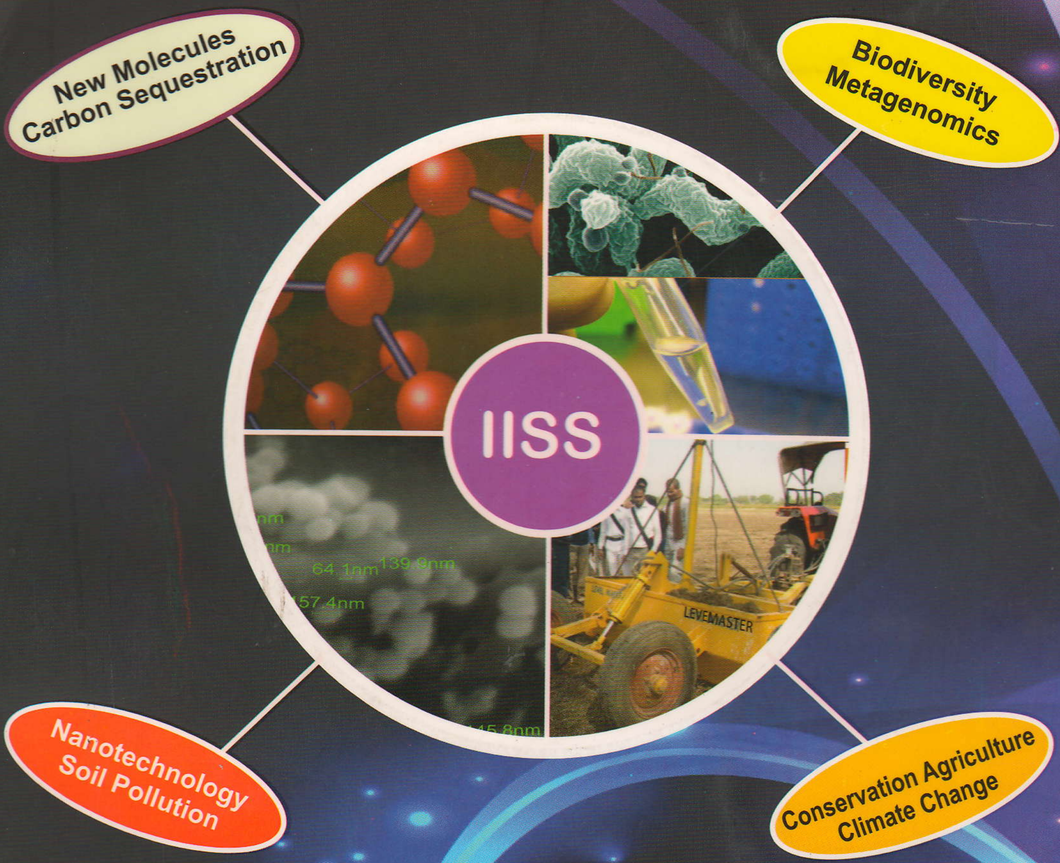
वार्षिक प्रतिवेदन
Annual Report
2011-2012



भारतीय मृदा विज्ञान संस्थान
INDIAN INSTITUTE OF SOIL SCIENCE
(Indian Council of Agricultural Research)
Nabi Bagh, Berasia Road, Bhopal - 462038 (M.P.)

Annual Report
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भाकृअनुप
ICAR

INDIAN INSTITUTE OF SOIL SCIENCE
(Indian Council of Agricultural Research)
Nabi Bagh, Berasia Road, Bhopal - 462 038 (M.P.)

Editors
Dr. A. Subba Rao
Dr. Tapan Adhikari
Dr. A. K. Tripathi
Dr. Brij Lal Lakaria
Dr. Pramod Jha
Dr. (Mrs.) K. Bharati
Dr. Manoranjan Mohanty
Dr. M. Vassanda Coumar

Typing & Computer Assistance
Mrs. Yojana Meshram

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Dr. A. Subba Rao
Director
Indian Institute of Soil Science, Nabi Bagh, Berasia Road Bhopal – 462 038 (M. P.)
Phone : 0755-2730946
E-mail : director@iiss.ernet.in, asrao@iiss.ernet.in, asrao_iiss@yahoo.co.in

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PREFACE

Soil is debatably the most complex of all geological materials, a combination of mineral and organic constituents in solid, aqueous and gaseous forms, organized into a loose, porous and horizontal plant bearing material that is constantly changing. It acts as the natural geological cover of most of the land surface of earth. Soil science discipline has been very successful in contributing to other scientific domains, such as environmental engineering, geosciences, environmental science, hydrology and ecology. Microbial communities study is important to understand the soil ecology and biodiversity. The advent of nucleic acid technologies allows microbial communities to be quantified and classified. Better management of soil carbon helps in better management of soil health which ultimately leads to evergreen revolution in agriculture comprehensively. Understanding the role of the rhizosphere on biogeochemical processes within the soil is essential for developing bioremediation technology of inorganic and organic contaminants. Comprehension of the long-term implications of decreased soil quality as well as sustainability and addressing the aforementioned challenges will require new information based on advances and breakthroughs in soil science research that need to be effectively communicated to stakeholders, policy makers, and the general public.

The Institute addresses some of the above issues under twelve thematic areas including basic, strategic and applied research of National and International importance. The knowledge of physical, chemical, and biological processes that interact across a large range of spatial and temporal scales is covered under fundamental research which is basic to agriculture. Research involved multiscale approach—from the nanotechnology to the landscape levels—to address issues related to biogeochemical reactions and processes in the environment, nutrient availability, loss, metagenomics, conservation agriculture, land use and degradation, regional climate change, food security, soil and water quality. There have been several issues of national importance like biofortification of grains with micronutrients and soil quality and human health. During the year, new research projects in different platforms were developed and the institute now has been identified for projects on conservation agriculture (NICRA), solid waste management (Solid Waste Platform) and climate change etc. During this period emphasis was also given to farmers' participatory research, on farm trials, balanced fertilization, integrated nutrient management, nutrient enriched compost preparation and front line-demonstrations under AICRP projects.

The institute was strengthened with manpower through new joining of seven scientists as well as recruitment of two stenographers. Also two scientists, four administrative staffs and one technical assistant got promoted to the next higher scale. Our international and national level interactions and exposure were continued at all levels. The institute developed research (academic) linkages with ICAR institutes/SAUs and other organizations. Apart from national linkages, further linkages at international level were also established. One scientist from Rwanda was imparted training on advanced soil research. Not only that our institute scientists (2 nos.) received advanced training from Ohio State University, USA.

This year witnessed all round improvement in the infrastructure development. A boundary wall and building have been constructed with an outlay of Rs. 300 lakhs that will be equipped with sophisticated laboratory on soil biodiversity. The institute also purchased two new tractors and a motor bike for smooth functioning of the farm section. Many new equipments/instruments were also purchased to strengthen the laboratories. It is thus, a great pleasure for me to bring out the "Annual Report 2011-12' of the Indian Institute of Soil Science.

I wish to express my sincere appreciation to the Head of Divisions and Project Coordinators for timely compilation of data of the respective areas of research. I also extend my gratitude to the scientists and other staff members of the Institute for their painstaking efforts in carrying out the research and other activities of the Institute and for providing requisite material for compilation of this report.

I also take this opportunity to put on record my appreciation to Drs. Tapan Adhikari, A.K.Tripathi, Brij Lal Lakaria, Pramod Jha, K. Bharati, Manoranjan Mohanty and M. Vassanda Coumar for their sincere efforts in compiling and editing the report. I also thank Mrs. Yojana Meshram for the assistance provided in typesetting the manuscript.

I am highly grateful to Dr. S. Ayappan, Secretary, DARE & Director General, ICAR and Dr.A.K.Singh, Deputy Director General (NRM), ICAR, New Delhi for their constant support and encouragement for the successful conduct of the research.

July 2012
Bhopal

(A. Subba Rao)
Director

1. कार्यकारी सारांश

मृदा उर्वरता मूल्यांकन

- वर्टीसोल एवं एल्फीसोल दोनों ही मृदा पर एन. पी. के. के साथ गोबर की खाद अथवा केवल गोबर की खाद के प्रयोग से मृदा कार्बनिक कार्बन के प्रतिरोधी कार्बन पूल (जैव–रासायनिक रूप से स्थिर कार्बन) की मात्रा में वृद्धि हुई। केवल रासायनिक उर्वरकों (एन.पी.के.) के दीर्घकालीन प्रयोग से एल्फीसोल मृदा में मृदा कार्बनिक कार्बन के प्रतिरोधी कार्बन पूल की मात्रा पर कोई प्रभाव नहीं देखा गया जबकि वर्टीसोल मृदा में इसकी मात्रा में अर्थपूर्ण रूप से वृद्धि पाई गई। एल्फीसोल मृदा में रासायनिक उर्वरकों के प्रयोग से मृदा कार्बनिक कार्बन के धीमे पूल की मात्रा में अर्थपूर्ण रूप से वृद्धि पाई गई।

- मृदा में सम्पूर्ण कार्बनिक कार्बन की मात्रा (R^2=0.12, P=0.01) की तुलना में एसिड–हाइड्रोलायजेबिल पूल में कार्बन की मात्रा (R^2=0.64, P=0.01) द्वारा मृदा से नाइट्रोजन की उपलब्धता का अच्छा सह–सम्बन्ध पाया गया।

- वाक्ले–ब्लैक कार्बन और सम्पूर्ण कार्बनिक कार्बन के मध्य एक सार्वभौमिक सम्बन्ध स्थापित किया गया, इसके द्वारा मृदा के सम्पूर्ण कार्बनिक कार्बन के निर्धारण में टी ओ सी/सी एच एन एस एनालाइजर के प्रयोग को अलग रखा जा सकता है। सरलता से मापे जाने वाले गुणो जैसे डब्लू बी सी, सिल्ट + क्ले और औसत वार्षिक वर्षा के आधार पर मृदा कार्बनिक कार्बन और नाइट्रोजन पूल का अनुमान लगाने के लिए प्रयोग में सहयोगी विजुअल बेसिक मोडेल का विकास किया गया। देश के विभिन्न कृषि जलवायु क्षेत्रों से एकत्र किए गए मृदा नमूनों से मोडेल को कैलीब्रेटिड एवं प्रमाणित किया गया।

- विभिन्न मृदा पुंजों से मृदा कार्बन का खनिजीकरण का आक्सीकृत मृदा कार्बन की मात्रा से अर्थपूर्ण रूप से धनात्मक सम्बन्ध (r=0.60, p=0.05) है। जबकि विभिन्न मृदा पुंज समूहों से अवशेषिक कार्बन खनिजीकरण का मृदा पुंज आक्सीकृत मृदा कार्बन की मात्रा (r=0.95, p=0.01), इकट्ठा होने वाले कार्बन खनिजीकरण (r=0.89, p=0.01), प्रतिरोधी मृदा कार्बन पूल (r=0.80, p=0.05) और सक्रिय कार्बन की मात्रा ($KMnO_4$ आक्सीकृत कार्बन) के साथ विपरीत सम्बन्ध पाया गया।

- नागालैंड के विभिन्न स्थानों पर विभिन्न आई एन एम मध्यस्थता के मूल्यांकन के परिणामों के अनुसार धान की औसत उपज 4.63 टन/है. और 6.02 टन/है. के बीच प्राप्त हुई। अधिकांश जगहों पर 50% एन पी के + 5 टन गोबर की खाद/है. + हरी खाद/फास्फोरस घोलक बैक्टीरिया/अजोला के प्रयोग से अधिकतम उपज प्राप्त हुई।

- नागालैंड में बहुत ही सीमित उर्वरकों का प्रयोग (2.5 किग्रा./है.) हो रहा है। सभी सम्भावित स्त्रोतों से नाइट्रोजन, फास्फोरस एवं पोटेशियम की उपलब्धता कमशः 1.72, 0.39 और 1.49 हजार टन है जबकि विभिन्न फसलों द्वारा इन पोषक तत्वों का अवशोषण क्रमशः 13.5, 2.78 और 8.85 हजार टन है।

आढाय प्रयोग की दक्षता में सुधार

- ई डी ए एक्स से सुसज्जित इलेक्ट्रान माइक्रोस्कोप से जियोलाइट नमूनों की भौतिक एवं तात्विक संरचना का अध्ययन किया गया। प्राकृतिक रूप से पाये गये जियोलाइट की संरचना नलिकाकार जबकि कृत्रिम रूप से निर्मित

जियोलाइट की संरचना घनाकार पाई गई। ई डी ए एक्स के द्वारा जियोलाइट की संरचना को सुनिश्चित किया गया। प्राकृतिक जियोलाइट में सिलिका/ एल्यूमिनियम का अनुपात 3–5 (अम्लीय जियोलाइट) पाया गया जबकि कृत्रिम जियोलाइट में यह संख्या एक से कम पाई गई।

- रासायनिक उर्वरकों के अकेले प्रयोग की तुलना से उर्वरकों की 100% अनुशंषित मात्रा के साथ आलविन वन्डर और आलविन टाप की संयुक्त मात्रा के आधे प्रयोग से मक्का की उपज में 10% अधिक वृद्धि हुई।
- नैनो रॉक फास्फेट के कण एस.आर.पी. II (110 nm) के प्रयोग से मक्का एवं सोयाबीन के शुष्क भार में वृद्धि के साथ–साथ एन्जाइम जैसे–नाइट्रेट रिडक्टेज और फोस्फाटेज की सक्रियता में भी वृद्धि हुई।
- पादप वृद्धि पर बगैर किसी विषैले प्रभाव के जिंक नैनों कणों को जिंक मैटल के द्वारा बीज पर 1000 पी.पी.एम. तक लेपित किया जा सकता है जबकि जिंक ऑक्साइड (<100 nm) के द्वारा 1330 पी. पी.एम. तक लेपित किया जा सकता है।
- वर्टीसोल मृदा पर सामान्य यूरिया की तुलना से ओलियोरेजिन लेपित यूरिया के प्रयोग से अमोनियम वाष्पीकरण हानि में 40% तक कमी आई।
- विभिन्न प्रकार की फसलों, सब्जियों एवं फलों वाली फसलों में पोटाशियम, मैग्नीशियम और गन्धक का पेटेन्ट काली अथवा अन्य मानक स्त्रोतों का प्रयोग उत्पादकता बढ़ाने में बराबर ही प्रभावी पाये गये। परन्तु, अधिकांश फसलों में पेटेन्ट काली के अपशिष्ट प्रभाव की अपेक्षा इसके सीधे अनुप्रयोग ने अच्छी अनुक्रिया दर्शाई।

दीर्घकालीन उर्वरता का सतत् निरीक्षण

- दीर्घकालीन उर्वरक परीक्षण परियोजना के विभिन्न केन्द्रों पर दीर्घकालीन उर्वरक परीक्षण के परिणामों में अकेले एन.पी.के. के प्रयोग अथवा एन.पी.के. के साथ गोबर की खाद अथवा चूना वाले उपचार में सूक्ष्मजैविक बायोमास एवं एन्जाइम सकियता अधिक पाई गई। जबलपुर में सोयाबीन–गेंहूँ फसल चक्र प्रणाली के अर्न्तगत नाइट्रोजन संतुलन की गणना के परिणाम स्पष्ट रूप से दर्शाते हैं कि सोयाबीन द्वारा 98 से 238 किग्रा./है. नाइट्रोजन का स्थिरीकरण हुआ। इसमें से मृदा में जैविक रूप से स्थिरीकृत नाइट्रोजन का 24–66 किग्रा./है. मात्रा गेंहूँ की नाइट्रोजन सम्बन्धी आवश्यकता की कुछ हद तक पूर्ति कर सकती है।
- दीर्घकालीन उर्वरक परीक्षण अनुसंधान परियोजना के केन्द्रों पर सूक्ष्म–जैविक अनुसंधानों के परिणामों के अनुसार विभिन्न मृदाओं में उर्वरकों के प्रयोग से मृदा की सूक्ष्म जैविक जनसंख्या जैसे कि बैक्टीरिया, एक्टीनोमाइसिटीस और फन्जाई में वृद्धि पाई गई जिससे नाइट्रोजन, फास्फोरस और अन्य पोषक तत्वों का अधिक टर्न ओवर हुआ, फलस्वरूप मृदा गुणवत्ता एवं उत्पादकता में सुधार हुआ।
- ए.ई.एस.आर. 10 (कृषि पारिस्थितिक क्षेत्र) की वर्टीसोल मृदा पर मिट्टी की रेजीलिएन्स कैपेसिटी ज्ञात करने के लिए एक प्रक्षेत्र परीक्षण के परिणाम दर्शाते हैं कि विभिन्न स्थानों पर पैत्रिक जमीन की तुलना से मृदा गुणवत्ता में हानि भिन्न पाई गई। हस्तक्षेप करने के उपरान्त प्रत्येक जगह की एस. .क्यू.आई. मान (मृदा गुणवत्ता मान) में सुधार हुआ। औसत रेजिलिएन्स इन्डेक्स में 39.28% से 68.78% की वृद्धि हुई। यह भी ज्ञात हुआ कि 10 जगहों पर रेजिलिएन्स इन्डेक्स का मान 28.12 से 68.78% के बीच पाया गया जिससे सोयाबीन की उपज में 264 से 442 किग्रा./है. और उसके बाद वाली गेंहूँ की उपज में 103 से 815 किग्रा./है. की वृद्धि हुई।

मृदा के भौतिक वातावरण का प्रबन्धन

- नाइट्रोजन के विभिन्न स्तरों पर मक्का की फसल की एल ए आई और बायोमास की मात्रा में स्पष्ट अन्तर पाया गया नाइट्रोजन के बगैर प्रयोग एवं 50% प्रयोग की तुलना से नाइट्रोजन के 100% एवं 150% प्रयोग में एल.ए.आई. का मान अर्थपूर्ण रूप से उच्च पाया गया और एल.ए.आई. का सर्वाधिक मान बुआई के 55 दिन बाद प्राप्त हुआ।
- अन्य वानस्पतिक अवस्था पर जी एन.डी.वी.आई. की तुलना में मक्का की आरम्भिक अवस्था पर एल.ए.आई. और बायोमास उपज का अनुमान लगाने में एन.डी.वी.आई. अच्छा अनुमानक पाया गया परन्तु वानस्पतिक वृद्धि की पूर्ण अवस्था (जब एल.ए.आई. मान 1.7 से अधिक है) तब एन.वी.डी.आई. की तुलना में मक्का की एल.ए.आई. और बायोमास के लिए जी.एन.वी.डी.आई. अच्छा अनुमानक पाया गया।
- सोयाबीन की फसल में दीर्घ कालीन टिलेज अनुसंधान में विभिन्न उपचारों में मृदा का स्थूल घनत्व अर्थपूर्ण रूप से प्रभावित हुई जबकि नाइट्रोजन स्तरों का इस पर कोई प्रभाव नहीं पड़ा।
- वर्टीसोल मृदा पर सोयाबीन की उपज में टिलेज के विभिन्न उपचारों जैसे मोल्ड बोर्ड प्लाऊ (एम. बी.), परम्परागत टिलेज (सी.टी), रिड्यूस्ड टिलेज (आर.टी) और नो टिलेज (एन.टी) का कोई प्रभाव नहीं देखा गया।
- जुताई वाली परती जमीन पर सर्वाधिक जल अपवाह एवं मृदा हानि देखी गई। एकल फसलों में अरहर में सर्वाधिक जल अपवाह एवं मृदा हानि पाई गई जबकि सोयाबीन में सबसे कम। अर्न्तवर्ती फसलों जैसे मक्का+अरहर (1:1) में सर्वाधिक जल अपवाह एवं मृदा हानि पाई गई जबकि सोयाबीन+अरहर (2:1) में सबसे कम।
- अन्य फसल चक्र प्रणालियों की तुलना में सोयाबीन आधारित विभिन्न फसल चक्र प्रणालियों में सोयाबीन+कपास (2:1) प्रणाली में सर्वाधिक खरपतवार बायोमास पाया गया परन्तु, मक्का–चना प्रणाली में सोयाबीन आधारित फसल चक्र प्रणाली से अधिक खरपतवार बायोमास पाया गया। यद्यपि, रिड्यूस्ड टिलेज (आर.टी.) उपचार में खरपतवार नाशक के प्रयोग से चौड़ी पत्ती वाले खरपतवारों की संख्या कम पाई गई और घास जैसे खरपतवारों की संख्या अधिक पाई गई।
- मृदा में लीफ लिटर को मिलाने का प्रभाव विभिन्न फसल चक्रों एवं मिट्टी के चटखने की मात्रा पर स्पष्ट रूप से देखा गया। तुलना किए गए फसल चक्रों में सोयाबीन+अरहर (2:1) द्वारा जमीन में सर्वाधिक लीफ लिटर मिलाया गया उसके बाद सोयाबीन+कपास (2:1) और सोयाबीन–गेंहूँ फसल चक्र प्रणाली द्वारा मिलाया गया। छः फसल चक्र प्रणालियों में से मक्का–चना फसल चक्र प्रणाली में सर्वाधिक मिट्टी के चटखने की मात्रा देखी गई। परम्परागत टिलेज की तुलना से रिड्यूस्ड टिलेज (आर.टी) में उच्च पत्तियों का गिरना/फसल अवशेषों का जमीन में मिलना देखा गया।
- सोयाबीन की विभिन्न प्रजातियों में सर्वाधिक जड़ लम्बाई घनत्व (आर.एल.डी) फूलों के आने की अवस्था पर देखा गया। लम्बी अवधि की किस्म (जे एस–335) में छोटी अवधि की किस्म (जे.एस. 9305) की तुलना में उच्च जड़ लम्बाई घनत्व पाया गया क्योंकि जड़ लम्बाई घनत्व वानस्पतिक वृद्धि का कारक है। अतएव जिन किस्मों का लम्बा जीवन काल होगा उनमें उच्च जड़ लम्बाई घनत्व होगा।

मृदा के रासायनिक गुणों का परीक्षण

- रांची और भुवनेश्वर की मृदाओं में गोबर की खाद और जस्ता के प्रयोग से डी टी पी ए निष्कर्षण योग्य जस्ता की मात्रा में अर्थपूर्ण रूप से वृद्धि हुई। गोबर की खाद और जस्ता के बढ़ते स्तरों के प्रयोग से पौधों में जस्ता के स्तर में बढ़ोत्तरी हुई और चूना प्रयोग की दर में वृद्धि से जस्ता में कमी आई।

मृदा की जैविक दशा में सुधार

- 25,35 और 45° सेग्रे. तापमान पर तुलनात्मक रूप से कार्बन डाई आक्साइड का उत्सर्जन मैक्रो एग्रीग्रेट्स (250–2000 माइक्रो मीटर) में अधिक पाया गया उसके बाद माइक्रो एग्रीग्रेट्स (53–250 माइक्रो मीटर) और सील्ट एवं क्ले भाग (<53 माइक्रो मीटर) में पाया गया। तापमान ने कार्बन खनिजीकरण की दर को प्रभावित किया और यह प्रयोग किए पदार्थ का स्त्रोत एवं उसकी दर पर निर्भर पाया गया।
- दीर्घकालीन उर्वरक परीक्षण प्रयोग में संतुलित उर्वरक प्रयोग (100% एन.पी.के + गोबर की खाद) करने से सोयाबीन के 100 दानों के भार एवं पोषण मान जैसे प्रोटीन, एमीनो एसिड्स, सूक्ष्म पोषक तत्वों की मात्रा में सुधार हुआ।

सूक्ष्म जैविक विविधता और जैव उर्वरक

- सोयाबीन एवं मूँगफली के लिए रायजोबिया की आनुवांशिक विविधता का वर्गीकरण किया गया। गुजरात के कच्छ में मूँगफली के लिए लवण सहिष्णु (10% नमक) रायजोवियल आइसोलेट्स तैयार किए गए।
- गुन्टूर (आंध्र प्रदेश) की वर्टीसोल मृदा में मूँग–धान फसल चक्र में उर्वरकों एवं कीटनाशियों का प्रयोग अनुशंषित मात्रा से लगभग दोगुना है। इसमें सूक्ष्म जीवों की संख्या, पोषक एवं कार्यकारी समूह, मृदा एन्जाइम, 16 एस.आर. डी.एन.ए और एन.आई.एफ–एच विविधता पर कोई विपरीत प्रभाव नहीं देखा गया।
- एल्फीसोल में दीर्घकालीन रासायनिक उर्वरक अनुप्रयोग के वाबजूद यूबैक्टीरियल समुदाय की बहुलता एवं तुलनात्मक अनुपात पर कोई अन्तर नहीं पाया गया। दीर्घकालीन कार्बनिक खादों के अनुप्रयोग से एक्टीनो बैक्टीरिया और एसिडो बैक्टीरिया की संख्या में वृद्धि हुई।
- सोयाबीन राईजोबियम (आर 33) और चना राईजोबियम (आर 40) ने 52–56% जड़ ग्रंथि धारिता दर्शाई। सोयाबीन में दोनों ही सोयाबीन एवं चना प्रभेद से निवेशन किया गया लेकिन चना में केवल इसकी प्रभेद से ही निवेशन किया गया। वर्टीसोल मृदा पर सोयाबीन में राइजोबियम और पी.जी.पी. आर की उत्तम प्रभेद के सम्मिलित निवेशन से सोयाबीन के दानों की उपज में 28% की वृद्धि हुई।
- शुष्क और अर्धशुष्क क्षेत्रों में अधिकांश एक्टीनोमाइसिटीस स्ट्रेप्टोमाइसीस (61%) और नोकाडिया (29%) पाई गई। लगभग 2/3 आइसोलेट्स मक्का की वृद्धि में प्रभावी पाये गये और 1/3 आइसोलेट्स अप्रभावी पाए गए।
- बिहार में लघु एवं सीमांत किसानों के खेतों पर सूक्ष्मजीव आधारित बायो–न्यूट्रिएन्ट का धान में प्रयोग करने से उसके दानों एवं भूसा की उपज में 11–23% की वृद्धि हुई और उर्वरक उपयोग दक्षता में 5–10% की वृद्धि हुई।
- जड़ सड़न की बीमारी से ग्रसित सेव के बगीचे में जैव नियंत्रण कारक बैसीलस लिचीनी–फोरमिस के प्रयोग से पौध स्वास्थ्य पुनर्जाग्रित एवं ओजस्वी हुआ साथ ही फलों की उपज में 43–70% की वृद्धि हुई।
- उड़ीसा के आदिवासी इलाकों में अग्रिम पंक्ति प्रदर्शन में जैव उर्वरकों का प्रयोग एकीकृत पौध पोषण का एक अभिन्न हिस्सा है। इससे किसान विधि की तुलना से देशी आलू, लोविया, मक्का, मूँग, अरहर और मटर की उपज में अर्थपूर्ण रूप से वृद्धि हुई।
- बगैर बी.टी–कपास की तुलना में बी.टी– कपास में मृदा जीवों की तुलनात्मक बहुलता अधिक पाई गई। बगैर बी.

