1992
Sh. Lalaram Sahu	Beldar	Skilled Supporting Staff	24.07.1992	24.07.1992
Sh. Rakesh kumar Sen	Beldar	Skilled Supporting Staff	08.09.1997	08.09.1997
VEHICLE SECTION				
Dr. J.K. Thakur	Scientist	Officer In-Charge	20.04.2010	27.08.2010
Sh. Naresh Singh Yadav	T-4	Sr. Technical Assitant	23.09.1987	03.05.1999
Sh. Sukh Ram Sen	T-3	Technical Asstt (Driver)	25.01.1991	25.01.1991
ADMINISTRATION SECTION				
Sh. V. K. Derashri	AO	Administration	19.05.1976	16.06.2012
Sh. G. D. Dubey	FAO	Audit & account	25.07.1977	28.03.2011
Sh. Rajesh Dubey	AF&AO	Audit & account	21.12.1988	26.11.1998
Sh. P. S. Sunil Kumar	AAO	Administration	30.01.1989	30.01.1989
Sh. T. A. Ramaiah	PA	Administration	29.12.1980	15.07.1996
Sh. Anupam S. Rajput	Assistant	Establishment section	14.03.1990	14.03.1990
Sh. M. S. Hedau	Assistant	Audit & account	31.10.1995	31.10.1995
Smt. Babita Tiwari	Assistant	Central store	30.05.1996	30.05.1996
Sh. Bansilal Sarsodia	Assistant	Purchase section	10.09.1997	10.09.1997
Sh. Saurav Kumar	Assistant	Purchase section	22.10.2012	22.10.2012
Sh. Hiralal Gupta	UDC	Bill section	23.12.1988	23.12.1988
Sh. Om Prakash Yadav	UDC	Audit & Account	19.12.1988	19.12.1988
Sh. Jineshwar Prasad	UDC	Administration	13.12.1988	13.12.1988
Sh. Somnath Mukharjee	LDC	Bill section	30.09.1999	30.09.1999
Sh. Sanjay Katinga	LDC	Cash section	20.06.1989	20.06.1989
Sh. Anurag	Security Supervisor	Security Section	29.09.1997	29.09.1997
Sh. Laxmi Narayan Chouksey	Messenger	Skilled Supporting Staff	17.12.1988	17.12.1988
Sh. Sunil Kumar Batham	Messenger	Skilled Supporting Staff	19.12.1988	19.12.1988
Sh. Dharam Raj Singh	Messenger	Skilled Supporting Staff	10.09.1993	14.06.1999
Sh. Amarjeet Singh	Watchman	Skilled Supporting Staff	08.11.1996	08.11.1996