टी–कपास–गेंहूँ फसल चक्र प्रणाली की तुलना (56 पी.पी.एम) की तुलना में बी.टी–कपास–सोयाबीन फसल चक्र प्रणाली में ग्लोमालिन की मात्रा (123 पी.पी.एम) अधिक पाई गई। मृदा की सूक्ष्म जीव संख्या जल विलय कार्बन, अम्ल घुलनशील कार्बोहाइड्रेट्स और कुल कार्बन की मात्रा से अर्थपूर्ण से सम्बन्धित पाई गई जो यह दर्शाती है कि कार्बन की अधिक घुलनशील अवस्था पौधों के जड़ क्षेत्र में सूक्ष्मजीवों की संख्या को बढ़ाती है।

बायोफोर्टिफिकेशन

- ज्वार की सी.एस.वी. 21 एफ और पन्त चरी 3 प्रजातियों और मोटे अनाज की पैयूर 1, एम.आर–1 और एम.आर–6 प्रजातियों के दानों में जस्ता की सर्वाधिक मात्रा पाई गई।

संदूषित मृदाओं का सुधार

- दीर्घकालीन उर्वरक परीक्षण अनुसंधान के अन्तर्गत भारी तत्वों एवं सूक्ष्म जैविक विविधता के ऊपर लगातार रासायनिक उर्वरकों के प्रयोग का प्रभाव देखने के लिए एक अध्ययन किया गया। बैरकपुर केन्द्र पर एन.पी.के+गोबर की खाद वाले उपचार में मृदा अभिक्रिया प्रभावित हुई। मृदा की ऊपरी सतह पर 100% एन.पी.के+गोबर की खाद वाले उपचार में एसिड फास्फाटेज, एल्केलाइन फास्फाटेज, एफ.डी.ए और डी.एच.ए सक्रियता में सर्वाधिक वृद्धि हुई।

- जहाँ पर संतुलित उर्वरक गोबर की खाद का प्रयोग किया गया वहाँ पर उच्च सूक्ष्म जैविक वायोमास कार्बन पाया गया।

- उर्वरक भारी तत्वों के एक स्त्रोत है जिसमें आकस्मिक रूप से भारी तत्वों की भिन्न–भिन्न मात्रायें पाई जाती है। उर्वरकों में एस.एस.पी और डी.ए.पी उच्च मात्रा में लैड, क्रोमियम, निकिल और कैडमियम की आपूर्ति करते है। गोबर की खाद में भी उच्च मात्रा में क्रोमियम (14.25 पी.पी.एम) और निकिल (51.75 पी.पी.एम) पाया गया है।

- कैडमियम की 100 मिग्रा./किग्रा. मात्रा से संदूषित मृदा में ट्यूबरोज की तीन प्रजातियों (प्राज्वल, श्रंगार और मेक्सीकन सिंगल) की फाइटोरेमिडिएशन के लिए क्षमता देखी गई। अध्ययन से पता चलता है कि उपरोक्त तीनों ही प्रजातियों में कैडमियम की विषालुता के कोई लक्षण प्रदर्शित नहीं हुए क्योंकि ट्यूबरोज में कैडमियम को अधिक एकत्रित करने की एक विशेष क्षमता है। इसके कारणों में–(1) इसके तना में 100 माइक्रोग्राम कैडमियम/ग्राम शुष्क भार एकत्रित हुआ जो कि मापने के क्रान्तिक मानक से अधिक है और, (2) पौधे के तना और जड़ में कैडमियम का अनुपात एक से अधिक होना शामिल हैं। कैडमियम से प्रदूषित मृदाओं के फाइटोरेमिडिएशन के लिए ट्यूबरोज की खेती को बढ़ावा दिया जा सकता है।

- इन–विट्रो दशा में कैडमियम और लैड का प्रयोग करते हुए विलगित फंजाई (ट्राइकोडर्मा विरिडी) की बायोएक्यूमुलेशन क्षमता देखी गई। यह देखा गया कि टी. विरिडी में कैडमियम से अधिक लैड इकट्ठा करने की क्षमता है जैसा कि इसकी 300 पी.पी.एम तक इसकी वृद्धि देखी गई। हालांकि इसकी माइसीलियल वृद्धि 75 पी.पी.एम. कैडमियम तक देखी गई।

विभिन्न अपशिष्ट पदार्थों का कृषि मृदाओं में पुन: चक्रण और विवेकपूर्ण उपयोग

- एम.एस.डब्लू कम्पोस्ट के बड़े आकार के कणों (>500 माईक्रो मीटर) में सभी भारी तत्वों की औसत सान्द्रता सबसे कम जबकि छोटे आकार के कणों (10–75 माईक्रो मीटर) में यह मात्रा सर्वाधिक पाई गई।

- आंशिक रूप से अलग किए गए अपशिष्ट पदार्थ अथवा मिश्रित अपशिष्ट पदार्थ की तुलना में बी.डब्लू.सी. से तैयार कम्पोस्ट के छोटे आकार के कणों में भारी तत्वों की मात्रा कम पाई गई।

- अलग किए गए जैवविघटन शक्ति अपशिष्ट पदार्थों की तुलना से एम.एस.डब्लू कम्पोस्ट जो कि मिश्रित अपशिष्ट पदार्थ अथवा आंशिक रूप से अलग किए गए अपशिष्ट पदार्थों से तैयार की गई थी, में एच सी एल, अम्ल से निष्कर्षित सम्पूर्ण भारी तत्वों की मात्रा अधिक पाई गई।

जैविक खेती

- विभिन्न श्रेणी के सूक्ष्मजीवों (बैक्टीरिया, फन्जाई, एक्टीनोमाइसीट्स, वायुजीवी नाइट्रोजन स्थिरीकरण करने वाले और स्यूडोमोनास) की जैव विविधता पन्चगव्य, बी.डी 500 और गाय के गोबर से उपचारित क्षेत्रों में देखी गई। परिणाम दर्शाते हैं कि पन्चगव्य उपचार में वायुजीवी नाइट्रोजन स्थिरीकरण करने वाले, फास्फोरस घोलक और स्यूडोमोनास की संख्या अधिक पाई गई।

किसानों के खेतों पर अनुसंधान और प्रभाव मूल्यांकन

- किसानों के विभिन्न खेतों पर विभिन्न उपचारों में सोयाबीन की उपज अर्थपूर्ण रूप से भिन्न पाई गई। सोयाबीन की सर्वाधिक उपज वर्मीकम्पोस्ट उपचार में पाई गई उसके बाद क्रमश: समृद्धि कम्पोस्ट एवं किसान विधि उपचार में और सबसे कम 100% एन.पी.के. उपचार में पाई गई। गेंहूँ की उपज वर्मीकम्पोस्ट एवं समृद्धि खाद कम्पोस्ट में अर्थपूर्ण रूप से भिन्न नहीं पाई गई जबकि किसान विधि और 100% एन.पी.के. उपचार में यह अर्थपूर्ण रूप से भिन्न पाई गई।

- उर्वरकों के लाभकारी उपयोग के लिए मृदा परीक्षण मान के आधार पर उर्वरक नुस्खा समीकरण विकसित किए गए और बहुक्षेत्रीय परीक्षण। वेरीफिकशन फोलो–अप परीक्षण तथा अग्रिम पंक्ति प्रदर्शन के द्वारा प्रदर्शित किए गए परिणाम दर्शाते हैं कि जूट की लक्षित उपज (35 और 40 क्वि./है.) बगैर गोबर की खाद के प्रयोग के (+) 2.10–4.17 प्रतिशत उपज अन्तराल से प्राप्त हुई और 5 टन/है. गोबर की खाद के प्रयोग से 7.62 और 7.5% अन्तराल से प्राप्त हुई।

- धान की लक्षित उपज (40 और 50 क्वि./है.) वगैर गोबर की खाद के प्रयोग (+) 2.10 से (–) 1.11% उपज अन्तराल से प्राप्त हुई। 5 टन/है. गोबर की खाद के साथ यह (+) 11.1 और 4.3% पाई गई। गेंहूँ की 55 क्वि./है. लाक्षित उपज ±5% अन्तराल के भीतर प्राप्त की गई।

- वर्टीसोल मृदा पर अरहर, हरी मटर, धान, मटर, चना और गेंहूँ पर प्रमाणीकरण परीक्षण ट्रायल के परिणाम दर्शाते हैं कि किसान विधि और उर्वरकों की सामान्य अनुशंसा की तुलना में मृदा परीक्षण एवं शष्य अनुक्रिया से अधिक लाभ प्राप्त हुआ।

- बैरकपुर की जलोढ़ मृदा पर जूट–धान–अलसी फसल चक्र पर एस.टी.सी.आर. आई पी एन एस प्रदर्शन पर

दीर्घकालीन परीक्षण के परिणाम दर्शाते है कि सामान्य उर्वरक अनुशंसा (17.6 किग्रा./किग्रा.) एवं किसान विधि (15.3 किग्रा./किग्रा.) की तुलना में औसत अनुकिया अनुपात क्रमशः 21.0, 19.6 और 19.1 किग्रा./किग्रा. प्राप्त हुआ।

- दिल्ली की टिपिक हैप्लूस्टर्ट मृदा पर बाजरा–गेहूँ फसल चक्र में केवल कार्बनिक और नियंत्रण उपचार में बाजरा की फसल के बाद एन पी के की मात्रा में कमी आई।
- मक्का–गेहूँ फसल चक्र प्रणाली के अन्तर्गत आई.पी.एन.एस. के साथ गेहूँ की लक्षित उपज 25 क्वि./है और बगैर आई पी एन एस के साथ गेहूँ की लक्षित उपज 35 क्वि./है. और बगैर आई पी एन एस के साथ गेहूँ की लक्षित उपज 35 क्वि./है., ±10% अन्तराल के साथ प्राप्त हुई। नियंत्रण की तुलना से आई पी एन एस का प्रयोग करते हुए नुस्खा आधारित उर्वरक अनुशंषा समीकरणों का प्रयोग करने से ₹ 34344 प्रति है. का लाभ हुआ।
- तिलहनी फसलों (जिन्जैली, मूँगफली, अलसी, सरसों, नाइगर, सोयाबीन, सूरजमुखी और तोरिया) पर अग्रिम पंक्ति प्रदर्शन के परिणामों के अनुसार उपज निवल आय और लाभः लागत अनुपात के आधार पर उर्वरकों की अनुशंसित मात्रा के प्रयोग एवं किसान विधि की तुलना से एस.टी.सी आर–आई पी एन एस अनुशंसाओं द्वारा स्पष्ट श्रेष्ठता दिखाई दी।

2. EXECUTIVE SUMMARY

Soil Fertility Evaluation

- Application of either NPK+ farm yard manure (FYM) or FYM alone increased the carbon content of resistant pool (bio-chemically stabilized carbon) of soil organic matter (SOM) in both Vertisol and Alfisol. Long-term application of chemical fertilizer (NPK) alone did not influence the carbon content of resistant pool of SOM in Alfisol whereas it was significantly increased in Vertisol. Chemical fertilization significantly increased the carbon content of slow pool of SOM in Alfisol.
- Availability of N in soil was well correlated with the amount of carbon in the acid-hydrolyzable pool ($R^2=0.64, p=0.01$) rather than total soil organic carbon content ($R^2=0.12, p=0.01$).
- A universal relationship between Walkley Black carbon (WBC) and total organic carbon (TOC) was established, thereby eliminating the use of TOC/CHNS analyzer for soil TOC determination. A user friendly visual basic model was also developed for predicting soil carbon and nitrogen pools with simple measurable parameters (WBC, silt + clay and mean annual rainfall). The model was calibrated and validated by samples collected from different agro-ecological regions of the country.
- Soil carbon mineralization from different aggregates had a significant ($r=0.60, p=0.05$) positive relationship with their oxidizable soil carbon content. Residue carbon mineralization in different aggregate size classes was inversely related to aggregate oxidizable soil carbon content ($r=-0.95, p=0.01$), cumulative soil carbon mineralization (r=-0.89, p=0.01) and resistant soil carbon pool ($r=-0.80, p=0.01$). Residue carbon mineralization in different aggregate size classes was also inversely ($r=-0.61, p=0.05$) related to the active carbon content ($KMnO_4$ oxidizable carbon) of the aggregates.
- Among different INM interventions evaluated at different locations in Nagaland, revealed mean paddy yield between 4.63t ha^{-1} and 6.02 t ha^{-1}. Application 50%NPK+5 t FYM + Green manuring/PSB/Azolla resulted in highest yield at most of locations.
- The Nagaland state registered a very limited use of fertilizers (2.5 kg ha^{-1}) but at the same time availability of nutrients such as N, P and K from all possible organic sources was 1.72, 0.39 and 1.49 thousand tonnes only against the crop removal of 13.5, 2.78 and 8.85 thousand tonnes, respectively.

Improving Input Use Efficiency

- The morphology and elemental composition of zeolite samples were studied through scanning electron microscope equipped with EDAX. Natural zeolite sample had a tubular assembly while synthetic one had cube assembly. Composition of zeolites was ascertained through EDAX. Natural zeolites had a Si/Al ratio of 3-5, (acidic zeolites) while synthetic had a value lesser than one.
- The combination of Allwin wonder and Allwin top as half of the dose used for individual application along with 100% of recommended fertilizer dose increased maize yield up to 10% higher than the application of chemical fertilizers alone.
- Application of nano rock phosphate particles SRP II (110 nm) increased the dry matter yield of rice and soybean and also enhanced the enzyme activity like nitrate reductase, and phosphatase.

- The Zn nano particle can be loaded up to 1000 ppm in seed through Zn_{Metal} (<50 nm) and 1330 ppm through ZnO (<100 nm) without any toxic effect on plant growth. \
- The supply of K, Mg and S through either of the sources, i.e. Patentkali and standard sources could not make any difference in yield response. The economic response was less when K, Mg and S were supplied through Patentkali in potato-garlic, rice-cowpea and maize-wheat cropping systems as compared to standard sources.

Monitoring Long Term Productivity

- The long term fertilizer studies at different LTFE locations indicated higher microbial count, biomass and enzymatic activities under NPK either alone or along with FYM or lime. The N balance calculations made in soybean-wheat system at Jabalpur clearly demonstrated that soybean fixed 98 to 238 kg N. Out of this, added 24 to 66 kg biologically fixed N per hectare to soil subsequently met the N requirement of wheat to some extent.
- Biological studies conducted under LTFE at different locations indicated that irrespective of soil, application of fertilizer resulted in increase in soil microbial population (bacteria, actinomycetes and fungi). Incorporation of FYM along with fertilizer, further enhanced microbiological activities in soil which resulted more turnover of nitrogen, phosphorus and other nutrients and ultimately resulted in improvement of soil quality and productivity.
- A field experiment carried out to study the resilience capacity of Vertisol of AESR 10.1 showed that the loss of soil quality as compared to respective pristine soil is different in different sites. After imposition of interventions, SQI values were improved in each site. The mean resilience index increased gradually from 39.28% to 68.78%. It was further observed that in of the ten sites the value of resilience index ranged from 28.12 to 68.78 % which resulted in gain in soybean yield ranging from 264 to 442 kg ha^{-1} and gain in succeeding wheat yield ranging from 103 to 815 kg ha^{-1}.

Managing Soil Physical Environment

- The LAI, biomass values of maize crop showed distinct variations among the different N levels. LAI reached the highest value at 55 days after sowing and was significantly higher in 100% and 150% than that in 0% and 50% doses of nitrogen.
- The NDVI was found to be a good predictor for the LAI and biomass yield of maize at the initial stages compared to the other vegetation indices like GNDVI but during the full vegetation stage (when LAI value exceeded the value 1.7), GNDVI was found to be a better predictor for LAI and biomass than NDVI.
- In a long term tillage experiment, imposition of different tillage treatments significantly influenced the bulk density of the soil during the soybean growing season, but nitrogen level had no effect on it.
- Different tillage treatments like mould board plough (MB), conventional tillage (CT), reduced tillage (RT) and no tillage (NT) did not show any significant effect on soybean yield in Vertisol.
- Cultivated fallow resulted in maximum runoff and soil loss. Among the sole crops, pigeon pea resulted in the highest runoff and soil loss while soybean recorded the lowest. In case of intercrops, the highest run off and soil loss was in maize and pigeon pea (1:1) and the lowest in soybean + pigeon pea (2:1).

- Amongst the soybean based cropping systems, soybean+ cotton (2:1) recorded significantly higher weed biomass as compared to other systems. However, maize–gram recorded higher weed biomass than soybean based cropping system. Although, population of broad leaved weeds were less under reduced tillage (RT) due to herbicide spray, grassy weeds were found to be more.
- Different cropping systems had clear effect on leaf litter addition to the soil and also on crack volume. Among cropping systems compared, soybean + pigeon pea (2:1) recorded the highest leaf litter addition followed by soybean + cotton (2:1) and soybean-wheat systems. Maize–gram system recorded the highest crack volume among the six cropping systems. Reduced tillage (RT) recorded higher leaf fall/crop residue addition than conventional tillage system.
- Maximum root length density (RLD) was observed at flowering stage (R1) for soybean cultivars. Long duration cultivar (JS335) was having higher RLD compare to shorter duration cultivar (JS 9305) because that RLD is the function of vegetative growth, hence a variety having longer vegetation period will have higher RLD.

Monitoring Soil Chemical Parameters

- In Ranchi and Bhubaneswar soils, addition of FYM and Zn significantly increased DTPA extractable Zn. Concentration of zinc in plant increased with increased levels of FYM and Zn and decreased with increased levels of lime application.

Improving Soil Biological Condition

- The CO_2 emission was relatively greater in macroaggregates (250-2000 μm) followed by micro aggregates (53-250 μm) and mineral associates (<53 μm) at 25, 35 and 45°C. Temperature affected C mineralization rate and it depended upon source and amount of substrate applied.
- Balanced fertilization (100% NPK + FYM) under LTFE improved the nutritional parameters such as protein, amino-acids, micro nutrient content of soybean seeds and 100-seed weight of soybean samples.

Microbial Diversity and Biofertilizers

- Genetic diversity of soybean and groundnut rhizobia was characterized. Salt tolerant (10% NaCl) rhizobial isolates made for groundnut in Kutch.
- In Vertisols of Guntur, usage of chemical fertilizers and pesticides at twice the recommended dose in blackgram- rice had no adverse effect on microbial counts, nutritional and functional groups, soil enzymes, 16s rDNA and *nifH* diversity.
- In an alfisol, the abundance and relative ratio of eubacterial communities remained unchanged due to long term chemical fertilization. Proportions of Actinobacteria and Acidobacteria increased due to long term organic manuring.
- Soybean rhizobia (R 33) and chickpea rhizobia (R 40) showed nodule occupancy of 52-56%. Soybean was nodulated by both soybean and chickpea strains. But chickpea was nodulated by only its own strains. Inoculation of the best combination of rhizobia and PGPR increased soybean seed yield (28%) in Vertisols.

- Majority of actinomycetes from arid and semi-arid regions were *Streptomyces* (61%) and *Nocardia* (29%). About 2/3rd of the isolates were effective in promoting growth of maize while 1/3rd were ineffective.
- Microbial based bionutrient package for rice improved grain and straw yield by 11-23% and fertilizer use efficiency by 5 -10% in small and marginal farmers fields in Bihar.
- Biocontrol agent *Bacillus lichiniformis* application in root rot infested apple orchards led to rejuvenation of plant health and vigour and improved fruit yield by 43 to 70%.
- FLD's with biofertilizers as integral component of INM practice in tribal areas of Odisha brought highly significant improvement in yields of local potato, cowpea, maize, greengram, arhar and garden pea over farmer's practice.
- Relative abundance of soil biota was greater in Bt- cotton than non-Bt cotton cropping system. Glomalin content in Bt- cotton-soybean was higher (123 ppm) than Bt-cotton-wheat cropping system (56 ppm). Soil biological population was significantly correlated with water soluble carbon, acid hydrolysable carbohydrates and total organic carbon content of soil indicating that higher soluble phase of carbon enhanced rhizospheric microbial population.

Biofortification

- The highest zinc content in grain was observed in CSV 21 F and Pant chari 3 of sorghum cultivars, and Paiyur 1, MR 1 and MR 6 of millet cultivars.

Amelioration of Contaminated Soils

- A study was carried out to assess the impact of continuous fertilization on heavy metals, and microbial diversity in soils under long term fertilizer experiment. Application of NPK+FYM moderated the soil reaction (pH) at barrackpore centre. The highest value of acid phosphatase, alkaline phosphatase, FDA and DHA activity was recorded in surface horizon with 100% NPK + FYM, application.
- Higher microbial biomass carbon was observed in treatments where balanced fertilization/FYM was practiced.
- Fertilizers contain heavy metals in varying quantity. Amongst the fertilizers, SSP and DAP supply higher quantity of Pb, Cr, Ni and Cd. FYM also contains higher quantity of Cr (14.25 ppm) and Ni (51.75 ppm).
- The potential of three varieties of tuberose (Prajwal, Shringar and Mexican single) for phytoremediation of soil contaminated with cadmium to a level of 100 mg kg^{-1} soil revealed that Cd did not exhibit any toxic symptom in all the three varieties of tuberose. Tuberose possessed the typical ability of Cd hyper accumulation as (1) 100 µg Cd g^{-1} DW accumulated in the shoots that exceeds the critical judging standard, and (2) the ratio of Cd in the shoots to roots was > 1. Cultivation of tuberose may be advocated for phytoremediation of cadmium in polluted soils.

Recycling and Rational Usage of Different Wastes in Agricultural Soils

- Mean concentration of all heavy metals was minimum in the biggest size fraction (i.e., > 500 µm) and maximum in smallest size fraction (i.e., 10 - 75 µm) of MSW compost.
- Heavy metals contents in the smallest size fraction of compost prepared from BWC were lower as compared to those prepared from partially segregated wastes or mixed wastes.
- The proportions of the total heavy metals (except Cd) extracted by HCl were more where MSW composts were prepared from either mixed wastes or partially segregated wastes as compared to those prepared from segregated biodegradable wastes.

Organic Farming

- Cultural diversity of different group of microbes (bacteria, fungi, actinomycetes, aerobic nitrogen fixer, solubilizers and Pseudomonas) were estimated from panchagavya, BD500 and cow dung manure treated soil revealed that population of plant growth promoting bacteria like aerobic nitrogen fixer, P solubilizers and pseudomonas were found to be the highest in panchagavya.

On-farm Research and Impact Assessment

- Seed yield of soybean at different farmers' fields varied significantly among various treatments. The highest seed yield of soybean was recorded with vermicompost treatment followed by enriched compost, farmer's practice and the lowest with 100% NPK. However, seed yield of wheat did not vary significantly between vermicompost and enriched compost treatments but it varied significantly between farmer's practice and 100% NPK treatment.
- The fertilizer prescription equations developed by different centres for profitable use of fertilizers based on soil test values demonstrated through various multi-location / verification follow up trials as well as front line demonstrations revealed that jute targeted yield (35 and 40 q ha^{-1}) was achieved within (+) 2.10 to 4.17 per cent yield deviation without FYM and 7.62 and 7.50% with FYM (@ 5 t ha^{-1}.
- Targeted yield (40 and 50 q ha^{-1}) of rice without FYM application was achieved within (+) 2.10 to (-) 1.11 per cent yield deviation while with FYM @ 5 t ha^{-1} it was (+) 11.1 and 4.3%. In case of wheat, the targeted yield of 55 q ha^{-1} was achieved within ± 5% variations.
- Test verification trials conducted with pigeon pea, paddy, field pea, gram and wheat in montmorillonitic hypothermic *Typic Hapulustert* deep black fine soil showed greater benefit of STCR technology over fertilizer application as general recommended dose or farmers' practice.
- Under long term STCR-IPNS demonstration, jute-rice-lentil sequence on alluvial soil at Barrackpore showed an average response ratio of 21.0, 19.6 and 19.1 kg kg^{-1} over blanket (17.6 kg kg^{-1}) and FP (15.3 kg kg^{-1}).
- Pearlmillet - wheat sequence on a *Typic Haplustept* soil at Delhi showed depletion of available N, P and K after pearlmillet in organic alone as well as control treatment.
- In maize-wheat cropping sequence, wheat yield under IPNS and non-IPNS situations were 25 and 35 q ha^{-1}, respectively which was within $\pm$10% of target yield. The highest net benefits over control under prescription based fertilizer applications using IPNS equations was Rs 34344 ha^{-1}.

- Front line demonstrations conducted with oilseed crops (gingelly, groundnut, linseed, mustard, niger, soybean, sunflower, toria) showed distinct superiority of STCR-IPNS recommendations over blanket and farmer's practice in respect of yield, net returns and B: C ratio.

3. INTRODUCTION

India is endowed with a diversity of soil and water resources having different prospects for supporting wide range of flora and fauna. The overall sustaining growth of our country's economy is heavily dependent on good soil health, the productivity of which is the resultant effect of its intrinsic characteristics, coupled with interactions of external inputs like water, plant nutrients, climate, energy, tillage and other factors. Over-exploitation of soil resource as a result of burgeoning population, industrialization/urbanization with the quest for short-term gains to meet the growing demands without long term perspectives have resulted in soil degradation at an alarming rates. Therefore, to tackle the basic problems pertaining to scientific management of nutrient, water and energy in crop production, the ICAR established Indian Institute of Soil Science (IISS) in 1988 at Bhopal as a nodal center to provide scientific basis for enhancing and sustaining productivity of our soil resources through basic and strategic research.

Since its inception, the Institute completed twenty four years of its existence after crossing a number of hurdles and has grown up in its stature in terms of scientific manpower, R & D infrastructure and research out-put. The Institute activity has been strengthened further by the scientific and managerial activities of All India Coordinated Research Projects/Network Project. These four institute based projects act as a part of the "Network-support-programmes" of the IISS with these 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 programmes of the Institute on regional basis. During the year under report, the Institute has made notable scientific contribution in the areas of nanotechnology, biofortification, climate change and carbon sequestration, integrated plant nutrient supply system (IPNS), organic farming, efficient utilization of applied nutrients, nutrient transformation processes and dynamics in soil-plant systems, environmental impact due to utilization of solid wastes, waste water, bioremediation etc. The salient research findings are briefly highlighted in the report.

3.1 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.

3.2 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: Enhancing Nutrient and Water Use Efficiency

- Precision agriculture
- Nano-technology
- Fertilizer fortification
- Integrated nutrient management: Indigenous mineral and by-product sources

Programme 2: Sustaining Soil Quality through Integrated Nutrient Supply Systems

- Organic farming and produce quality
- Efficient and improved composting techniques
- Developing a workable index of soil quality assessment imbibing influence of different physical, chemical and biological soil attributes
- Resilience of degraded soils

Programme 3: Soil Biodiversity and Genomics

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

Programme 4: Minimizing Soil Pollution

- Bio-remediation/ phyto-remediation of contaminated soils
- Quality compost production and quality standards
- Solid waste – quality assessment and recycling

Programme 5: Climate Change and Carbon Sequestration

- 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 simulation modeling and remote sensing
- Crop adaptation to climate change and rhizospheric study

3.3 Organization Set-Up

Divisions

(i) Soil Chemistry and Fertility
(ii) Soil Physics
(iii) Soil Biology

(iv) Environmental Soil Science

Section

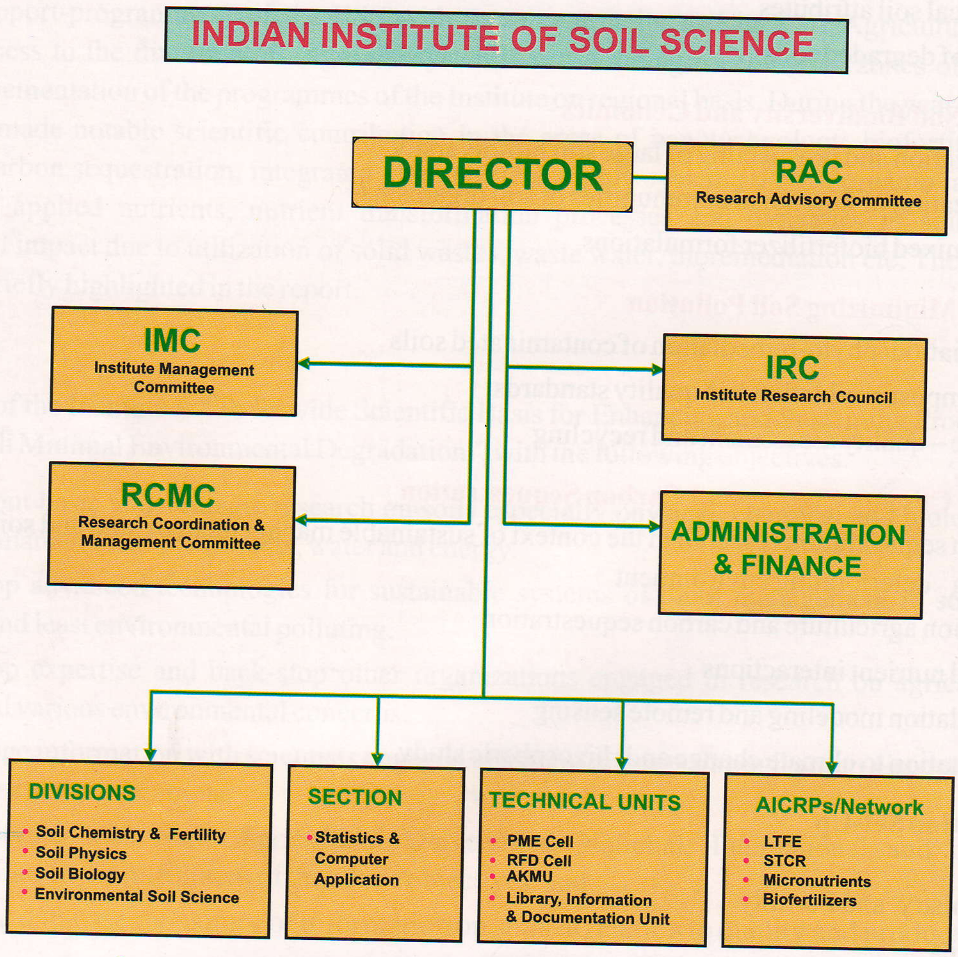
Statistics and Computer Application

Technical Units

(i) Project Monitoring and Evaluation Cell (PME)
(ii) Results Framework Document Cell (RFD)
(iii) Agriculture Knowledge Management Unit (AKMU)
(iv) Library, Information and Documentation Unit

All India Co-ordinated Research Projects (AICRPs)

(i) Long-Term Fertilizer Experiments (LTFE)
(ii) Soil Test Crop Response Correlation (STCR)
(iii) Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (Micronutrients)
(iv) All India Network Project on Biofertilizers (BF)



Organizational Structure of Indian Institute of Soil Science, Bhopal.

3.4 Manpower

a) Scientific

S.No.	Discipline	Sanctioned				In Position			
		PS	SS	S	Total	PS	SS	S	Total
1	Agricultural Economics	0	1	1	2	0	0	0	0
2	Agricultural Extension	0	0	1	1	0	0	1	1
3	Agricultural Microbiology	1	1	2	4	1	1	2	4
4	Agricultural Statistics	0	1	2	3	0	0	2	2
5	Agronomy	1	2	4	7	0	1	3	4
6	Computer Application	0	1	0	1	0	0	0	0
7	Plant Biochemistry	0	1	1	2	0	1	0	1
8	Plant Physiology	1	1	1	3	1	1	1	3
9	Soil Science	9	8	16	33	9	7	16	32
	Total	**12**	**16**	**28**	**56**	**11**	**11**	**25**	**47**

b) Technical

Sl.No.	Class of Posts	Sanctioned	In Position
1	T-1	11	0
2	T-2	-	1
3	T-3	9	3
4	T-4	-	6
5	T-5	-	1
6	T-6	-	6
7	T-7-8	1	0
8	T-9	-	1
	Total	21	18

c) Administrative

S. No.	Designation	Sanctioned	In Position
1	Sr. Administrative Officer	1	1
2	Finance & Accounts Officer	1	1
3	Asstt. Finance & Accounts Officer	1	1
4	Asstt. Administrative Officer	1	1
5	Private Secretary	2	2
6	Assistant	6	4
7	Personal Assistant	5	4
8	Stenographer Gr- III	2	0
9	Security Supervisor	1	1
10	Upper Division Clerk	2	1
11	Lower Division Clerk	6	3
12	Skilled Supporting Staff	25	22
	Total	**53**	**42**

3.5 Finance

The Budget statement (₹ in lakhs) for the financial year 2011-2012 is as follows:

Institute/AICRPs	Budget			Expenditure		
	Non-Plan	Plan	Total	Non-Plan	Plan	Total
Main Institute	689.97	354	1043.97	699.57	353.97	1053.54
AICRP- LTFE	0.00	440	440.00	0.00	439.74	439.74
AICRP- STCR	28.50	620	648.50	31.06	619.99	651.05
AICRP- MSN	44.68	720	764.68	42.76	719.93	762.69
AINP on Biofertilizer	0.00	285	285.00	0.00	285.11	285.11
Total	**763.15**	**2419**	**3182.15**	**773.39**	**2418.74**	**3192.13**

3.6 Resource Generation

S. No.	Particulars	Amount (₹)
1	Sale of Farms Produce	845227
2	Sale of Publication and Advertisement	56208
3	Licence Fee	278797
4	Interest earned on Loans and Advances	1011301
5	Leave Salary and Pension Contribution	316256
6	Receipts from Services Rendered	3150
7	Interest earned on Short Term Deposits	980274
8	Income generated from Internal Resource Generation	97405
9	Recoveries of Loans & Advances	2113685
10	Miscellaneous Receipts	93225
	Total	**5795528**

4. RESEARCH ACHIEVEMENTS

4.1 Soil Fertility Evaluation

4.1.1 Soil carbon stability as affected by long term chemical fertilization and manuring

Long-term fertilizer experiments (>37years) and permanent maurial trial (PMT) conducted at several locations in India provide an opportunity for assessing the influence of chemical fertilizer and manure on soil carbon stability and nitrogen dynamics. Irrespective of sites, chemical fertilization (NPK) and integrated approach (NPK+FYM) for a period of 37 to 54 years lead to an increase in total organic carbon (TOC) in comparison to control. Application of FYM in addition to NPK resulted in a further increase in soil carbon stock to the tune of 18, 20 and 33% at Palampur (Alfisol), Jabalpur (Vertisol) and Ranchi (Alfisol), respectively. Long-term fertilization had the variable effect on soil carbon stability. In Alfisol, application of chemical fertilizer (NPK) alone did not influence the carbon content of the resistant pool of SOM (soil organic matter) whereas it was significantly increased (1.61 times) in Vertisol. However, long-term application of chemical fertilizer significantly increased the carbon content of the slow pool of SOM in Alfisol. Long-term application of either NPK+ farm yard manure (FYM) or FYM alone increased the carbon content of the resistant pool (bio-chemically stabilized carbon) of SOM with the concomitant increase in total carbon content of soil in both Vertisol and Alfisol (Fig. 4.1.1 a&b). Carbon stability affected the N dynamics in soil. There was a buildup of the total N content of soil in all the 3 sites from the initial value under the treatments of NPK and NPK+FYM. Long-term adoption of an integrated approach (NPK+FYM) further increased the total N content of the soil by 22, and 31% over NPK treatment in Jabalpur (Vertisol) and Palampur, respectively. It was observed that the availability of N in soil is well correlated (Fig. 4.1.2) with the amount of carbon in the acid-hydrolyzable pool (*R^2=0. 64, p=0. 01*) rather than total soil organic carbon content (*R^2=0.12, p=0. 01*).

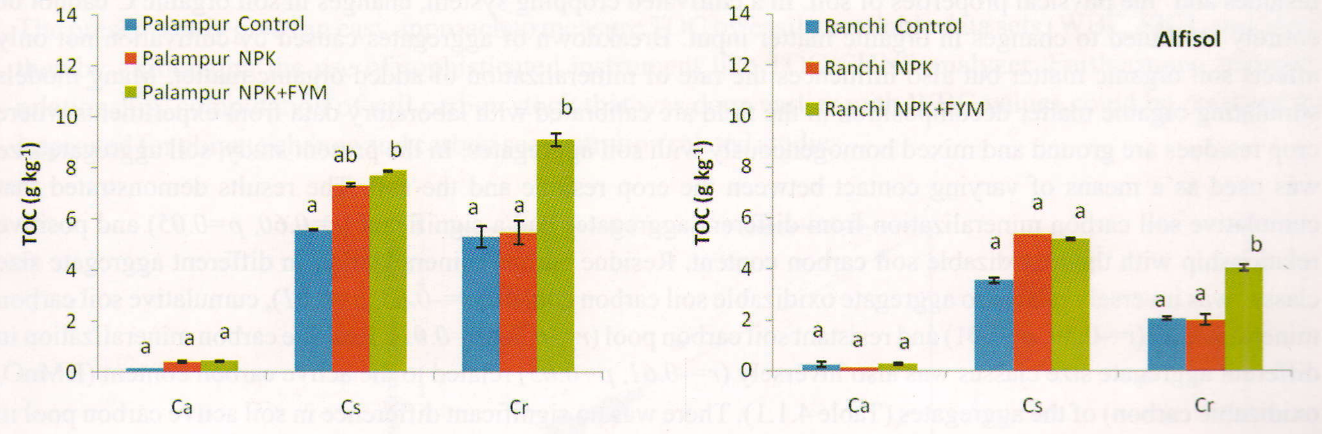


Fig. 4.1.1a Effect of long-term chemical fertilization and manuring on soil carbon pools at Palampur and Ranchi (C_a, C_s, and C_r indicate soil carbon in active, slow and resistant pool; bar indicates standard error of mean).

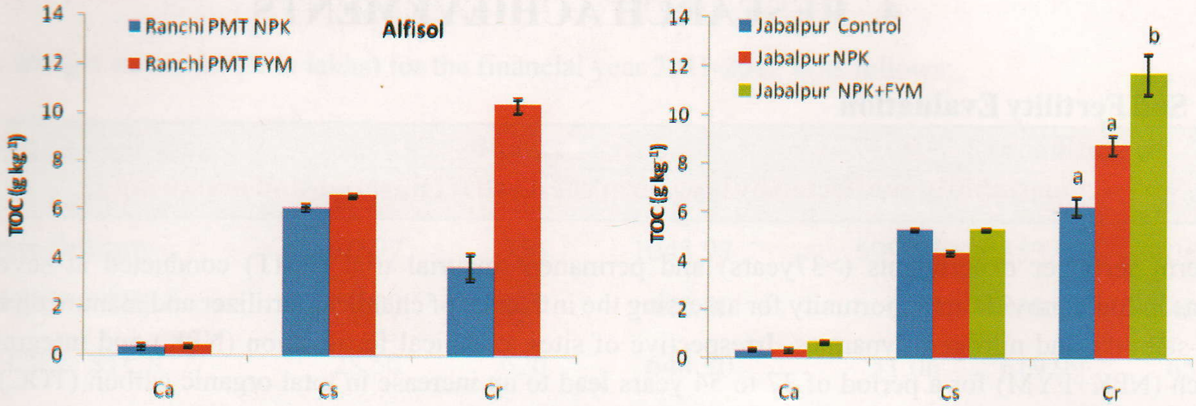


Fig. 4.1.1b Effect of long-term chemical fertilization and manuring on soil carbon pools at Jablapur, Palampur and Ranchi (C_a, C_s, and C_r indicate soil carbon in active, slow and resistant pool; bar indicates standard error of

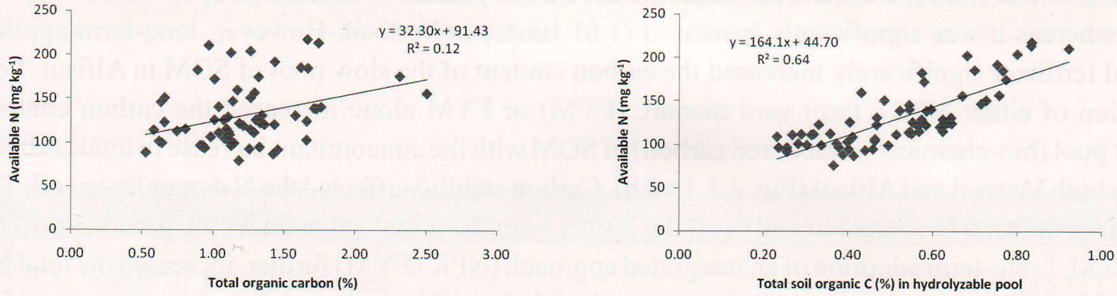


Fig. 4.1.2 Soil N availability as affected by soil carbon pools (*N=66*, inclusive of all sites).

4.1.2 Soil and residue carbon mineralization as affected by soil aggregate size

The nature of contact between the fresh organic matter and soil depends mainly on the characteristics of the plant residues and the physical properties of soil. In a cultivated cropping system, changes in soil organic C cannot be entirely attributed to changes in organic matter input. Breakdown of aggregates caused by cultivation not only affects soil organic matter but also influences the rate of mineralization of added organic matter. Many models simulating organic matter decomposition in the field are calibrated with laboratory data from experiments where crop residues are ground and mixed homogeneously with soil aggregates. In the present study, soil aggregate size was used as a means of varying contact between the crop residue and the soil. The results demonstrated that cumulative soil carbon mineralization from different aggregates had a significant ($r=0.60, p=0.05$) and positive relationship with their oxidizable soil carbon content. Residue carbon mineralization in different aggregate size classes was inversely related to aggregate oxidizable soil carbon content ($r=-0.95, p=0.01$), cumulative soil carbon mineralization (r=-0.89, p=0.01) and resistant soil carbon pool ($r=-0.80, p=0.01$). Residue carbon mineralization in different aggregate size classes was also inversely ($r=-0.61, p=0.05$) related to the active carbon content ($KMnO_4$ oxidizable carbon) of the aggregates (Table 4.1.1). There was no significant difference in soil active carbon pool in different aggregate size classes. Determination of size and turnover of a slow pool showed significant difference in different aggregate size classes. The slow carbon pool in different aggregate size classes ranged from 13.7-25.5% with mean residence time of 1.8 to 5.4 years. Water soluble carbon and active carbon (alkaline $KMnO_4$ oxidizable C) were significantly higher in macro-aggregates than in micro-aggregates.

Table 4.1.1 Correlation matrix

	WBC	WSC	AC	DHA	Cr	Cum soil C min	Cum res C min
WBC	1.00						
WSC	0.57*	1.00					
AC	0.61*	0.68*	1.00				
DHA	-0.06	0.16	0.18	1.00			
Cr	-0.77**	-0.63*	-0.76**	-0.14	1.00		
Cum soil C min	0.60*	0.13	0.31	0.07	-0.22	1	
Cum res C min	-0.95**	-0.48	-0.61*	-0.06	-0.80**	-0.89**	1
N	15.00	15.00	15.00	15.00	15.00	15.00	15.00

Note: WBC-oxidizable carbon (Walkley & Black carbon); WSC-water soluble carbon; AC: active carbon (alkaline $KMNO_4$ oxidizable); DHA-dehydrogenase activity Cr: resistant pool soil carbon; C min- soil carbon mineralization in 183 days; Res C min; residue carbon mineralization in 183 days; Cum - cummulative
*Correlation is significant at the *0.05 level*; **Correlation is significant at the *0.01 level*.

4.1.3 Predicting total organic carbon content of soils from original Walkley and Black method of analysis

Globally, there is problem of computing soil carbon stock due to prevalence of Walkley-Black method which gives only an approximation of soil organic carbon content. Till now, no universal relationship between Walkley-Black carbon (WBC) and total soil organic carbon (TOC) has been developed which could be applicable in all kinds of soil. In present study, relationships between WBC and TOC were established in diverse soil types of Central and Northern-India under different land uses. TOC was measured by dry combustion technique and WBC by wet digestion methods. We developed relationship between WBC and TOC by taking into account the silt+clay content (SICL) of soil and mean annual rainfall (MAR) of the region (Adj. R^2= 0.99, n=100). Fig. 4.1.3 shows the relationship between observed and predicted TOC values of soil collected from different agro-ecological regions of the country. The study clearly demonstrated that a universal correction factor for WBC to TOC is an unrealistic proposition and could lead to error in TOC determination. The present study gives an easy approach to measure TOC by easily available data sets (WBC, SICL and MAR) thereby eliminating the use of sophisticated instrument like TOC/CHNS analyzer. Furthermore, using this relationship, computation of soil carbon stock that was done earlier with WBC values could be revisited and improved for climate change and carbon sequestration related studies.

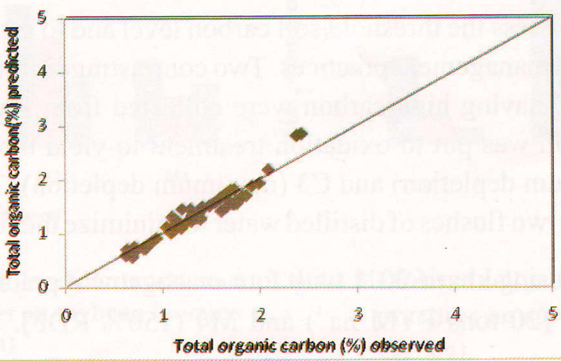


Fig. 4.1.3 Relationship between observed and predicted soil total organic carbon

Development of methodology for determining maximum attainable carbon content of soil

Regardless of potential, the amount of carbon a soil can actually hold is limited by factors such as climate, soil and can be reduced further due to factors such as nutrient availability, insect pest and disease incidence. An effort has been made to determine the maximum attainable carbon content of soil by using the soil series dataset (NBSSLUP) of different states of country. It was observed that maximum carbon content of soil was the function of land use, silt+clay content and rainfall of the region. We observed that rainfall indirectly influences the net primary productivity of the system which in turn determines the net carbon input to the soil. We used cluster analysis for determination of maximum attainable carbon content of soil by taking into account of rainfall of the region, silt and clay content. The entire dataset (1400 soil series) was sorted in ascending order of rainfall. Thereafter, cluster analysis was performed for the rainfall interval of 250 mm along with silt+clay content and Walkley and black carbon content. Each cluster was divided into three groups. The maximum value of Walkley and Black carbon in each cluster group was selected. Finally multiple regression analysis was performed for determining the maximum carbon content of soil by using independent variable of silt, clay and rainfall of the region from each cluster group. A ready reckoner table was developed for determining maximum attainable carbon content of soil under different agro-climatic region of the country.

Predicting soil carbon pools by simple measurable soil parameters

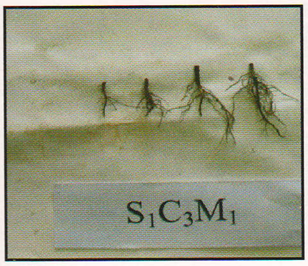
Simulation accuracy of global bio-geochemical carbon model depends on the initial carbon content of soil and their relative distribution of soil carbon pools. The availability of reliable measurements of total SOC may not be sufficient to properly initialize soil C models. We developed an empirical equation for predicting the amount of carbon in resistant (acid un-hydrolysable) and mineralizable carbon (acid hydrolysable) pools by using the soil samples collected from different agro-ecological regions of the country. We determined total organic carbon, acid non-hydrolyzable carbon (resistant carbon pool) and silt and clay content of soil for developing this relationship. We observed that the amount of carbon in resistant pool was the function of silt and clay content of soil. We used separate dataset for model development and model validation. The following empirical equation was developed for determining the amount of carbon in resistant pool. Subtracting the amount of carbon in resistant pool from total organic carbon would give the amount of carbon in mineralisable pool (active + slow pool).

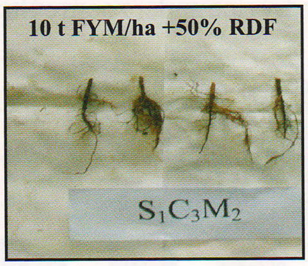
Carbon in resistant pool (%) = 10^(1.27274*log10(TOC %)+0.50439*log10*(Silt+Clay content%)-1.13814) (Adj. R^2= 0.95, p=0.001)

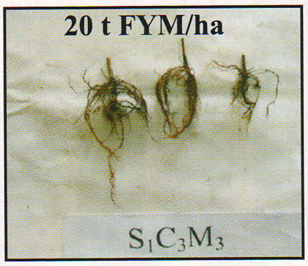
4.1.4 Soil resilience in relation to soil organic matter in selected soils of India

Experiments were carried out to assess the threshold soil carbon level and to estimate the resilience behaviour of C depleted soils under selected management practices. Two contrasting soils (1) coarse textured having low carbon and (2) medium textured having high carbon were collected from Ranchi (Jharkhand) and Aizawl (Mizoram) respectively. Each soil was put to oxidation treatment to yield three soil organic carbon (SOC) levels: C1 (untreated), C2 (medium depletion) and C3 (maximum depletion). The treated soil was sun dried and then leached thoroughly with two flushes of distilled water to minimize the risk of chemical residues.

Pot experiment was conducted during kharif 2011 with four management practices : M1 (control), M2 (50% RDF + 10 tons FYM ha^{-1}), M3 (20 tons FYM ha^{-1}) and M4 (150% RDF). Initial trends showed greater importance of SOC in soils having high native C. Above ground and below ground plant biomass was severely affected with reduction in SOC (50%) and the effect was high with SOC content. The depletion of C also deteriorated the soil physical properties with a clear surface hard pan and the penetration resistance crossing above 2.0 MPa even at half of the available water range (Plate 4.1.1 and 4.1.2). The reduced crop growth in the lowest C level recovered with addition of 20 t FYM ha^{-1}. The poor crop performance in the 150% RDF treatment, suggested requirement of a minimum threshold carbon for maintaining soil structure which can optimally promote plant growth with nutrient supplements. The difference among three SOC levels with respect to crop growth was comparatively lower in the low C (Ranchi) soil (Fig. 4.1.4) as compared to the high C (Aizawl) soil (Fig 4.1.5).







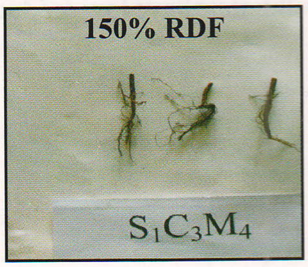
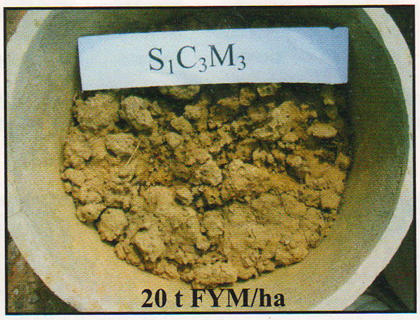


Plate 4.1.1 Soybean root growth under four management levels in maximum depleted carbon level in Aizawl soil



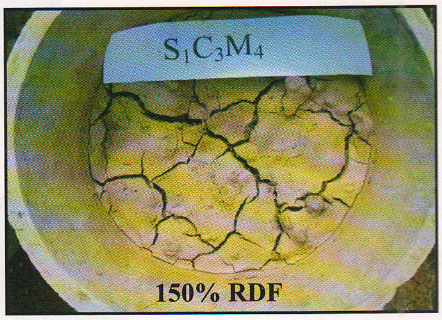


Plate 4.1.2 Soil structural differences under amelioration measures compared to control in maximum depleted carbon level in Aizawl soil

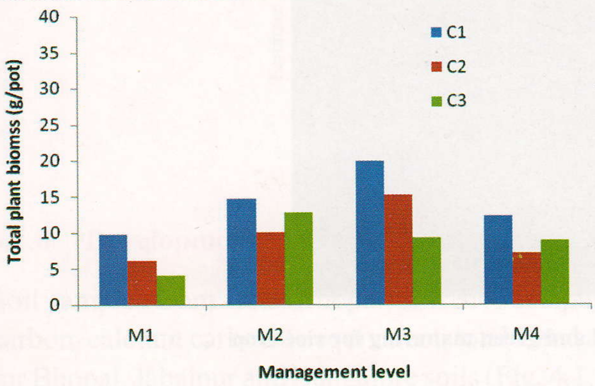


Fig. 4.1.4 Effect of soil native carbon levels and management practices on soybean biomass in Ranchi (low carbon)

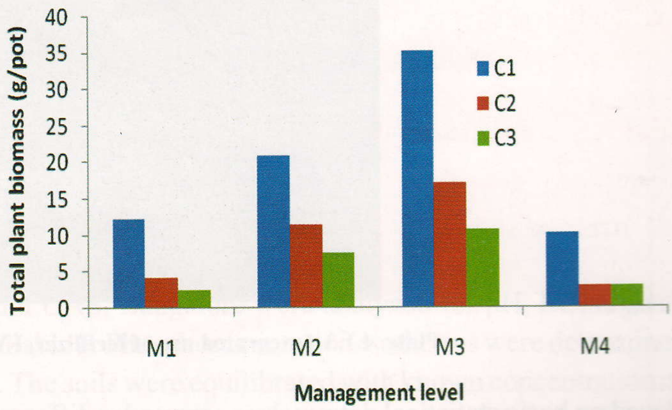


Fig.4.1.5 Effect of soil native carbon levels and management practices on soybean biomass in Aizawl soil (high carbon)

4.1.5 Paddy productivity in Nagaland under INM intervention

During 2011, experiments were conducted on about 10 locations on paddy productivity in Nagaland with INM modules. The data for six locations presented in Fig. 4.1.6 revealed that even with farmers' practice the mean yield of paddy was 4.63 t ha^{-1} which further improved with the INM interventions to 6.02 t ha^{-1} with 100% NPK application. However, out of six locations the treatment of 50%NPK + 5 t FYM + Green manuring/PSB/Azolla superseded the other treatments. Since the fertilizer consumption is too low in the state and farmers' are reluctant towards its use, limited application of fertilizers along with other sources of nutrients such as FYM, green manuring/azolla/PSB (Plate 4.1.3) to paddy can improve the rice productivity in the region. Also, very high level of yield in the tested region hold promise to meet the rice demand of the state, since other regions in the state have low productivity due to low temperature or dry rice under zoom cultivation.

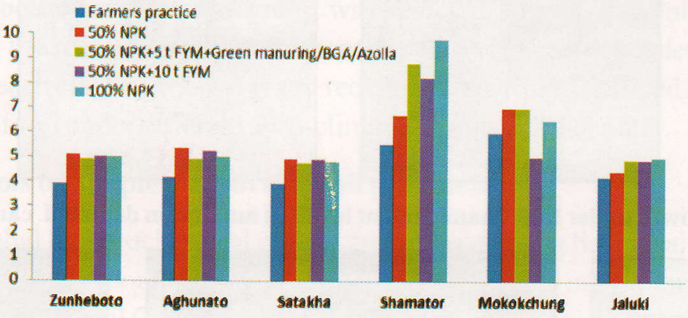


Fig. 4.1.6 Grain yield of rice at different locations of Nagaland

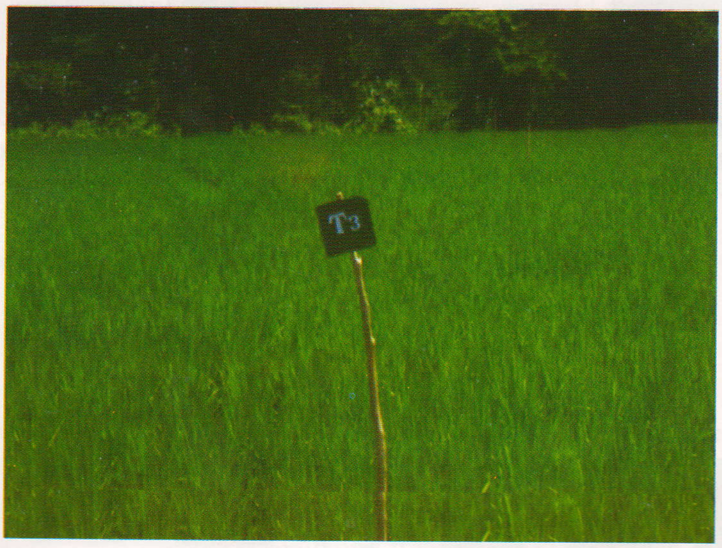


Plate 4.1.3 Integrated use of fertilizer, FYM and green manuring for rice crop

Based on basic statistical data such as area under different crops, their average yield, number of animals in the state etc., the balance between the nutrient removal and supply through manure availability (Fig. 4.1.7) and other sources of nutrients was assessed. It was found that total N, P and K removal in the state through crop removal alone exceeded total nutrient supply through all possible organic sources. Total N removal in state was 13.5 thousand tonnes against supply of only 1.72 thousand tones through organic sources. Similarly, there is supply of only 0.39 and 1.49 thousand tonnes of P and K against removal of 2.78 and 8.85 thousand tonnes. Keeping in view the present poor fertilizer use in the state (Fig. 4.1.8) it is the need of the hour to educate farmers to adopt INM interventions to meet the deficit in nutrient supply and crop removal, otherwise the effects would be reflected in due course of time and the sustainable crop production would not be possible.

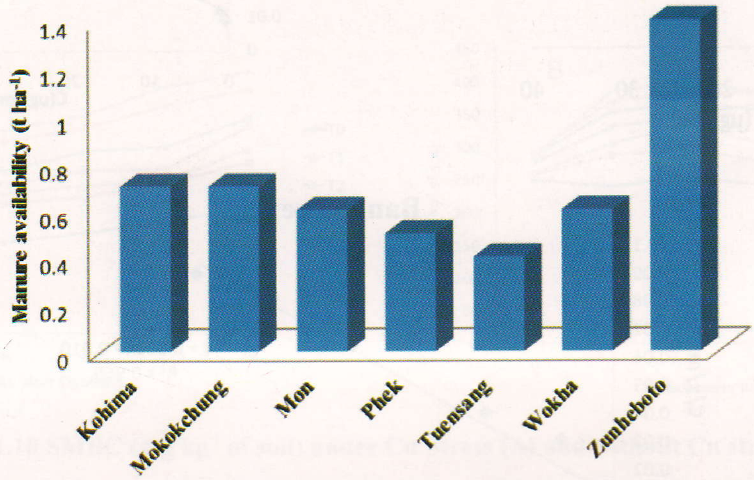


Fig. 4.1.7 Manure availability in different districts of Nagaland

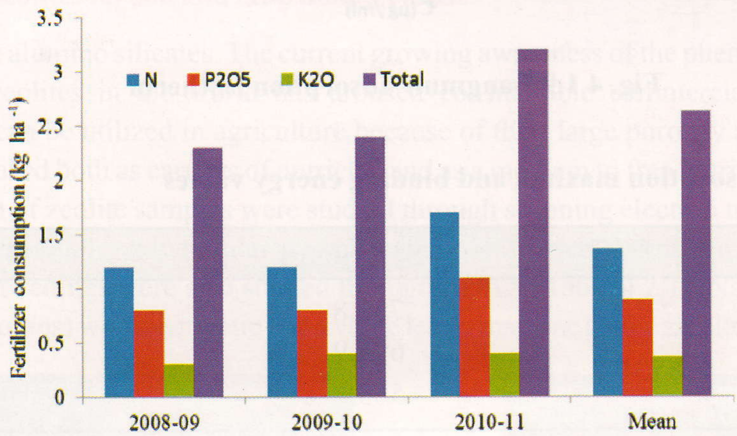


Fig. 4.1.8 Fertilizer consumption (kg ha^{-1}) in the Nagaland

4.1.6 Development of phosphorus saturation indices for selected soils of India.

Soil samples from IISS, Bhopal, DWSR Jabalpur and UAS, Bangalore were analyzed for pH, EC, organic carbon, calcium carbonate equivalent, total P and available P. Phosphorus sorption isotherms were determined for Bhopal, Jabalpur and Bangalore soils (Fig. 4.1.9). The soils were equilibrated with known concentration of graded phosphorus levels and phosphorus isotherm was computed. The values for the three soils were fitted to different equations namely Langmuir, Freundlich and Tempkin approaches. Among the three soils, sorption maxima was found to be the highest in Jabalpur soils, followed by Bhopal and Bangalore soils (Table 4.1.2)..

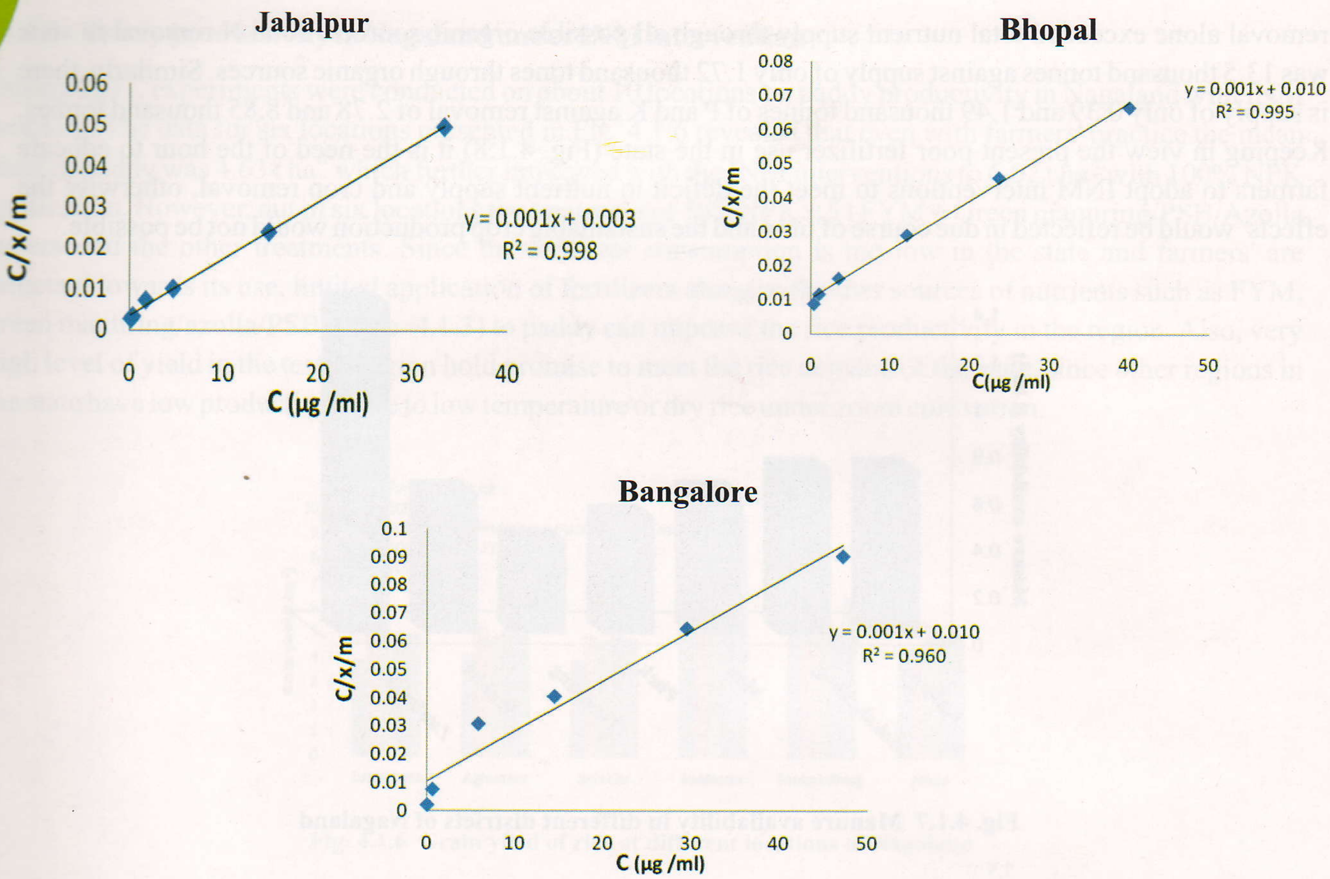


Fig. 4.1.9 Langmuir adsorption isotherm

Table 4.1.2 Phosphorus sorption maxima and binding energy values

Soil	S_{max} (µg/g)	k (l/mg)
Jabalpur	716.8	0.39
Bhopal	694.9	0.14
Bangalore	563.8	0.17

4.1.7 Effect of FYM management practices on recovery rate (Soil resilience) in *Vertisol*

An incubation study was carried out to ascribe the recovery rate of *Vertisol* under various doses of fully decomposed FYM. Cu stress was given for reducing the short-term decomposition and to find the recovery rate under various FYM managements (@ 5 - 50 g/kg of soil) practices. The result from the incubation study revealed that Cu stress significantly (17.98- 29.30%) reduced the soil microbial biomass C (SMBC) and the enzymatic activities as compared to untreated soils (without Cu stress). At the end of incubation period (16^{th} week), microbial biomass carbon (SMBC) ranged from 173.8 to 352.7 mg kg^{-1} of soil under Cu stress (Fig.

4.1.10 A) and 239.0 to 371.3 mg/kg of soil under unstressed soil (Fig. 4.1.10 B). In general, SMBC showed its recovery after 4 weeks of incubation period under Cu stressed condition. However, it showed recovery after 2 weeks only in case of higher doses of FYM application. Among the various treatments, soil without FYM showed the lower resistance, hence higher reduction in SMBC (70.7%) followed by other FYM treated soils (range 56.6 to 66.3 %) at the end of 2-4 weeks after incubation. The study suggested that there was a significant effect of management practices on recovery rate. Soil amended with higher doses of fully decomposed FYM were more resistant to copper stress and much faster to recover its initial status than the untreated soil.

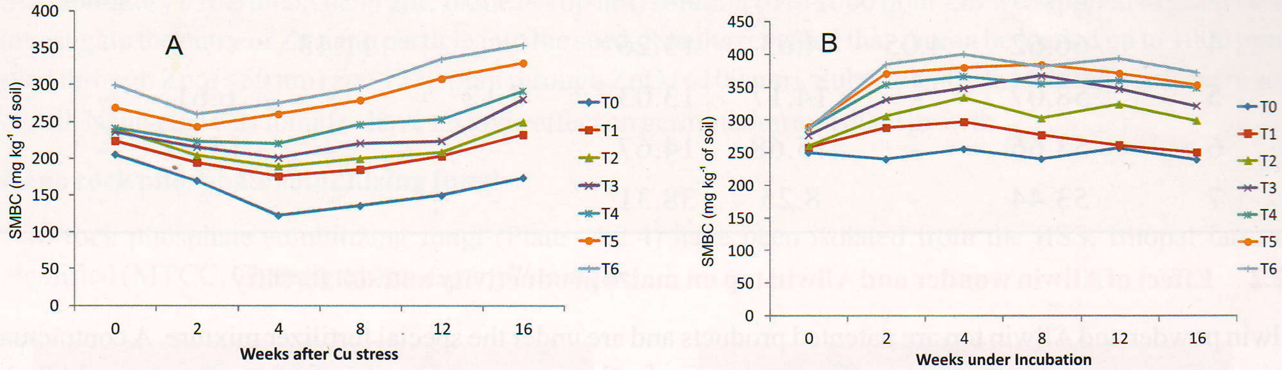


Fig. 4.1.10 SMBC (mg kg^{-1} of soil) under Cu Stress (A) and without Cu stress (B)

4.2 Improving Input Use Efficiency

4.2.1 Nanoporous zeolites for soil and crop management

Zeolites are crystalline alumino silicates. The current growing awareness of the phenomena and availability of inexpensive natural zeolites in the world has aroused considerable commercial interest. Ion-exchange properties of zeolites can be utilized in agriculture because of their large porosity and high cation exchange capacity. They can be used both as carriers of nutrients and as a medium to free nutrients.The morphology and elemental composition of zeolite samples were studied through scanning electron microscope equipped with EDAX. Natural zeolites sample had a tubular assembly (Plate 4.2.1) while synthetic had cube assembly (Plate 4.2.2). Composition of zeolites were also studied through EDAX (Table 4.2.1). Natural zeolites had a Si/Al ratio of 3-5, (Acidic zeolites) while synthetic had a value lesser than one (basic zeolites).

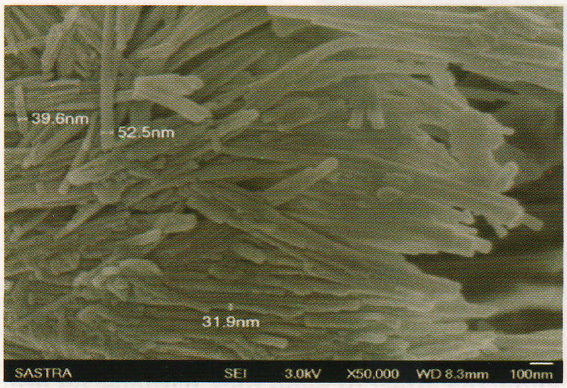


Plate 4.2.1 Tubular structure of a natural zeolite with width in nano dimension

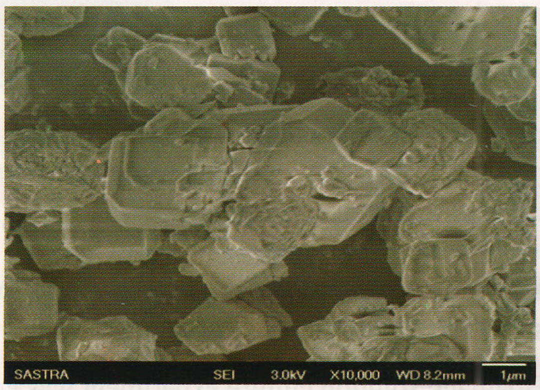


Plate 4.2.2 Cubic structure of synthetic zeolite

Table 4.2.1 Weight (%) of various elements in selected zeolites

Zeolite code	O	Mg	Al	Si	K	Ca	Na	Fe
1	63.07	9.94	3.4	19.94	-	3.65	-	-
2	66.33	-		33.67	-	-	-	-
3	60.54	-	8.47	25.75	-	-	-	5.24
4	66.62	4.05	4.63	13.26	-	11.43	-	-
5	58.07	-	14.17	13.03	8.12	-	6.61	-
6	53.66	-	15.68	14.67	-	-	15.99	-
7	53.44	-	8.25	38.31	-	-	-	-

4.2.2 Effect of Allwin wonder and Allwin top on maize productivity and soil fertility

Allwin powder and Allwin top are patented products and are under the special fertilizer mixture. A contractual project was carried out to study their efficacy on maize for three year. Application of Allwin wonder and Allwin top as separate doses along with 100% of recommended fertilizer dose increased yield of maize only to a marginal extent. However the combinations of Allwin wonder and Allwin top applied as half of the dose used for individual application along with 100% of recommended fertilizer dose increased maize yield up to 10% higher than the application of chemical fertilizers alone (Plate 4.2.3).

Plate 4.2.3 A view of the field experiment on Allwin wonder and Allwin top.

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

Effect of nano rock phosphate particle on growth and enzyme activity of rice (*Oryza sativa L.*) and soybean (*Glycine max L.*) plant

Hoagland solution culture experiment was conducted to know the effect of nano rock particles on growth of rice (*Oryza sativa* L.) and soybean (*Glycine max* L.) plant. Phosphorus was applied through nano rock phosphate particle SRP II (110 nm) and also through KH_2PO_4. Nano rock phosphate particles of SRP II recorded the highest dry matter yield of both the plants. The other plant parameters like, plant height, root length, root volume, root dry matter weight were improved due to application of rock phosphate nano particle. Application of nano rock phosphate particles also enhanced the enzyme activities like nitrate reductase, phosphatase of both the plants.

Fortification of gram (*Cicer arietinum L.*) seed with nano zinc

In a laboratory experiment nano zinc oxide (<100 nm) solution (0 to 1000 ppm Zn) was applied to gram seed to investigate the entry of Zn nano particle into the seed. Results revealed that Zn can be loaded up to 1000 ppm in seed through Zn_M (<50 nm) and 1330 ppm through ZnO (<100 nm). Subsequently the treated seeds were sown in soil. Nano zinc was found to have no toxic effect on germination and plant growth.

Nano rock phosphate solubilizing fungi

Two rock phosphate solubilizing fungi (Plate 4.2.4) have been isolated from the IISS, Bhopal farm and identified (MTCC, Chandigarh) as *Aspergillus niger*.

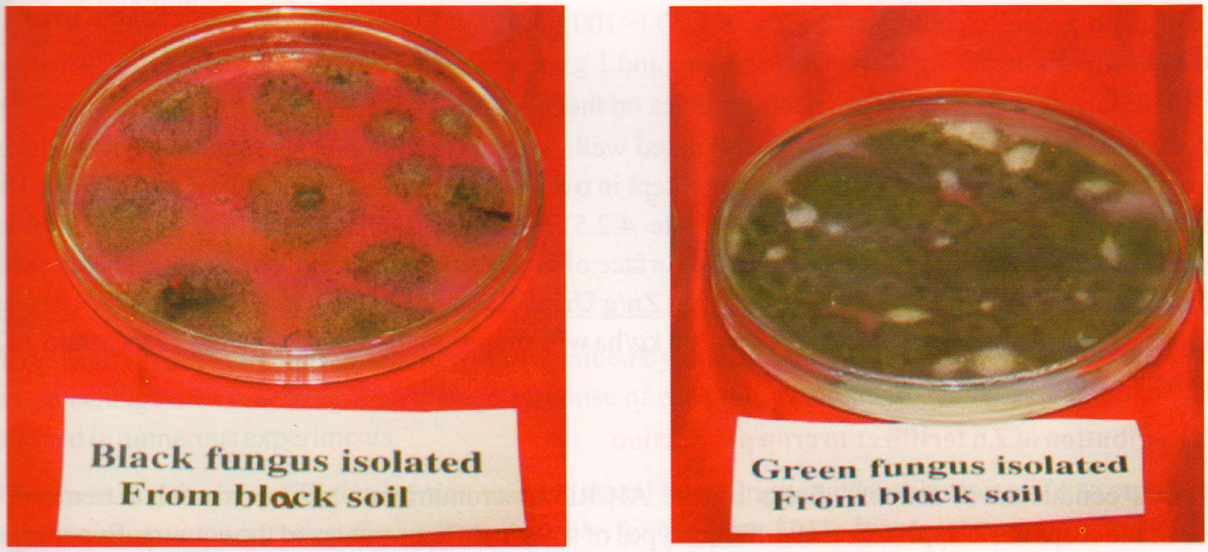


Plate 4.2.4 Rock phosphate solubilizing fungi

Effect of nano particle on growth of fungi

The release of heavy metal-containing nano particles (NP) into the environment may be harmful to the efficacy of beneficial microbes that function in element cycling, pollutant degradation and plant growth. Currently, there are no standard methodologies for evaluating the effects of nano particles on microbial growth in soil. The toxicity of NP against environmental microbes has been little studied. In the present investigation effect of nickel (Ni) and chromium (Cr) (III) nano particles on growth of black, yellow and green fungi was studied. Parallel experiments were also carried out with free metal ion of Cr (VI) and Ni (II) on microbial growth. The dose of both the nano particles did not show any detrimental effect on microbial growth. On the contrary, free metal ion Cr (VI) and Ni (II) badly affected the microbial growth at higher doses.

Oleoresin coated urea fortified with nano-particles

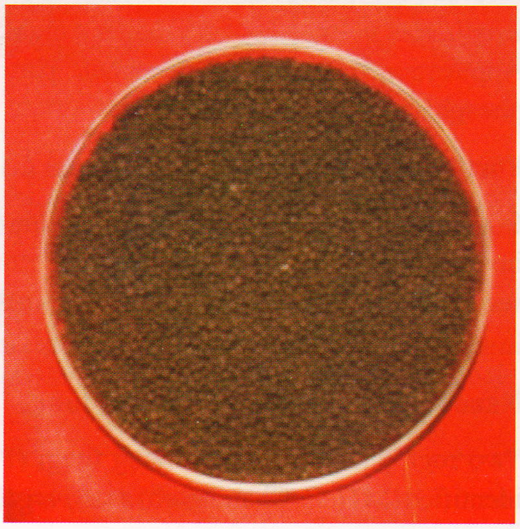


Plate 4.2.5 Oleoresin coated urea fortified with Nano-particles

A protocol was developed to fortify the Urea granules with a consortium of nano-particles of Zn, Cu, Fe, Si using oleoresin. For easy dispersion of nano particle in water, ethyl alcohol was used instead of hexane to dissolve oleoresin for coating urea and then fortified with nano particles. This protocol can successfully be used to deliver nano-particles of micronutrients along with urea.

About 12 g crude oleoresin was dissolved in 100 ml ethyl alcohol in a wide mouth bottle and to it 220 g urea was mixed and shaken for 5 minutes. After that whole content was transferred to plastic tray fitted snugly on a horizontal shaker and shaking operation was continued with maximum speed to evaporate the alcohol. When 80% of the alcohol evaporated, a mixture of nano-particles were uniformly sprayed over the tray using a 53 µm sieve. The mixture of nano-particles contained 1 g Zn as ZnO (<100 nm), 0.5g Fe as Fe_3O_4 (50 nm) 0.3 g Cu as CuO (50 nm) and 1 g Si as SiO_2 (<20 nm). Before spraying these nano-particles on the pine oleoresin coated urea, they were mechanically mixed well. After the addition of nano-particles, the shaking operation continued for 10 minutes and thereafter kept in oven at 50°C for hardening to get free flowing urea fortified with the consortium of nano-particles (Plate 4.2.5). Out of the total amount of nano-particles added, 48.42% of the nano-particles got adsorbed on the surface of oleoresin coated urea. The nano-particles coated urea, thus produced, contained 43.84% N, 2.20 mg Zn/g Urea, 1.10 mg Fe /g Urea, 0.66 mg Cu / g Urea and 1.06 mg Si / g Urea. Application of such urea @ 200 kg/ha will supply , 440 g Zn, 220 g Fe, 132 g Cu and 212 g Si along with 87.68 kg N/ha to the crops.

4.2.4 Contribution of Zn fertilizer to crop production

Experiments conducted in farmers' fields by the AICRP (micronutrients) centers revealed tremendous response of the crops to Zn application in different types of soils in different states of the country. Experiments revealed that average response of the crops spanned from 0.16 to 5.13 t ha^{-1} This signifies the necessity of Zn application for obtaining higher crop yield in Zn deficient areas. In general fertilizer contributes about fifty per cent of the food grain production in the country. Zn management contribution to major food grain crops is estimated to be 18.44 million tonnes (economic value of Rs. 2,11,619 million), which may further enhance to 24.85 million tonnes (economic value of Rs. 2,32,119 million) by including sugarcane, cotton and potato (Table 4.2.2).

Table 4.2.2 Contribution of Zn towards production of major crops in India

Sl. No.	Crop	Average response to Zn application (t ha^{-1})	Area under crop (Million hectare)	Percentage area receiving Zn	Contribution of Zn to crop production* (Million tonnes)	Economic gain due to Zn fertilization** (Rs. In million)
1.	Rice	0.54	43.91	50	11.86	12,80,88
2.	Wheat	0.42	28.04	30	3.53	39,536
3.	Maize	0.47	8.12	35	1.33	13,034
4.	Sorghum	0.36	7.76	10	0.28	2,744
5.	Pearl millet	0.19	9.57	02	0.19	1,862
6.	Gram	0.36	7.54	05	0.13	2,730
7.	Green gram	0.26	3.10	05	0.04	1,400
8.	Black gram	0.24	2.97	05	0.03	990
9.	Pigeon pea	0.26	3.51	05	0.04	1,280
10.	Groundnut	0.32	6.29	15	0.30	8,100
11.	Soybean	0.36	8.88	20	0.64	10,560
12.	Mustard	0.27	5.40	05	0.07	1,295
	Major crops				**18.44**	**2,11, 619**
13.	Cotton	0.22	9.41	10	0.20	5,600
14.	Sugarcane	3.77	5.05	20	3.81	5,300
15	Potato	2.96	1.80	45	2.40	9,600
	Total				**24.85**	**2,32, 119**

* Contribution of Zn to crop production was obtained by multiplying average response with area under crop and percentage area receiving Zn. Average response of each crop was calculated by averaging the responses obtained in numerous experiments.

** Economic gain due to Zn fertilization was estimated by multiplying contribution of Zn to crop production with minimum support price for each commodity for the year 2011. Wholesale price of Rs. 4.00/kg was considered for calculation in case of potato.

4.2.5 Evaluation of *'Patentkali'* (a fertilizer product) for K, Mg and S nutrition of different crops

It is assumed that Indian soils are rich in K, however, extensive research carried out in the country revealed that a number of crops are responding to K application even if available soil K content is medium. A product namely *'Patentkali'* containing K, Mg and S was tested against standard sources supplying K, Mg and S in equal amount to assess the efficacy of *'Patentkali'* in enhancing yield of different crops as direct effect in single crops or direct as well as residual effect of K, Mg and S in cropping system mode at different locations of peninsular part of the country. Most of the crops and cropping systems responded to K and S application supplied through either of the sources. In general, supply of K, Mg and S through either of the sources, i.e. *'Patentkali'* and standard sources could not make any difference in yield response, however, in maize-gobhi sarson and cauliflower-cauliflower cropping systems in Himachal Pradesh and potato-sesame system in Orissa, *'Patentkali'* had an edge over standard sources while standard sources had equal or better effect as compared to *'Patentkali'* in rice-cowpea system in Karnataka, maize-wheat system in Madhya Pradesh and potato-garlic system in Tamil Nadu (Table 4.2.3). The economic response was less when K, Mg and S were supplied through *'Patentkali'* in potato-garlic, rice-cowpea and maize-wheat cropping systems as compared to standard sources. However, it was beneficial to use *'Patentkali'* in cauliflower-cauliflower, maize-gobhisarson and potato-sesame cropping systems. As far as economic response to individual nutrient, i.e. K, Mg or S alone is concerned, the standard sources were proved superior or at par to *'Patentkali'* at most of the locations except in Himachal Pradesh where *'Patentkali'* was better than that of standard sources.

4.2.3 Yield response in terms of rice equivalent yield (t ha^{-1}) of different cropping systems to application of K, Mg and S through Patentkali and standard sources at different locations of the country

Name of the centre	Cropping system	Patentkali vs standard sources	Response to K		Response to S		Response to Mg	
			Patent Kali	Standard sources	Patent Kali	Standard sources	Patent Kali	Standard sources
CSKHPKV, Palampur	Maize-Gobhisarson	0.46	1.43	0.96	1.11	0.65	0.48	0.58
	Cauliflower cauliflower	5.41	3.34	-2.07	4.58	-0.83	-0.73	6.24
UAS, Bangalore	Rice-cowpea	-0.36	1.11	1.48	-0.35	0.01	-0.20	0.33
OUAT, Bhubaneswar	Potato-sesame	0.14	4.76	4.61	1.46	1.32	1.87	2.88
IISS, Bhopal	Maize-wheat	-0.07	0.88	0.96	0.89	0.97	0.26	0.59
TNAU, Coimbatore	Potato-garlic	-0.39	3.92	4.31	5.18	5.56	0.63	2.70
	Average	0.87	2.58	1.71	2.15	1.28	0.39	2.22

4.3 Monitoring Long Term Productivity

4.3.1 Soil biological status as influenced under long term fertilizer experiments

To sustain productivity consistently over years maintenance of soil health is essential. Biological properties of soil are equally important in assessing soil health. In soil all nutrients are mediated to plant through biochemical reactions which are performed by the soil organisms. The activities of the organisms in soil give an idea about soil condition. Biological properties are influenced by nutrient management practices. In order to assess the impact of nutrient management option on biological health of soil, samples from LTFE were subjected to analysis of biological properties at different locations.

CRIJAF Barrackpore

Dehydrogenase activity (µg TPF/ g of oven dry soil /hr at 37°C) of soil has been considered as an index of overall microbial activity. Hydrolysis of fluorescein diacetate (FDA) (µg fluorescein g^{-1} oven dry soil h^{-1} at 24°C) appears to be widely spread among the primary producers, bacteria and fungi. This hydrolysis is mediated by a number of enzymes like proteases, lipases and esterase, at a single time. Microbial biomass carbon (MBC) is another biological indicator which gives status of soil. The data presented in (Table 4.3.1) demonstrated that absence of P and K reduced microbial biomass carbon due to imbalance of nutrients status in soil. Increase in MBC on application of 50% NPK supports the hypothesis. There is no definite trend in activities of urease, acid and alkaline phosphatase. However addition of organic manure resulted increased activities of these enzymes by out large.

Table 4.3.1 Microbial properties of soil after completion of 39 years of cropping

Treatments	FDA (µg fluorescin $g^{-1}h^{-1}$)	MBC (mg kg^{-1})	Dehydrogenase activity (µg TPF $g^{-1} h^{-1}$)	Urease activity (mg NH_4^+-N kg^{-1} soil 2 hr^{-1})	Acid phosphatase activity (µg PNP g^{-1} h^{-1})	Alkaline phosphatase activity (µg PNP g^{-1} h^{-1})
Control	132	85	2.99	120	130	430
100% N	104	123	0.18	142	159	422
100% NP	108	79	0.80	161	124	322
100% NPK	118	101	1.81	134	167	390
150% NPK	119	74	4.13	133	157	382
100% NPK+ $ZnSO_4$	157	160	0.22	145	192	398
100% NPK + FYM	148	221	3.45	181	228	436
100% NPK(-S)	134	86	2.45	150	147	299

TNAU Coimbatore

The biological properties indicated that application of fertilizer resulted increase in population of bacteria, fungus and actinomycetes as compared to control (Table 4.3.2). There has been increase in population of microorganisms on application of N, P and K. However, very sharp increase in population of organism in INM treatment was recorded. This suggested that application of fertilizer had positive effect on microbial population. Further, incorporation of FYM favoured build up in their population. The increase in biomass C and N on application of fertilizer with and without FYM supports the observation. Increase in microbial biomass C and N on application of fertilizer and organic manure is due to requirement of these elements for the synthesis of body of organisms.

Table 4.3.2 Microbial population, biomass C and N after maize crop

Treatments	Bacteria (X10^6 CFU/g of soil)	Fungi (X10^4 CFU/g of soil)	Actino mycetes (X10^3 CFU/g of soil)	Biomass carbon (mg kg^{-1})	Biomass nitrogen (mg kg^{-1})
Control	47	20	7	219	24.6
100% N	68	21	8	230	32.4
100% NP	67	20	9	287	32.4
100% NPK	85	22	11	329	54.0
150% NPK	77	23	10	327	54.4
100% NPK(S free)	84	22	10	337	44.3
100% NPK+Zn	79	22	10	324	53.8
100% NPK+FYM	110	24	15	346	67.9
LSD (*$P \leq 0.05$*)	5.72	2.95	3.42	11.46	3.75

IGKV Raipur

Carbon evolution

Production of CO_2 is a good indicator to assess the biological condition of soil because CO_2 production is cumulative effect of soil biological properties. Data (Table 4.3.3) revealed that evolution of CO_2 was more at 60% moisture at all three growth stages (transplanting, tillering and panicle initiation) of rice. Data further revealed that application of fertilizer increased production of CO_2 and maximum was noted at tillering.

Application of FYM maintained CO_2 production relatively at higher level compared to other treatments. It may be due to additional supply of carbon through FYM. The larger release of CO_2 at tillering may be due to release of photosynthates (carbohydrate) during this particular growth stage.

Table 4.3.3 Interactive effect of moisture and fertilizer on CO_2 production (mg g^{-1} of dry soil)

Treatment	Transplanting		Tillering		Harvesting	
	60% WHC	Submerged	60% WHC	Submerged	60% WHC	Submerged
Control	0.96	0.66	1.01	0.91	1.00	0.88
100% N	1.16	0.86	1.98	1.21	1.74	1.00
100% NPK	1.01	0.77	1.84	1.12	1.29	0.91
50% NPK+GM	1.19	0.86	2.18	1.43	1.98	1.01
100% NPK+FYM	1.29	0.97	2.36	1.94	2.01	1.21

Microbial biomass C and N

Increase in microbial biomass C was noted on application of fertilizer which was further enhanced on incorporation of FYM (Table 4.3.4). The increase in MBC on application of fertilizer is expected due to incorporation of more root biomass as a result of increase in productivity. Data further indicated that irrespective of treatment, decline in MBC was noted with advancement in age of the crop. Microbial biomass N also followed similar trend as that of SMBC.

Table 4.3.4 Effect of nutrient management on soil SMBC and carbon pools in water stable aggregates

Treatments	SMBC (mg kg^{-1})				SMBN (mg kg^{-1})	WSAC (mg kg^{-1})				
	Trans planting	Tillering	Panicle initiation	Harve sting	Harv esting	1.0 mm	0.5 mm	0.25 mm	0.125 mm	<0.125 mm
Control	281.0	227.7	199.5	180.2	10.1	0.41	0.49	0.66	0.76	0.88
100% N	280.8	227.7	171.4	131.2	10.9	0.62	0.56	0.67	0.62	0.77
100% NPK	295.2	230.3	227.7	201.2	13.2	0.51	0.54	0.63	0.57	0.91
50%NPK+ GM	312.9	312.1	228.8	200.1	15.9	0.72	0.79	0.84	0.89	1.18
100% NPK+ FYM	330.4	455.4	255.8	212.2	15.7	0.56	0.62	0.62	0.66	0.91

Water Stable Aggregates Carbon (WSAC)

The amount of carbon locked in water stable aggregates (WSA) is another soil quality indicator. Data (Table 4.3.4) indicated that amount of carbon locked in soil aggregates increased with increase in size of aggregates.

Application of fertilizer, FYM and green manuring enhanced WSAC compared to control due to increase in proportion of larger size aggregate on application of fertilizer. Application of fertilizer and manure added larger amount of organic matter through residual biomass of rice and wheat which acted as binding material for soil particles and contributed to WSAC.

OUAT Bhubneshwar

Data (Table 4.3.5) indicated that application of nutrients resulted increase in bacteria, fungi and actinomycetes. Amending soil with lime and FYM over and above NPK further enhanced the microbial population. On the contrary to microbial population, application of chemical fertilizer showed adverse effect on number of nematodes (Table 4.3.5) in soil compared to control plot. However, lime suppressed the population of nematodes might be due to sudden change in soil pH, so that the nematodes (saprophytic) could not acclimatized themselves so quickly. Increase in microbial population on application of chemical fertilizer is due to increase in availability of more root biomass as a result of increase in biomass yield. Application of lime and FYM moderate the soil environment and provide more carbon to soil microbes. Increase in activity of urease and amidase (Table 4.3.6) on application of nutrients and soil amendments support the findings.

Table 4.3.5 Effect of nutrient management on biological properties

Treatment	Bacteria (CFU g) ($x10^7$)	Fungi (CFU g^{-1}) $x10^5$	Actinomycetes (CFU g^{-1}) ($x10^5$)	Nematode population (Nos./250 cc dry soil)		
				Saprophytic	Parasitic	Total
Control	5.78	4.6	0.92	1223	626	1849
50% NPK	5.13	6.6	1.77	684	294	978
100% NPK	6.20	7.45	1.42	987	485	1472
100% NPK + FYM	8.70	3.03	7.23	795	253	1048
100% NPK +Lime	10.70	5.32	0.47	449	334	784
100 % NPK + FYM+ Lime	12.77	5.90	0.32	930	291	1221

Table 4.3.6 Effect of soil amendments on urease and amidase activity

Treatments	Enzyme activities (mg NH_4^+-N kg^{-1} soil 2 hr^{-1})	
	Urease	Amidase
Control	11.7	4.8
100% NPK	13.5	8.8
100% NPK + FYM	16.5	11.7
100% NPK + Lime	23.3	12.7

JNKVV Jabalpur

Biological N fixation

Biomass N_2 fixation in soybean was estimated by using % Ndfa, taking into account inputs and outputs of N (Table 4.3.7). The annual average N fixed by soybean was significantly influenced by the nutrient combination applied in a particular treatment. The lowest amount of biologically fixed N was recorded in control (62.8 kg ha^{-1} yr^{-1}) and the highest was in NPK+FYM (161.1 kg N ha^{-1}) by harvestable biomass of soybean. Though application of N, P and K has resulted in an increase in the quantity of N_2 fixation by soybean compared to the control treatment the maximum benefit was due to P application. Data indicated that continuous absence of S decreased N_2 fixation by soybean. The decline in N_2 fixation in absence of P is due to reduction in biomass of soybean which ultimately had an adverse effect on the assimilation of N by the crop. Increase in N_2 fixation on application of N suggests that soybean needs a small quantity of N as starter dose in this environment. The N_2 fixation reported in the literature varied from 0 to 333 kg ha^{-1}.

Computation of net gain or loss of N was made by subtracting the N derived from soil by soybean from total amount of N added through RBN_s considering the % Ndfa in each case. The data observed in all treatment indicated net N gain in soil that ranged from 24.2 to 66.5 kg ha^{-1} (Table 4.3.7). Nitrogen fixation and gain of biologically fixed N_2 in soil recorded in 100% NPK+FYM and 100% NPK treatments were almost equal and were relatively larger compared to other treatments but less than 150% NPK suggesting that in a cropping

Table 4.3.7 Mean annual input output of N (kg ha^{-1}) in soil due to soybean and fixed N accredited to soil under different nutrient management

Treatment	Total annual N uptake (kg ha^{-1})	Fixed N in above ground biomass	N derived from soil in aboveground biomass	Biological fixed N added to soil	Net N balance gain by soil
	A	B	C= (A-B)	D	E=(D-C)
Control	65.1	62.8	2.3	42.0	39.7
100% N	87.7	73.1	14.6	43.9	29.3
100% NP	138.6	114.5	24.1	75.5	51.4
100% NPK	150.4	128.8	21.5	87.5	66.2
150% NPK	153.0	110.4	42.6	75.9	33.3
100% NPK+ FYM	185.9	161.1	23.8	90.3	66.5
100% NPK +Zn	149.3	123.3	26.0	86.0	60.0
100% NPK (-S)	131.0	93.9	37.1	61.3	24.2
LSD $p < 0.05$	9.2	8.7	5.4	7.8	4.8

Note : A the difference between total soil N at the initial and at the harvest of 33rd crop of soybean; B values of % Ndfa; D % Ndfa values of each treatment and total N added to soil through residue of soybean (e.g. in control total N added through residual biomass is 43.48 X 0.96% Ndfa =42.0) system which included a legume, application of increasing amounts of N fertilizer lead to lower fixation and less gain of N in soil. The results indicate that under very high yield condition negative N balance is expected.

PDKV Akola

The data on population of various organisms under different treatments indicated that irrespective of nutrient combination, application of chemical fertilizer resulted increase in population of bacteria, fungi and actinomycetes (Table 4.3.8). Data further indicated that imbalance use of nutrient say N alone had negative effect on population of all three types of organisms when compared with balanced treatment but superior to control. This indicated that soil biota also required nutrient for their multiplication and growth. Incorporation of biomass in larger quantity through root and stubble added to soil as a result of higher productivity in plot receiving balanced nutrient application favored microbial population. Evolution of CO_2-C and presence of SMBC in larger quantity on balanced application of nutrient support the higher microbial population in this treatment (Table 4.3.8). The evolution of CO_2-C and SMBC were proportional to population of these organisms.

Table 4.3.8 Effect of long term manuring and fertilization on soil microbial count after harvest of sorghum (2009-10)

Treatment	Bacteria cfu ($\times 10^7$)	Fungi cfu ($\times 10^4$)	Actinomycetes cfu ($\times 10^6$)	CO_2 evolution mg 100 g^{-1}	SMBC mg kg^{-1}
Control	6.25	4.50	5.00	22.00	137.81
100% N	8.75	6.25	5.75	26.07	180.17
100% NP	13.00	8.25	8.75	28.32	204.39
50% NPK	9.50	7.25	6.00	27.35	197.49
100% NPK	15.50	11.25	11.75	31.62	216.39
100% NPK + Zn @ 2.5 kg ha^{-1}	17.75	11.50	12.00	32.72	218.70
100% NPK + FYM @ 10 t ha^{-1}	30.50	15.50	16.25	41.52	249.01
100% NPK +S @ 37.5 kg ha^{-1}	20.25	9.00	12.25	35.47	221.05
LSD ($P \leq 0.05$)	2.05	1.94	1.74	2.10	14.88

GBPAUT Pantnagar

Data on microbial biomass carbon, dehydrogenase, phosphatase and urease activity (Table 4.3.9) revealed that application of fertilizer resulted increase in microbial biomass C which was due to incorporation of more residual biomass. Further increase in biomass C on application of FYM strengthen the findings. It was observed that incorporation of biofertilizer even though resulted increase in biomass C but not to the extent recorded in the plots those received fertilizer and FYM. Probably less availability of residual biomass as a result of poor growth in absence of fertilizer could be the reason. Enzyme activity gives an overall assessment of microbial activity. More the enzymatic activity more will be their effectiveness in nutrient transformation process in soil. Perusal of data on dehydrogenase activity (DHA) in soil indicated that application of fertilizer resulted in increase in DHA and effect was more pronounced on balanced application of nutrient. Incorporation of FYM application further increased the DHA in soil. More or less similar effect of fertilizer was also recorded on urease and phosphatase activity.

Thus, the results at Pantnagar showed that application of nutrient increased productivity of crops which added more residual biomass carbon to soil, resulted increase in microbial population that ultimately enhanced the activities of soil enzymes and carbon turnover in soil.

Table 4.3.9 Effect of long term treatments on biological activities

Treatment	DHA (µg TPF $g^{-1}h^{-1}$)	Mineralizable-N (µg TPF $g^{-1}h^{-1}$)	MBC (mg kg^{-1})	Urease (mg NH_4^+-N kg^{-1} soil 2 hr^{-1})	Phosphatase (µg PNP $g^{-1}h^{-1}$)	Bacteria CFU ($\times10^6$)	Actinomycetes CFU ($\times10^3$)	Fungi CFU ($\times10^4$)
Control	386	26	202	0.82	9.0	10.1	2.5	3.0
100% N	304	36	264	0.64	9.6	9.4	3.0	10.9
100% NP	353	35	304	1.17	11.8	11.4	3.5	2.8
50% NPK	391	26	279	1.15	11.2	12.9	1.7	5.6
100% NPK	478	34	313	1.14	12.3	17.1	3.2	4.1
100% NPK +Zn	502	48	356	1.44	14.0	16.9	5.0	3.2
100% NPK+FYM	931	48	413	1.19	17.7	19.3	8.2	3.2
100% NPK(-S)	554	34	284	0.86	11.2	14.4	3.1	4.1
Biofertilizer	414	26	235	0.73	8.9	10.5	2.1	2.9

4.3.2 Assessing resilience of the degraded systems/soils with appropriate interventions

A field experiment was carried out to study the resilience capacity of Vertisol of AESR 10.1 on ten farmer's fields which were selected based on the SQI values so as to get a gradient of Soil Quality Index values (having a regime of SQI value ranging from low to high). Each of the ten identified sites was divided into four plots (minimum size 20X20 m) and the soil was amended with wood charcoal @ 5.4 t/ha (I_1), 10.8 t/ha (I_2) and 16.2 t/ha (I_3) at the time of land preparation before the sowing of soybean crop in 2010. Thereafter soybean followed by wheat crop was raised (with uniform recommended fertilizer management practice for soybean and wheat) and yields were recorded. After the harvesting of wheat crop in 2011, soils samples were collected from all the sites and analyzed for quantitative values of the identified key indicators. Based on this quantitative value of the key indicators, SQI values were computed for all the interventions of the ten sites. The resilience index (RI) of the soils of each of the ten sites due to application of charcoal was computed using the following expression

$$RI = \frac{SQI\ (I) - SQI\ (d)}{SQI\ (p) - SQI\ (d)} \ X\ 100$$

Where, SQI (I): SQI value of soil after management intervention (I)

SQI (d): SQI value of soil before the management intervention (I)

SQI (p): SQI value of pristine soil near the corresponding site.

The numerator in the above expression indicates the recovery of SQI value due to management intervention where as the denominator indicates the loss of SQI value due to soil degradation processes. The result showed that the loss of soil quality as compared to respective pristine soil was different in different sites and the values ranged from 0.114 unit (site no. 9) to as high as 0.650 unit (site no. 2). After imposition of interventions, there was improvement in SQI values in each site, however, magnitude of improvement in SQI value varied from site to site. Under intervention I_1 (5.4 t charcoal/ha), I_2 (10.8 t charcoal/ha) and I_3 (16.2 t charcoal/ha) the improvement in SQI value was 0.026 unit (site no. 10) to 0.246 unit (site no. 4), 0.051 unit (site no. 9) to 0.287 unit (site no. 2) and 0.067 unit (site no. 9) to 0.392 unit (site no. 2), respectively. Similarly, the resilience index under each intervention showed wide variation. Under intervention I_1, I_2 and I_3 the resilience index ranged from 10.97 % (site no. 10) to 58.01 % (site no. 4), 28.27 % (site no. 10) to 65.09 % (site no. 4) and 45.14 % (site no. 10) to 87.95 % (site no. 3), respectively. Logically it was expected that the soils with low SQI value should show higher degree of resilience but the observed results are not in line with this hypothesis. The mean resilience index (summed over effect of I_1, I_2 and I_3) increased gradually from 39.28 % (site no. 1, SQI (d) = 0.959) to 68.78 % (site no. 4, SQI (d) = 1.117) and thereafter no definite trend was observed (Fig. 4.3.1). It was further observed that out of the ten sites the value of resilience index ranged from 28.12 to 68.78 % which resulted in gain in soybean yield ranging from 264 to 442 kg/ha and gain in succeeding wheat yield ranging from 103 to 815 kg/ha (Fig. 4.3.2). The soil analysis carried out after the harvest of wheat crop showed that out of the eight key indicators identified for vertisol, only two indicators, namely, total organic carbon (TOC) and alkaline phosphatase activity showed significant improvement due to application of wood charcoal. Also significant improvement in microbial biomass C content in the soil due to charcoal application was observed. It could be concluded that improvements in TOC and alkaline phosphatase activity were responsible for the increased resilience in the Vertisol.

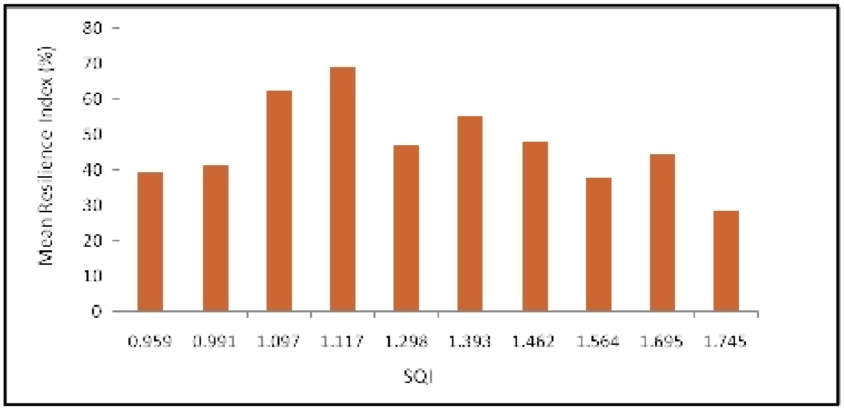


Fig. 4.3.1 Mean resilience index (%) of Vertisol at ten sites having different degree of degradation as measured by Soil Quality Index (SQI)

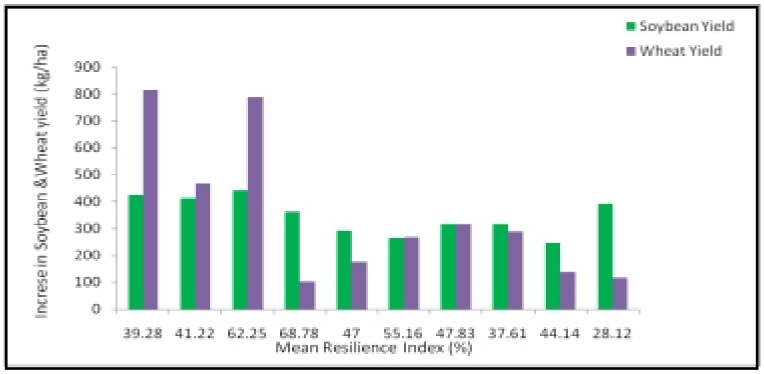


Fig. 4.3.2 Average gain in soybean and succeeding wheat yield at different resilience index in vertisol

4.4 Managing Soil Physical Environment

4.4.1 Spectral reflectance and vegetation indices for prediction of nitrogen stress, leaf area (LAI) and yield of maize (*Zea mays*, L.)

A field experiment was conducted with maize crop grown at four nitrogen levels namely, 0, 50, 100 and 150% of the recommended dose of nitrogen during the rainy season. During cropping season leaf area, biomass, and spectral reflectance from crop as well as from the bare soil were recorded during important growth stages. The moisture content of soil profile was also recorded four times during the cropping season. The LAI, biomass values showed distinct variations between the nitrogen levels. LAI reached the highest value at 55 days after sowing (DAS). LAI at 55-81 days after sowing was significantly higher in $N_{100\%}$ and $N_{150\%}$ than that in $N_{0\%}$ and $N_{50\%.}$ Grain and biomass yield of maize increased with increasing nitrogen levels. Grain yield recorded at N_0 level was 833 kg/ha while at $N_{150\%}$ it was 4132 kg/ha. Broadband vegetation indices viz. normalized difference vegetation index (NDVI), green-NDVI, and narrow-band vegetation indices viz. normalized difference red edge (NDRE) calculated from the spectral reflectance of maize crop recorded at important growth stages were used for prediction of leaf area index and biomass of the crop at different growth stages. The results showed that the NDVI is a good predictor for the LAI and biomass of maize at the initial stages compared to the other vegetation indices GNDVI but during the full vegetation stage (when LAI value exceeded the value 1.7) GNDVI was found to be a better predictor for LAI and biomass than NDVI. However, in both days' hyper-spectral vegetative indices NDRE was found to predict LAI more accurately (R^2 = 0.65 and 0.64, respectively) than both the NDVI and G-NDVI. The N-content of the leaves showed a significant and positive correlation with the Red Edge Position (REP) (0.78) and REP slope (0.81). The study thus indicates that the N stress in maize can be predicted by the REP and REP slope values.

4.4.2 Conservation tillage and residue management effects on crop yield and soil physical properties

The effect of long-term imposition of different tillage treatments and N levels on soil physical properties, like bulk density and water retention of the undisturbed soil cores at field capacity were assessed. In the rainy season soybean was grown as a rainfed crop with four tillage treatments namely, mould board plough (MB), conventional tillage (CT), reduced tillage (RT) and no tillage (NT) as main plot and three N levels (50%, 100% and 150%) as subplots. During the winter season wheat was grown with a combination of eight tillage systems and three nitrogen levels. The results showed that the imposition of tillage treatments significantly influenced the bulk density (BD) of the soil taken during the soybean growing season, but nitrogen level effect on soil bulk density was not significant (Table 4.4.1). The BD values increased with depth. The average bulk density of the soil increased from 1.22 Mg m^{-3} at 0-7.5 cm to 1.44 Mg m^{-3} at 22.5-30 cm depth. The BD at surface 7.5 cm depth was minimum in mouldboard (1.18 Mg m^{-3}) and conventional tillage (1.20 Mg m^{-3}) treatments while it was the highest in no tillage (1.26 Mg m^{-3}). However the BD under no tillage was well below the limit to hamper the root growth of soybean. At 7.5-15 and 15-22.5 cm depth the BD in mouldboard plough treatment was significantly less than other three tillage treatments. At (22.5 - 30 cm) depth difference was not significant. Soil moisture retention at field capacity estimated from undisturbed soil cores was found to be higher in conservation tillage treatments compared to the conventional tillage treatment (Table 4.4.2). Soil water retention on volume basis at field capacity was 33.5 and 33.6 per cent in no tillage and reduced tillage treatments while it was 31.1 per cent in conventional tillage treatment. Nitrogen level effect on soil water retention was not significant.

Table 4.4.1 Effect of tillage and nitrogen levels on bulk density (Mg m^{-3}) of the soil up to 30 cm soil depth

Treatment	Depth (cm)			
	0-7.5	7.5-15.0	15.0-22.5	22.5-30.0
NT	1.26	1.42	1.45	1.46
CT	1.20	1.36	1.41	1.44
RT	1.23	1.38	1.44	1.42
MB	1.18	1.31	1.38	1.46
LSD (0.05)	0.04	0.05	0.05	NS
N50%	1.22	1.37	1.42	1.42
N100%	1.20	1.35	1.44	1.45
N150%	1.23	1.38	1.41	1.46
LSD (0.05)	NS	NS	NS	NS

The performance of different tillage systems and N rates on soil quality and crop productivity in Vertisols has been assessed through a long-term tillage experiment. In the rainy season soybean as a rainfed crop was grown with four tillage treatments namely, mould board plough (MB), conventional tillage (CT), reduced tillage (RT) and no tillage (NT) as main plot and three nitrogen levels (50%, 100% and 150%) as subplots. Results showed that the seed and biomass yield of soybean did not differ significantly among the tillage treatments (Table 4.4.3). The biomass growth of soybean during the season was adequate in all the treatments but due to poor pod setting and inadequate seed filling in the pods, the average seed yield of soybean was very low. Analysis of the yield and yield attributes showed that the pod number per plant was very less and the seed test weight was also less. The average seed yield among the various treatments varied between 433 and 513 kg ha^{-1} while the total biomass production among the treatments ranged from 3703 to 4125 kg ha^{-1}. Only 637 mm of rainfall received during the monsoon season which is 33% lower than the long-term average rainfall for this season. But the distribution of rainfall was quite uniform.

Table 4.4.2 Effect of tillage and nitrogen levels on soil water retention at field capacity

Treatment	Soil water retention at 0.33 bar (%, v/v)			
	N50%	N100%	N150%	Average
NT	35.2	35.8	35.4	35.5
CT	32.8	33.4	33.1	33.1
RT	35.6	35.5	35.8	35.6
MB	34.4	34.8	35.0	34.7
Average	34.5	34.9	34.8	

Table 4.4.3 Yield and yield attributes of soybean as influenced by tillage treatment and nitrogen levels in 2010

Treatment	Seed (kg ha^{-1})	Biomass (kg ha^{-1})	Harvest Index	Pod no./plant
NT-Soybean	470	3703	0.13	8.1
RT-Soybean	513	3933	0.13	8.8
MB-Soybean	472	4125	0.12	10.0
CT-Soybean	433	3800	0.12	8.4
LSD (P=0.05)	NS	NS	NS	NS
NT- wheat	466	3974	0.12	9.1
RoT- wheat	478	3806	0.13	8.6
LSD (P=0.05)	NS	NS	NS	NS
N50%	450	3743	0.12	6.8
N100%	469	3918	0.12	8.8
N150%	499	4009	0.13	10.9
LSD (P=0.05)	NS	227	NS	NS

4.4.3 Long-term tillage and nitrogen levels effects on infiltration characteristics and bulk density of the soil

The data showed that imposition of tillage treatments and variations in N levels significantly influenced the bulk density of the top 15 cm soil, while below 15 cm depth were not significant (Table 4.4.4). The BD in most of the plots increased with increase in depth. The BD at 0-7.5 cm depth was minimal in reduced tillage (1.20 Mg m^{-3}) while the maximum value of BD 1.30 Mg m^{-3} was recorded in the conventional tillage treatment. In mould board tillage and no tillage treatments, the BD was 1.24 Mg m^{-3} and 1.25 Mg m^{-3}, respectively. At 7.5-15 cm depth, the BD in mould board treatment was significantly less than the other three tillage treatments. Among the nitrogen levels, BD was the highest at 50% N level and it was significantly higher than the BD recorded at 100% and 150% N level. The steady state infiltration rates of plots under no tillage (NT) and mould board

Table 4.4.4 Tillage and nitrogen level effect on BD (Mg m^{-3}) of the soil

Treatment	Depth (cm)			
	0-7.5	7.5-15	15-22.5	22.5-30.0
NT	1.25	1.36	1.44	1.54
CT	1.30	1.40	1.37	1.56
RT	1.20	1.34	1.37	1.56
MB	1.24	1.31	1.36	1.50
LSD (0.05)	0.04	0.05	NS	NS
$N_{50\%}$	1.28	1.38	1.35	1.54
$N_{100\%}$	1.25	1.33	1.38	1.55
$N_{150\%}$	1.21	1.35	1.42	1.54
LSD (0.05)	0.05	NS	NS	NS*

*NS= Not significant

tillage (MB) treatments were significantly higher than that under reduced tillage (RT) and conventional tillage (CT) treatments (Table 4.4.5). Amongst the nitrogen levels, $N_{100\%}$ and $N_{150\%}$ level recorded higher infiltration than $N_{50\%}$ level but the difference was not significant. The cumulative infiltration up to 300 minutes was significantly higher in no tillage and mould board tillage treatments compared with the reduced and conventional tillage treatments. Cumulative infiltration recorded at $N_{100\%}$ and $N_{150\%}$ levels was also significantly higher than that at $N_{50\%}$ level treatment.

Table 4.4.5 Tillage and Nitrogen level effect on steady state infiltration rate (cm/hr)

Tillage	Nitrogen levels			
	$N_{50\%}$	$N_{100\%}$	$N_{150\%}$	Average
CT	1.32	2.07	2.26	1.89
MB	3.77	2.64	2.73	3.05
RT	1.41	3.06	2.07	2.18
NT	1.56	4.05	5.19	3.60
Average	2.02	2.96	3.06	

LSD (P= 0.05): Tillage: 1.02 and Nitrogen level: NS

4.4.4 Impact of crop covers on soil and nutrient losses through run off in Vertisol

The study was carried out to assess the impact of crop covers on soil and nutrient losses through run off in Vertisol. The treatments consisted of three sole crops (soybean, maize and pigeon pea) and three intercrops namely soybean + maize (1:1), soybean + pigeon pea (2:1) and maize + pigeon pea (1:1) and one cultivated fallow as a control with three replications under randomized block design. In second year crop were sown during first week of July, 2011 with optimum soil moisture content. During crop growth period, runoff and rainfall data were recorded.

During June to December of 2011, total rainfall received at the experimental farm was 1067.8 mm and the distribution was uniform through out the crop growing season. The week wise rainfall distributions during the crop growth period are presented in Fig.4.4.1.

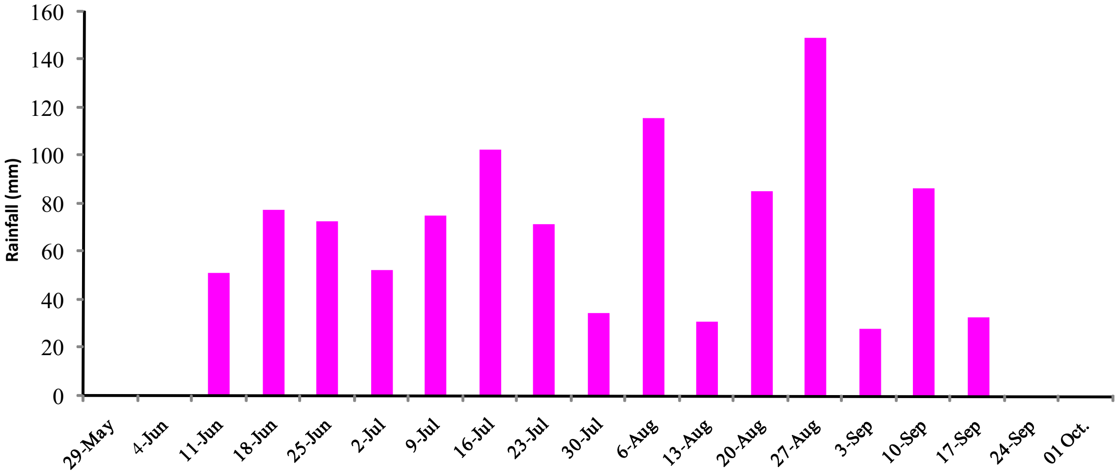


Fig. 4.4.1 Week –wise rainfall distribution (mm) during crop growing period, 2011

Runoff and soil loss through runoff

Total rainfall during crop period of year 2011 was 866 mm. Total quantity of water was 86.6 lakh litre ha^{-1} received through rains during crop period. The maximum runoff and soil loss was recorded under cultivated fallow over sole as well as intercrops. Amongst the sole crops, the highest runoff and soil loss were recorded under pigeon pea and the lowest was in soybean crop. In case of intercrops, the highest run off and soil loss were 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+pigeonpea > soybean + maize > soybean + pigeon pea > soybean. Among the sole crops, the reduction of runoff and soil loss was highest under soybean and the lowest was under pigeon pea crop but in case of intercrops, soybean + pigeon pea (2:1) recorded highest reduction runoff and soil loss and the lowest was in maize +pigeon pea (Table 4.4.6).

Table 4.4.6 Effect of crop covers on run off and soil loss during rainy season in 2011

Treatments	Run off (mm)	Run off (%)	Soil loss (kg ha^{-1})	Run off reduction (%)	% Soil loss reduction (%)
Soybean	212	24	2256	36.9	49.5
Maize	276	32	3186	17.8	28.7
Pigeon pea	296	34	3403	11.6	23.8
Soybean+Maize (1:1)	227	26	2575	32.4	42.4
Soybean+Pigeon pea (2:1)	222	26	2395	33.7	46.4
Maize+Pigeon pea(1:1)	235	27	2742	29.9	38.6
Cultivated fallow	335	39	4468	--	--

Nutrients losses through run off

Soil sediment samples were collected through runoff and analyzed for soil organic carbon, total phosphorus and total potassium. The maximum loss of soil organic carbon (SOC), total P and K were recorded under cultivated fallow as compared crop covers treatments. Among the crop covers treatments, the maximum nutrient losses were recorded under sole crops namely maize and pigeon pea and the lowest was in soybean crop and intercrops (Table 4.4.7).

Table 4.4.7 Nutrients loss (kg ha^{-1}) through runoff under different crop covers during rainy season

Treatments	SOC	Total N	Total P	Total K
Soybean	18.3	3.38	0.66	23.6
Maize	28.4	6.57	0.79	29.8
Pigeon pea	27.9	6.49	0.78	30.2
Soybean+Maize (1:1)	22.9	5.01	0.70	21.0
Soybean+Pigeon pea (2:1)	19.2	4.18	0.67	17.1
Maize+Pigeon pea(1:1)	26.1	5.59	0.67	18.0
Cultivated fallow	37.9	8.71	0.97	37.8

Crop and soybean grain equivalent yield (SGEY)

Sole crops namely soybean, maize and pigeon pea recorded higher crop yields as compared to intercrops (Table 4.4.8). Intercrops maize+ pigeon pea (1:1), recorded higher soybean grain equivalent yield followed by pigeon pea, maize, soybean + maize (2:1), soybean + pigeon pea (2:1) and soybean, based on minimum support price (MSP). Based on yield data, it is indicated that maize crop in combination with pigeonpea recorded the highest soybean grain equivalent yield.

Table 4.4.8. Crops yield and soybean equivalent grain yield under different crop covers in 2011

Treatments	Soybean yield (kg ha^{-1})	Maize yield (kg ha^{-1})	Pigeon pea yield (kg ha^{-1})	SGEY (kg ha^{-1})
Soybean	329	--	--	329
Maize	--	3354	--	1992
Pigeon pea	--	--	1061	2058
Soybean+ Maize (1:1)	113	1595	--	1060
Soybean+ Pigeon pea (2:1)	219	--	322	843
Maize+ Pigeon pea(1:1)	--	2163	531	2315

Minimum Support Price: Soybean Rs= 1650, Maize Rs = 980 and Pigeon pea Rs = 3200

4.4.5 Characterizing rooting behaviors of soybean crop under different tillage management practices in a Vertisol

The project was initiated with sowing of two soybean cultivars (cv JS 335 and JS 9305) during *kharif* season of 2011 under conventional and no-tillage. Plant root samples were taken at different growth stages of soybean like V4, V6, R1, R3, R5 and R7 (Physicologal growth stages). The result showed that root length distribution across different diameter classes was in lower diameter classes (Fig.4.4.2).

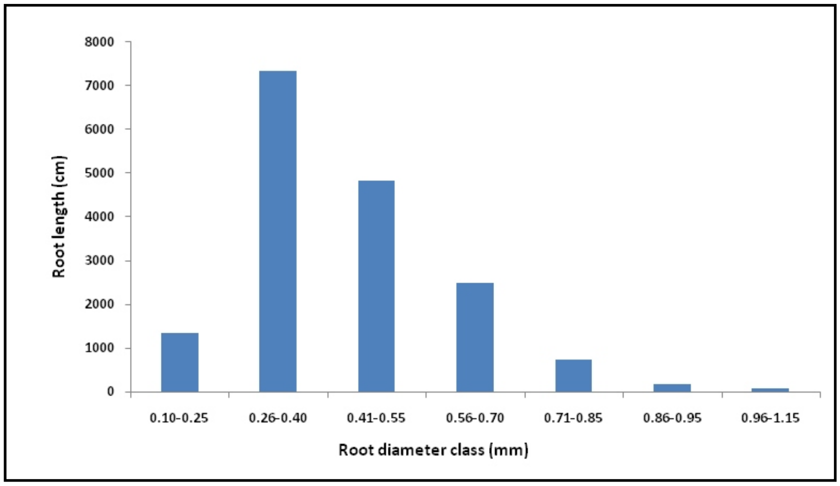


Fig.4.4.2 Root length distribution across different diameter classes for soybean cultivar

Maximum root length density (RLD) was observed at flowering stage (R1) for both the cultivar under both the tillage treatments. Long duration cultivar (JS 335) showed higher RLD distribution with depths compared to shorter duration cultivar (JS 9305) (Fig.4.4.3). It was because of the fact that RLD was a function of vegetative growth, so a variety with longer vegetative phase will have higher RLD. An exponential model was also tested to get the profile distribution of RLD and result showed that difference in observed and predicated RLD varied between 9.93 to 13.50 % (Table 4.4.9).

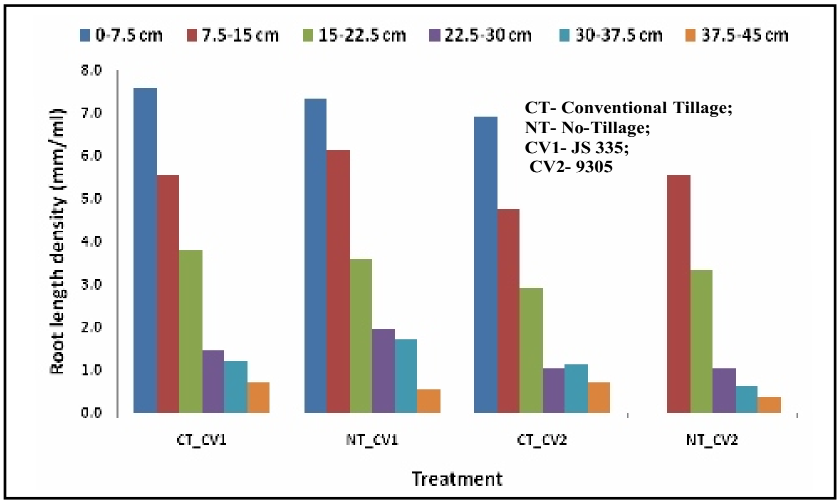


Fig. 4.4.3 Distribution of root length density (RLD) at flowering stage (R1) stage for soybean cultivar under different tillage systems

Table 4.4.9 Root mean square error (RMSE) and relative root mean square error of observed and predicted RLD at flowering stage for soybean cultivars under different tillage

Sampling stage	Treatments	RMSE (mm cm^{-3})	Relative RMSE (%)
Flowering (R_1)	CT_CV1	0.46	13.50
	NT_CV1	0.44	12.16
	CT_CV2	0.31	10.77
	NT_CV2	0.30	9.93

CT- Conventional tillage; NT- No-Tillage; CV1- JS 335; CV2- 9305

4.4.6 Effect of Conservation Tillage and various Cropping systems on weed biomass, organic carbon and crack volume in black soils

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 (Plate 4.4.1).

First year post-harvest soil samples were analyzed for soil organic carbon content. The SOC was higher in surface layer (0-15 cm) than in the sub-surface (15-30 cm) under both tillage systems. Irrespective of soil depth, SOC was found to be more under reduced tillage (RT) compared to conventional tillage (CT) system. However, significant difference was observed only under soybean cropping system at 0-15cm depth.

The second year experimental *kharif* and *rabi* crops (2nd year crop rotation) were taken up during first week of July 2011. Weed biomass, leaf litter and surface crack observations were recorded. From the weed biomass data, it was inferred that among the soybean based cropping systems studied, soybean+ cotton (2:1) recorded significantly higher weed biomass as compared to other systems. However, maize–gram system recorded higher weed biomass than soybean based cropping system. Although, population of broad leaved weeds was less under reduced tillage (RT) due to herbicide spray, grassy weeds were found to be more. The data showed that various cropping systems had clear effect on leaf litter addition to the soil and also on crack volume. Among the various cropping systems compared, soybean + pigeon pea (2:1) recorded the highest leaf litter addition followed by soybean+ cotton (2:1) and soybean-wheat systems. Maize–gram system recorded the highest crack volume among the six cropping systems compared. Reduced tillage (RT) recorded higher leaf fall/crop residue addition than conventional tillage system.

A project was sanctioned under competitive grant component (CGC) of NICRA-ICAR with a budget outlay of Rs 75.0 lakh with a basic aim to generate information on conservation agriculture in black soil with the following objectives i) to evaluate dominant cropping systems/sequence and conservation tillage for stabilizing crop productivity and its economics in black soils of Central India, ii) to study the effect of conservation agriculture (CA) on energy, nutrient and water fluxes and green house gases (GHGs) emission under different cropping systems and iii) to evaluate soil aggregation and carbon sequestration mechanisms under different tillage and cropping systems in black soils.

Plate 4.4.1 A view of experimental crops at research farm

4.4.7 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

Experimental field was prepared using laser land leveller (Plate 4.4.2) followed by Duckfoot cultivator by criss-cross ploughing. Immediately, sowing of *Rabi* crops i.e wheat and gram was taken-up. Biometric observations and soil moisture data at periodical intervals were recorded. The pH, EC, and OC varied from 8.16 to 8.17; 0.14 to 0.16 dS m^{-1}; 0.52 to 0.56 %, respectively. The organic carbon content showed a trend of decreasing content with increasing depth. The available phosphorus, potassium, microbial biomass carbon

(SMBC) and DHA also followed the similar trend. Yield parameters were recorded. The grain yield of wheat varied from 22.0 to 31.8 q ha^{-1} with an average of 28 q ha^{-1} and that of gram from 7.0 to 9.9 q ha^{-1} with an average of 8.5q ha^{-1} , respectively. Similarly, biomass yield of wheat after leaving the sufficient crop residues in the field, varied from 24 to 28 q ha^{-1} with an average of 26 q ha^{-1}; gram biomass yield varied from 4.7 to 6.3 with an average of 5.5 q ha^{-1}.

Plate 4.4.2 Demonstration of land leveling and its importance among farmers

4.4.8 Tillage effect on weed dynamics in soybean-wheat system on Vertisol

The predominant weeds observed in soybean (*Kharif*, 2011) were *Echinochloa colona*, *Cyperus rotundus*, *Saccharum spontaneum*, *Cynodon dactylon*, *Euphorbia hirta*, *Digera arvensis*, and *Tridex procumbens*. However, during previous year *Alternenthera sessilis* and *Trianthema portulacastrum* were the predominant weeds in tilled plots. Weeds shifts oriented to tillage system could not get confirmed in this experiment. It is because long term changes in weed flora are driven by an interaction of several factors: tillage, environment, crop rotation, crop type and the timing and type of weed management practice. Thus, several studies also indicated that weed species shifts have been inconsistent. Weed density (monocot as well as dicot weeds) was the least in the mold board (MB) plough treatment and the highest in no till (NT) and reduced tillage (RT) treatment, (Table 4.4.10). The weed abundance was the highest in NT (no tillage) followed by RT (reduced tillage), CT (conventional tillage) and MB (MB plough tillage) during crop growth stages. The RT and NT treatments had fewer monocot weeds than the dicot weeds because of the use of pre-emergence herbicide. Weed biomass accumulation differ significantly from one crop stage to another. Weed control efficiency (WCE, %) was also determined. The WCE was the lowest in NT followed by RT. The WCE differ with weed control system and tillage at first stage. However, there were no differences amongst the tillage treatments after 60 DAS and was found to vary from 80.9 to 91.6%.

Tillage system (NT, RT, CT and MB) did not influence soybean yield, however, it was in the ascending order as NT< RT< CT< MB (Fig. 4.4.4). Response to tillage treatments in soybean was not significant due to low soybean yield level (317-369 kg ha^{-1}) compared to its potential yield. However, time of weeding had significant influence on soybean yield. Weedy check (no weeding) recorded the lowest yield (247.8 kg ha^{-1}) as weed free period progresses the yield gradually increased from 301.9 kg ha^{-1} (weeding at only 30 DAS) to 496.6 kg ha^{-1} (weeding at 30 and 60 DAS). Weed index (WI) indicates the reduction in yield due to presence of weeds. The NT and RT treatments showed higher WI compared to CT and MB. The weed index gradually reduced from 53-61% for weedy check to 46 -51% at first weeding and 5-22% at second weeding.

Table 4.4.10 Weed density and biomass accumulation as affected by tillage system

Tillage	Weed abundance at 60 DAS (no. m^{-2})		
	Monocot	Dicot	Total
NT	0.7 (1.08)	25.0 (5.05)	25.7 (5.12)
CT	2.0 (1.58)	13.3 (3.72)	15.3 (3.98)
RT	3.7 (2.04)	19.3 (4.45)	23.0 (4.85)
MB	1.0 (1.22)	9.7 (3.19)	10.7 (3.34)
		Weed biomass (g m^{-2})	
		30 DAS	
NT	54.64	36.08	90.72
CT	5.32	8.17	13.49
RT	4.41	1.31	5.72
MB	2.17	11.12	13.29
		60 DAS	
NT	8.79	6.75	15.53
CT	9.79	3.95	13.74
RT	4.55	11.43	15.98
MB	4.22	10.41	14.63

Values in brackets represents Square Root Transformation ($\sqrt{X+0.5}$) for weed numbers

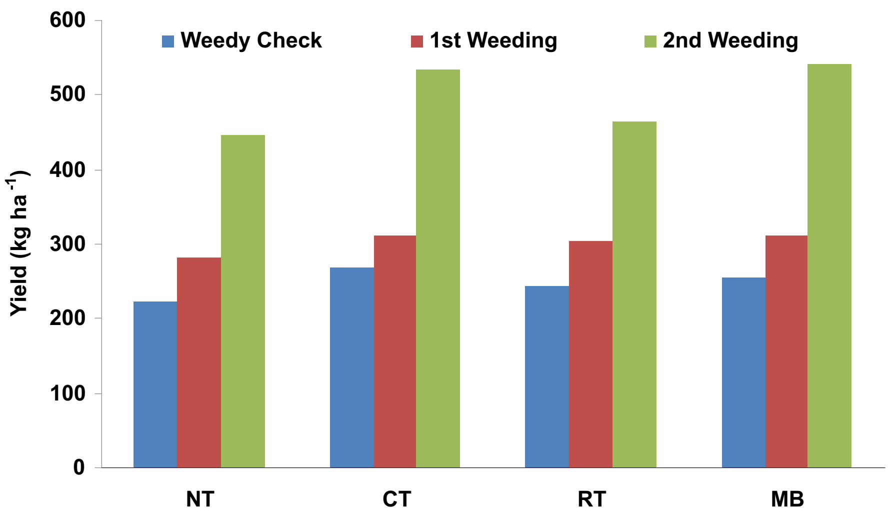


Fig. 4.4.4 Effect of tillage and weed control method on soybean yield

4.4.9 Carbon sequestration, emissions and net carbon flux in soybean-wheat system: comparing tillage practices in vertisols

A holistic approach (cradle to grave) is needed to evaluate the efficacy of agriculture practices in sequestering carbon and mitigating adverse effect of climate change. After three years of soybean-wheat cropping system soil carbon sequestration was found to be significantly higher in no tillage (257 kg/ha/yr) in surface 5cm soil depth compared to reduced tillage (34 kg/ha/yr). However carbon sequestration in surface to 45 cm soil depth was significantly higher in reduced tillage (2125 kg/ha/yr) than no tillage (1656 kg/ha/yr) probably because the residue is incorporated in case of reduced tillage (RT). Carbon emissions from use of agricultural inputs and farm machinery in soybean-wheat system were more in No tillage 215.7 kg C ha^{-1} yr^{-1} and least in reduced tillage (193.5 kg C ha^{-1} yr^{-1}). However, the net C flux to atmosphere was positive in conventional tillage (210.2 kg C ha^{-1} yr^{-1}) and negative in reduced tillage (-2142 kg C ha^{-1} yr^{-1}) and no tillage (-2082 kg C ha^{-1} yr^{-1}). Therefore among conservation tillage, reduced tillage helps in sequestering more carbon in the entire soil profile (upto 45 cm soil depth) in vertisols under soybean-wheat system.

4.4.10 Selective alternative N management practices on crop yield and soil organic C dynamics in soybean-wheat cropping system: Impact of climate change

The study describes how effectively the resources like water and N can be saved in the context of climate change. A well parameterized and validated APSIM model has been used for this study.

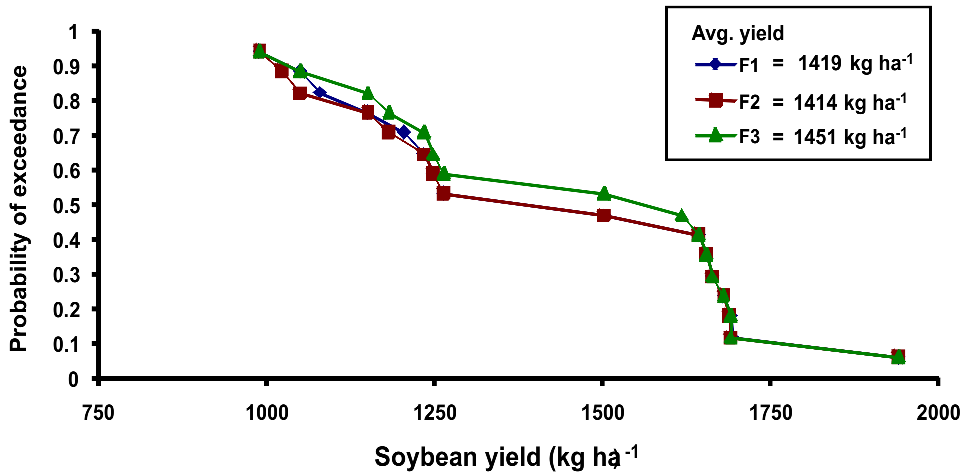


Fig. 4.4.5 Managemnet practices on soybean yield as predicted by APSIM model (cv JS 335)

The study of alternate N management practices for soybean-wheat cropping system was considered with three N management scenarios (F1 = 20 kg N to soybean and 100 kg N to wheat per ha^{-1}; F2 = 8 t FYM to soybean and 50 kg N to wheat per ha^{-1} and F3 = 16 t FYM to soybean and 0 kg N to wheat per ha^{-1}). The average predicted long-term (16 years) yield of soybean and wheat observed to be similar under all three N management scenarios (Fig.4.4.5 and Fig. 4.4.6). This suggested that use of alternative N management to inorganic fertilizers application is possible to obtain similar yields by the use of organics.

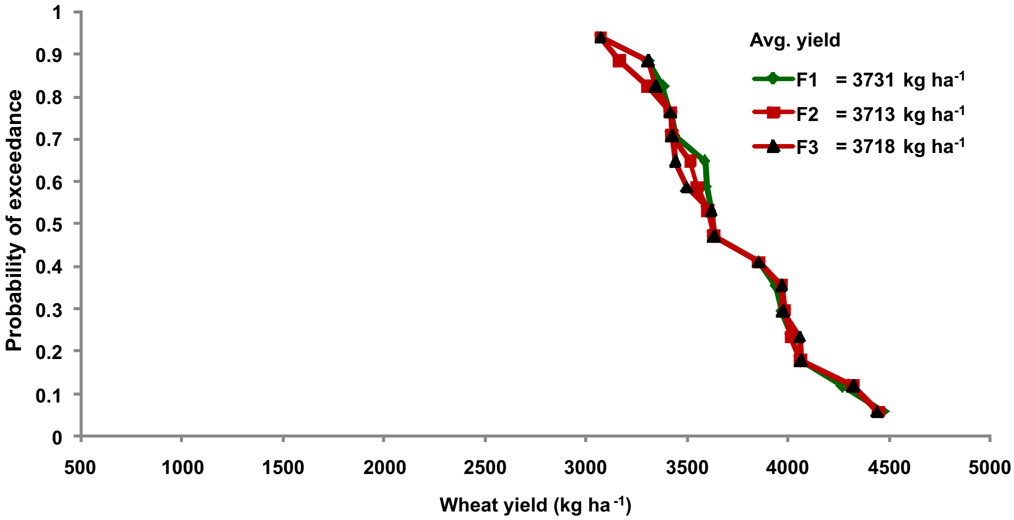


Fig. 4.4.6 Managemnet practices on wheat yield as predicted by APSIM model (cv C 306)

Both crops were clearly influenced by water stress during important phenological stages (e.g., pod fill and grain fill) due to increase in temperature or reduced rainfall/irrigation situation. Successful adaptation strategies such as increasing plant density and advancing the date of sowing minimized water stress during these stages. The N use by both crops was also decreased due to increased temperature. So, the options of managing N fertilizer under climate change scenarios should be considered.

Using the proposed model, the water and N use from different sources (organic, inorganic and integrated approach) by soybean and wheat can be estimated for given climatic conditions and growing seasons, which makes it possible to modify the growing season, water and N management for climate change. In the study, it was also observed that the increased surface temperature to 4 degree may significantly decrease the wheat yield from the normal temperature (Fig. 4.4.7).

Further simulation was carried out to explore the possibility of efficient use of the resources such as irrigation

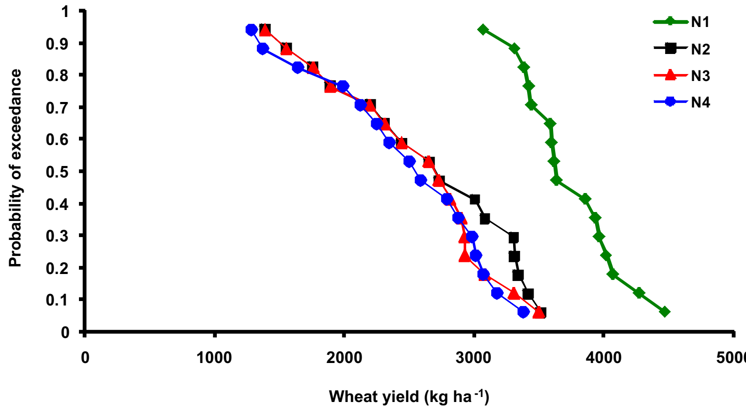


Fig. 4.4.7 Wheat yield (adaptation strategies) (N1 = normal; N2 = plus 4 degree + 4 irrigation and 100 kg N; N3 = plus 4 degree + 3 irrigation and 100 kg; N4 = plus 4 degree + 3 irrigation and 50 kg N)

water and N fertilizer in the context of climate change. Results revealed that in increased temperature scenarios, grain yield obtained from the application of 4 irrigations with 100 kg N ha^{-1} to wheat is at par with the yield obtained from 3 irrigations with 50 kg N ha^{-1} to wheat. Thus it suggested that in the present increased temperature scenario where the crop growing period is reduced by a week or so, it is possible to save valuable and important inputs such fertilizer N and irrigation water applied to wheat (Fig. 4.4.7).

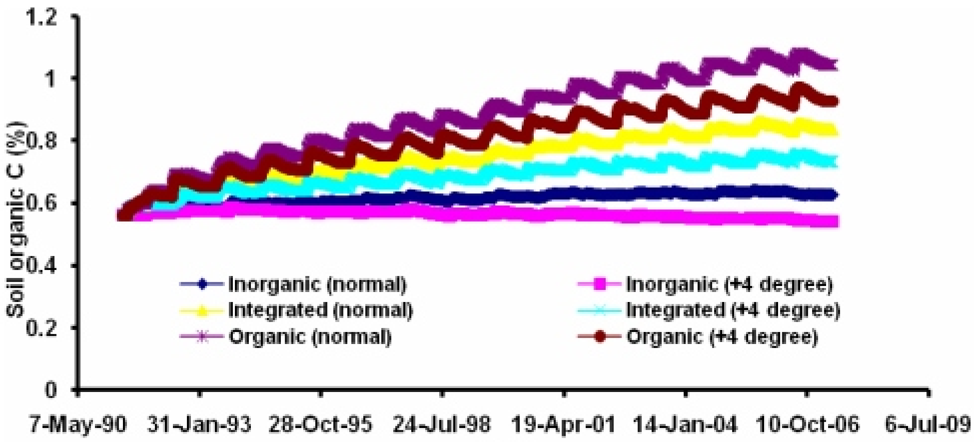


Fig. 4.4.8 Soil oranic C at surface soil (0-15 cm) as influnecd by increased temperature

Similar results were also obtained from the application from integrated and organic N sources to the cropping system. But apart from the application of organic manures, in alone or in combination with fertilizer N, it was revealed that the organic C content at the surface soil (0-15 cm) increased over pure application of fertilizer N (Fig. 4.4.8). Thus, there was increase in soil organic C in addition to yield of wheat at par with inorganic fertilizer application under increased temperature scenario condition. So application of organic manures alone or in combination with inorganic fertilizer not only yield similar grain yield at par with inorganic source of nutrients but also improved C sequestration in soils under climate change scenarios.

4.5 Monitoring Soil Chemical Parameters

4.5.1 Effect of lime and FYM application on soil properties, extractable Zn and Zn nutrition of maize crop grown on acid soil

Deficiency of Zn in some acid soils is observed due to low Zn content, formation of zinc sulfide and application of lime. A pot experiment was conducted using two acid soils (collected from Ranchi having pH value 5.8 and Bhubaneswar having pH value 4.5) with different levels of farm yard manure (FYM) (0 and 10 t ha^{-1}), lime (0, 1/10, 1/3, 2/3 and full lime requirement (LR)) and Zn (0, 2.5 and 0.5 mg kg^{-1}) to study the effect of their application on soil properties and Zn nutrition of maize crop. Maize plants (variety KH 101) were grown in pots up to 60 days. Soil pH was significantly influenced by application of graded levels of FYM and lime. In Ranchi soil, pH increased with application of 1/3 LR onwards whereas soil pH increased with application of 1/10 LR in Bhubaneswar soil. DTPA extractable Zn in soil was increased significantly with addition of FYM and Zn in both the soils. Biomass yield was significantly affected by the application of different levels of lime and Zn. It increased up to 1/3 LR. Concentration of zinc in plant was influenced by FYM, lime and Zn the application. Zn content was increased with increased levels of FYM and Zn and decreased with increased levels of lime application.

DTPA, Mehlich 1, 0.1 M HCl and ABDTPA extractable Zn in soil was also increased significantly with addition of FYM and Zn in both the soils. Biomass yield in Ranchi soil was significantly correlated with DTPA, Mehlich 1, 0.1 M HCl and ABDTPA extractable Zn in post harvest soil whereas in Bhubaneswar soil, DTPA extractable Zn was not correlated with biomass yield. Zn concentration and Zn uptake by maize was significantly correlated with DTPA, Mehlich 1, 0.1 M HCl and ABDTPA extractable Zn in post harvest soil. Correlation coefficient values indicated that both DTPA and ABDTPA extractants can be used for the extraction of available Zn in acid soils.

4.6 Improving Soil Biological Condition

4.6.1 Soil organic dynamics vis-à-vis anticipatory climatic changes for crop adaptation strategies

The effect of temperature (25, 35 and 45º C) on CO_2 evolution at 60 % moisture holding capacity was studied under laboratory conditions for 16 weeks in different aggregate size classes such as macroaggregate (250-2000 µm), micro aggregate (53-250 µm) and the mineral associates fractions (<53 µm). Irrespective of temperature CO_2 emission was higher in macroaggregate (250-2000 µm) followed by micro aggregate (53-250 µm) and the lowest in mineral associates (<53µm) CO_2 emission from macroaggregates increased with temperature but similar effect was not found in micro aggregates and mineral associates (silt + clay fraction). Microbial respiration rate constant (k) in most recalcitrant pools (<53 µm) increased by 5 to 13.9 % at 45 °C as compared to 25°C in all the treatments. A significant difference in the concentration of C in the macro-aggregate (250-2000-µm), micro aggregate (53-250-µm), and mineral associated organic matter (<53-µm) were reflected in differences in microbial respiration rate and labile pools in different aggregates size classes (Table 4.6.1). The amount of labile size pool (A_0) was greater in macro aggregates followed by micro aggregates and least was observed in recalcitrant fraction. Amednedmnet of N fertilizer stimulated CO_2-C rate in N, N-P and N-P-K treatments and further increased with FYM addition treatment. A_0 increased from 4.9 to 55.4% in the substrate pools in different treatments at 25 to 45°C in macroaggregate. Likewise mineralization rate (k_{resp}) increased from 10.5 to 32.5% in these treatments. The soil enzymatic activities, bacterial and fungal respiration, microbial biomass carbon and heterotrophic population were estimated under three temperature situations after 16 weeks of incubation (Fig. 4.6.1A-F). Microbial biomass, FDA and DHA activity significantly increased with temperature and was the highest in FYM + NPK (Fig. 4.6.1A, B, and E). Bacterial and fungal respiration increased with temperature (Fig. 4.6.1C and D) however the ratio of bacterial and fungal SIR decreased with increasing temperature. Irrespective of treatments, the population of heterotrophic bacteria was greater at 45°C compared to 25°C (Fig. 4.6.1F). Study revealed that C mineralization rate depend on types and amount of substrate utilizated by microbes. And higher temperature enable microbes to decompose larger portion of SOM (Soil organic matter).

Table 4.6.1 Effect of temperature on microbial respiration rate (K_{resp}) and pool size labile substrate (A_0) in different aggregate size classes under different fertilizer and manure application.

Treatments	Microbial respiration rate K (K_{resp} wk^{-1})								
	25ºC			35ºC			45ºC		
	250-2000	53-250	<53	250-2000	53-250	<53	250-2000	53-250	<53
	µm								
Fallow	0.077b	0.072a	0.058a	0.088a	0.072b	0.055a	0.083b	0.074b	0.05b
Control	0.076b	0.065b	0.047b	0.08a	0.075b	0.056a	0.084b	0.073b	0.048b
100% N	0.072b	0.067b	0.037c	0.091a	0.081b	0.041b	0.087b	0.076b	0.053b
100% NP	0.058c	0.04c	0.011e	0.061c	0.053c	0.034c	0.079b	0.06b	0.031c
100% NPK	0.088a	0.071a	0.021d	0.075b	0.067c	0.056a	0.08b	0.076b	0.05b
100% NPK+FYM	0.083a	0.077a	0.063a	0.098a	0.090a	0.051a	0.11a	0.093a	0.067a

Treatments	Pool size of labile substrate (A_0, mg C 100 g^{-1})								
	25ºC			35ºC			45ºC		
	250-2000	53-250	<53	250-2000	53-250	<53	250-2000	53-250	<53
	µm								
Fallow	107.2a	89.5a	49.9b	101.7b	91.7b	49.8d	102.3b	99.8c	49.8e
Control	93.5b	75.8c	62.1a	92.5c	87.1c	63.0a	93.5c	86.6d	60.3c
100% N	89.1d	79.5b	50.9b	105.7b	105a	59.8b	93.5c	102.6b	67.1b
100% NP	70.5e	56.4e	36.7d	72.6d	64.4e	48.3e	93.4c	66.9e	48.9e
100% NPK	102.4a	72.5d	42.5c	97.9c	76.3d	56.8c	103.7b	89.6d	57.1d
100% NPK+FYM	91.5c	87.1a	62.5a	117.5a	107.1a	55.8c	142.2a	131.1a	85.5a

†Within a column treatment means followed by different lowercase letters are significantly different at $P \leq 0.01$ by the Duncan's Multiple Range test.

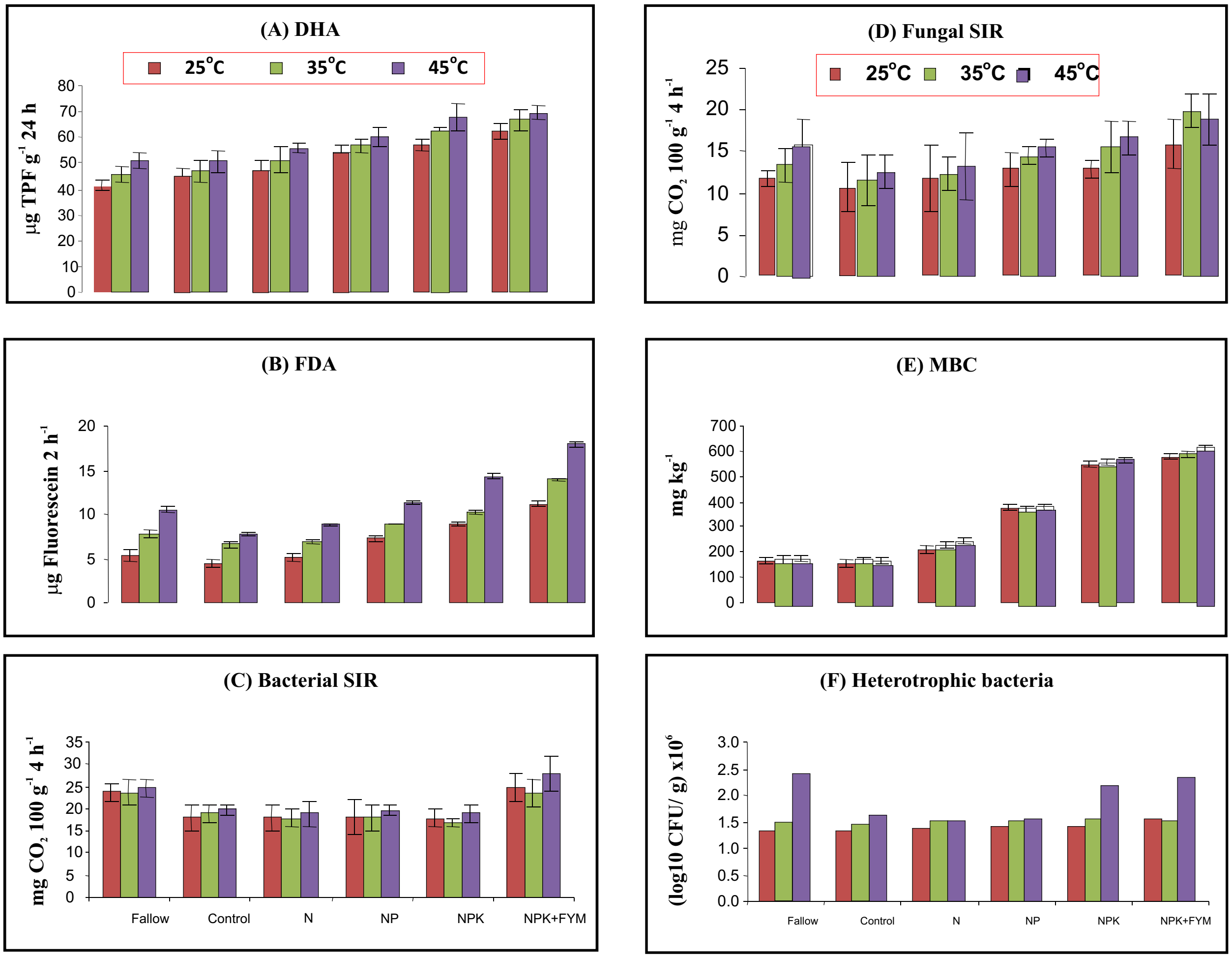


Fig. 4.6.1 **(A) Dehydrogenase activity(DHA) (B)Fluorescein diacetate (FDA) (C) Bacterial substrate induced respiration(SIR) (D) Fungal substrate induced respiration, (E) Microbial biomass C (MBC) and (F) Heterotrophic bacteria as influenced by 25, 35 and 45ºC under different manure and fertilizer application after 16 weeks of incubation. Bars labeled with different letters are significantly different between treatments at *P*≤0.05 by the Duncan's Multiple Range Test.**

4.6.2 Soybean quality assessment under long term fertilizer experiment (LTFE)

Soybean seed samples from LTFE of Jabalpur and Ranchi centers were analysed for the nutritional quality. 100-seed weight of soybean varied significantly in different fertilizer treatments over control. The highest 100-seed weight and protein content was recorded in 100% NPK + FYM and the lowest in control. Similar results were also recorded in Ranchi centre. Oil and methionine (S-containing amino-acid) content in soybean seed was at par with 100% NPK + FYM and 150 % NPK treatments followed by 100 % NPK treatment. Similar results were also recorded in LTFE Ranchi centre (Table 4.6.2).

Table 4.6.2 Nutritional quality constituents of soybean seed at Jabalpur and Ranchi LTFE Centre

Treatments	Jabalpur				Ranchi			
	100-grain wt (g)	Protein (%)	Oil (%)	Methionine (g/16g N)	100-grain wt (g)	Protein (%)	Oil (%)	Methionine (g/16g N)
Control	8.78	35.13	18.9	1.53	8.82	35.23	18.2	1.56
100% N	9.01	36.72	19.6	1.64	9.01	36.85	19.1	1.60
100% NP	9.09	36.91	20.2	1.68	9.12	37.24	19.5	1.64
100% NPK	9.13	37.89	20.7	1.70	9.17	37.95	19.7	1.73
150% NPK	9.22	38.40	20.6	1.75	9.16	38.64	19.1	1.76
100% NPK+FYM	9.30	38.60	20.9	1.74	9.35	38.78	19.2	1.74
100% N PK -S	9.15	38.28	19.5	1.69	9.16	38.13	19.2	1.77
CD=(0.05)	0.11	1.06	NS	NS	0.15	1.12	NS	NS

Nutrient content in soybean seed and nutritionally important micro-nutrient such as Zn, Mn, Fe and Cu contents in soybean seed did not vary significantly due to imposition of different nutrient treatments, except for nitrogen content. However, there was improvement in micro-nutrient contents of soybean seed due to different nutrient treatments as compared to control. The highest increase in Fe, Zn, Mn and Cu content was recorded with the application of 100% NPK + FYM followed by 150 % NPK and 100 % NPK treatments, respectively and the lowest was in control treatment at both the LTFE centres. (Table 4.6.3 and Table 4.6.4).

Table 4.6.3 NPK, Zn and Cu content in soybean seed at Jabalpur LTFE Centre

Treatments	N	P	K	Mn	Fe	Zn	Cu
	(%)			ppm			
Control	5.62	0.27	1.36	23	75	29	5
100% N	5.87	0.32	1.60	24	78	33	6
100% NP	5.90	0.35	1.58	25	80	35	6
100% NPK	6.06	0.40	1.64	26	82	36	7
150% NPK	6.14	0.43	1.68	26	85	37	7
100% NPK+FYM	6.17	0.45	1.70	28	92	39	8
100% NPK -S	6.12	0.31	1.67	25	87	36	6
CD (p=0.05)	0.19	NS	NS	NS	NS	NS	NS

Table 4.6.4 NPK, Zn and Cu contents in soybean seed at Ranchi LTFE Centre

Treatments	N	P	K	Mn	Fe	Zn	Cu
		(%)			ppm		
Control	5.63	0.24	1.59	26	78	31	4
100% N	5.89	0.29	1.62	31	80	33	5
100% NP	5.96	0.40	1.64	30	82	35	5
100% NPK	6.07	0.40	1.67	33	83	36	6
150% NPK	6.18	0.44	1.68	35	86	38	6
100% NPK+ FYM @15 t ha^{-1} yr^{-1}	6.20	0.47	1.69	36	94	41	7
100% NPK-S	6.10	0.31	1.66	32	91	39	5
CD (p=0.05)	0.21	NS	NS	NS	NS	NS	NS

Results from the study showed that, balanced application of nutrients not only resulted in improvement of the nutritional quality constituents such as protein, amino-acid but also improved nutritionally important micro nutrients of soybean and weight of 100 seed samples.

4.7 Microbial Diversity and Biofertilizers

4.7.1 Improving yields and nutrient uptake of selected crops through microbial inoculants in Vertisols of central India (AMAAS).

The project is aimed mainly at utilizing the plant growth promoting rhizobacteria and rhizobia of Vertisols of Central India possessing improved attributes of promoting growth, nodulation, nutrient transforming ability and with competitive antagonist ability for preparing consortia of beneficial microorganisms that can promote greater grain yield in field conditions. The main findings during 2011-12 are summarized below.

Cross nodulation among soybean and chickpea rhizobia

Soybean was nodulated by both soybean and chickpea strains. But chickpea was nodulated by only chickpea strains. Neither soybean nor chickpea strains nodulated *Trifolium alexandrium* (berseem), *Trigonella* (methi) or *Pisum sativum* (Pea). Soybean *rhizobia* also did not nodulate *Vigna radiata* (moong) but they nodulated *V. unguiculata* (Cowpea). Chickpea local strain nodulated moong and cowpea but not reference strain (ca-181)

Nodule occupancy by inoculated rhizobia (competition with native rhizobia)

Seven *Rhizobium* strains of soybean (4) and chickpea (3) were selected on the basis of crop, antibiotic resistance, carbohydrate utilization, ecological origin, and nodulation test, evaluation based experiments conducted in greenhouse and fields for two consecutive years. The nodule occupancy was studied in Vertisols on soybean seeds var. JS-335 and chickpea var. JG-315. It was found that locally adapted nif H and nod C positive rhizobia were more effective and competitive. Based on intrinsic antibiotic resistance effective local soybean *Rhizobium* R33 showed 56% nodule occupancy. Similarly effective local chickpea *Rhizobium* R40 showed 52% nodule occupancy.

Molecular characterization of the rhizobial, PGPR and PGP-B isolates.

Genomic identification of PGPR based on 16s ribosomal DNA was analysed. The bacteria belonged to various species of *Bacillus, Lysinibacillus* and *Dyella* spp. Genomic identification of oligotrophic PGPR based on 16s ribosomal DNA was also done. The bacteria belonged to various species of Bacillus sp. DNA sequence of 23 strains (22 plus 1) of PGPR deposited in gene bank in USA and the cultures were deposited with NBAIM, Mau.

Genomic identification of Rhizobia based on 16s ribosomal DNA was carried out. DNA sequence of 24 strains (17 soybean and 7 chickpea) deposited in gene bank (USA). Seven elite strains (3 soybean and 4 chickpea) were deposited with NBAIM, Mau. Location of nif H and nod C gene in rhizobial genome and plasmid was done by amplification by PCR of the gene and separation by gel electrophoresis. Two most effective local isolates of soybean rhizobia (*Bradyrhizobium sp*.) from Vidisha were nif H and nod C plus like *Bradyrhizobium japonicum* USDA-110 introduced initially in MadhyaPradesh. Similarly two most effective local chickpea strains R40 (Bhopal) and R56 (Barman) were nif H and nod C plus.

Formulation and testing of consortium of microorganisms

Selected promising rhizobial strains and PGPR strains were tested for compatibility among themselves. By and large compatibility of soybean strains was very good. Inoculation of the *Rhizobium* (R33) of soybean in field gave 19.3 % increase in seed yield; PGPR strain P10 gave 28.6 % increase and the combinations of both gave 29.9% increase in Vertisols. In chickpea, the rhizobial strain R40 gave 11.2 % increase in seed yield; PGPR P10 gave 13.2% increase and the combinations of both gave 17.2 % increase in seed yield. In wheat, the PGPR strain P10 gave 13.1 % increase; P10+P25 gave 18.2% and P3+P10+P25 gave 26.0 % increase when inoculated as consortium.

PGPR effect on soil health

Inoculation of 5 effective strains of PGPR on wheat in the field resulted in average increase of total dry matter by 9.2%. There was significant improvement in the activity of acid phosphatase (with 2 strains), alkaline phosphatase (3 strains), associative nitrogen fixers (1 strain), ammonium oxidizers (2 strains) and nitrite oxidizers (all strains). There was significant improvement in soil organic carbon (2 strains), available nitrogen (5 strains) and total nitrogen (5 strains). Overall the results indicated improvement in soil health as a result of PGPR inoculation in wheat.

Impact of Research

Bradyrhizobium japonicum R-33 and PGPR-*Bacillus megaterium* P-3 were supplied for mass production to JNKVV Biofertilizer production centre, Jabalpur. 9,85,250 inoculant packets were prepared with these strains and supplied all over the Madhya Pradesh state since 2009 (378574 during 2011-12).

4.7.2 All India Network Project on Soil Biodiversity-Biofertilizers

Microbial diversity

Diversity of Rhizobia in Indian soils

Studies on the "Genetic Diversity of Rhizobia of Indian Soils" is in progress. 600 rhizobial strains of 20 major legumes isolation and characterized from the major growing zones and soil types in Andhra Pradesh, Madhya Pradesh, Gujarat, Rajasthan, Haryana, Uttar Pradesh and Jharkhand. PCR amplified and gel purified 16S rRNA of 58 rhizobial isolates of soybean and 36 groundnut rhizobia were sequenced. Sequencing of others are in progress. nif H and nod C presence analyzed for selected, promising isolates. Salt tolerant (10% NaCl) rhizobial isolates made from groundnut in Kutch (DGR, Junagarh).

Majority of the rhizobial isolates from semi-arid region of Haryana are IAA producers. The P-solubilization and siderophore producing ability was restricted to a limited number of rhizobial isolates. A total of 43 moong bean *rhizobia* isolated from Sirsa district, Haryana were characterized for IAA production which ranged from 1.2 -37.0 µg ml^{-1} of growth media. 40% of these isolates were able to solubilize P on solid media. A total of 23 rhizobial isolates of *Fababean rhizobia* were obtained from nodules. The MPN counts of bean rhizobia varied from 430-1104 rhizobia/g soil showing the need for inoculation (HAU, Hisar).

Proteomics of Rhizobia

"Proteomic Profiles" of rhizobia of *Cajanus cajan* growing in acid soils of Jharkhand revealed many important protein changes in isolates from normal and acidic pH. Such protein changes, which are unique to the particular pH regime, may be implicated in imparting the selective tolerance / adaptability to the pH regime, and will serve as the prime candidates for future studies involving candidate gene identification by employing techniques such as, N-terminus protein microsequencing and / or Mass Spectrophotmetry analysis (BAU, Ranchi).

P-solublizing bacteria in rice rhizosphere

Two potent P-solublizing bacteria viz. *Bacillus megaterium* and *Enterobacter sp*. were identified. The *Enterobacter sp*. was most efficient at pH 8.0, temperature of 45°C and 10% salt concentration. It produced IAA, HCN and siderophores. The organisms solubilized 172 µg/ml and 167 µg/ml phosphate, respectively in 72 h at 30°C (CRRI, Cuttack).

Zinc solubilizing bacteria from diverse soils

Eleven (11) bacterial cultures capable of solubilizing zinc oxide were isolated from the rhizosphere of paddy and `toria' in NEH region. Zinc solubilizing abilities are in progress (AAU,Jorhat). Zinc solubilized from zinc carbonate by *rhizobacteria* (PSB-3 and PSB-1) in liquid medium after 15 days incubation was ~400 ppm (80%) and 374 ppm (75%). Zn-solubilization was related with drop in pH of the medium. Based on 16S rDNA homology the two strains were identified as *Burkholderia cepacia sp*. In a pot study on sorghum, inoculation of the zinc solubilizing isolates improved the plant height, biomass, leaf area, chlorophyll content etc over uninoculated control, both with and without $ZnCO_3$ application. Application of 100 ppm $ZnCO_3$ in alfisol showed toxic effects that was mitigated by microbial inoculation. Inoculation also improved P and Zn uptake significantly in both sets (CRIDA, Hyderabad).

Establishment of Cyanobacteria in Rice Soils

In wheat (Rabi 2010-11) and rice (*Kharif 2012*), combinations of cyanobacterial strains (BF1 *Anabaena torulosa*, BF2 *Nostoc carneum*, BF3 *Nostoc piscinale* and BF4 *Anabaena doliolum*) along with 75% N+ PK were at par with 100% NPK, thus saving 25% N. In wheat they improved soil health in terms of nitrogenase activity (ARA), soil chlorophyll, microbial biomass carbon, FDA hydrolysis and soil available P. In rice there was 5-10% higher microbial activity, availability of N and K. PCR based amplification profiles generated for four selected cyanobacterial strains using three primers, individually - STRR 1A, STRR $_{mod}$ and HIP $_{TG}$ proved discriminative and found useful in analyzing the establishment of the inoculated cyanobacterial strains in soil. BF1 *Anabaena torulosa* and BF2 *Nostoc carneum* were found to exhibit better establishment proficiency up to harvest stage in soil under wheat crop followed by rice crop (IARI, New Delhi).

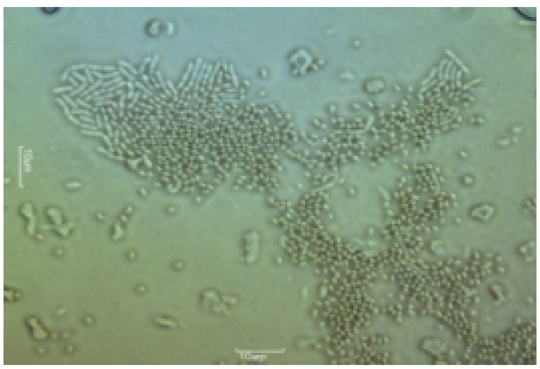
Diversity of fungi in upland rice

The Arbuscular mycorrhizal fungal diversity under rainfed rice based cropping systems, at generic level was repeated and confirmed that *Glomus* was the predominant genus under direct seeded rice based cropping systems in uplands with mostly aerobic soil conditions. However medium lands under transplanted rice with mostly anaerobic soil conditions were dominated by *Gigaspora*. This confirmed the higher anaerobic adaptation of *Gigaspora* (CRRI, Hazaribagh).

Plant growth promoting actinomycetes from arid and semi-arid soils

Actinomycetes were isolated (100 isolates) from rhizosphere soils of sorghum, pearl millet, pigeonpea, finger millet and groundnut in Karnataka, Andhra Pradesh and Rajasthan). Among various media used, humic acid vitamin agar gave about 2.5 times higher counts than other standard media like actinomycetes isolation agar, starch casein agar and arginine glycerol salts medium. Forty one isolates of actinomycetes were further characterized for morphological and biochemical traits. Majority belonged to Streptomyces (61%) (Plate 4.7.1), followed by *Nocardia* (29%) (Plate 4.7.2), *Micromonospora* and Saccharopolyspora (10 % isolates). In screen house experiments, in paper cups using maize as test crop, of the 41 isolates, 8 were highly effective (> 35% increase in plant DW), 10 were moderately effective (25-35%), and 9 strains were effective (15-25%). In chickpea, 10 promising isolates were shortlisted (IISS, Bhopal).

Streptomyces sp.



Nocardia sp.

Soil Genomics

In an effort to develop soil health indicators using soil genomic tools soils under organic management, organic farming and pesticide polluted soils were analyzed.

Organic Farming

The DGGE analysis of the amplicons obtained using universal primers PRBA338 and PRUN 518 primer showed that certain operational taxonomic units (OTU) were present in an increased concentration in organic orchard/cropping while other OTU's had drastically reduced. Thus, the inputs into the soil define the kind and quantum of bacteria that will proliferate in soil. The OTU's in case of the organically grown soybean and maize are higher than in the inorganic soil. The number of OTU's were clearly more at the vegetative stage of soybean and maize indicating their intense activity at the vegetative stage. Additionally, certain OTU's that were enhanced in terms of their population disappeared at later stages (flowering and podding). The gene specific amplicons showed distinct features. Ammonium oxidizers (amoA) were observed both in organic and inorganic soils at vegetative stage. However, they appear in inorganic soil at later stages. The AM representatives, Glomaceae and Gigasporaceae were found higher than Acaulosporaceae in both chickpea and wheat. The nifH appeared in organic soil only at flowering stage in cotton. Thus, it can be clearly seen that crop and its stage defines soil microbial dynamics. The finer analysis will help in rhizosphere engineering to harvest the best out of the crop (UAS, Dharwad).

Impact of long term chemical fertilization

The impact of long-term (100 years) organic management (OM) and inorganic nutrient management (IC) on eubacterial diversity of an alfisol was assessed by metagenomics using 16S rRNA gene sequence polymorphism. Organic management had a positive correlation with soil organic carbon, microbial biomass carbon, macronutrients, culturable microbial counts and enzymatic activities. The continuous application of mineral fertilizers at recommended dosage did not affect the soil variables, as they were on par with control unfertilized soil. The eubacterial community profiling of the soils revealed that proportions of *Actinobacteria* and *Acidobacteria* were considerably increased in OM soil than IC and control soil. The abundance and relative ratio of eubacterial communities remained unchanged due to mineral fertilizers. Interestingly, even though the *Azotobacter* population was significantly higher in OM soil than IC- and control soils, the genetic diversity was unaffected due to long-term addition of either organic manures or inorganic chemical fertilizers. These results emphasize the importance of organic manuring and underscore the recommended dose of chemical fertilizers to maintain the soil biological properties in semi-arid alfisol (TNAU, Coimbatore).

Pesticide pollution

In soils with high fertilizer and pesticide usage in Vertisols of Guntur, microbial counts, nutritional groups, functional groups and soil enzymes showed that usage of chemical fertilizers and other agrochemicals at twice the recommended dosages for blackgram and chilli do not necessarily deteriorate soil health as compared with control soil on the same farm. Clonal libraries of 16s rDNA, of four soils 200 clones each for 16S rRNA, 100 each for nifH and 50 each for phlD sequenced for diversity analysis confirmed the above results (DU, Delhi).

Mixed Biofertilizers

Bionutrient package for rice

Microbial based bionutrient package (enriched *mycostraw* + *Azospirillum* + *Pseudomonas* cyanobacterial inoculants) developed for rice improved grain and straw yield by 11-23% and fertilizer use efficiency by 5-10% in small and marginal farmers in Bihar. There was marked decrease in percentage of unfilled grain to bionutrient package alone or with chemical fertilizer (RAU, Bihar).

Development of organic package for rice

As a system approach in evaluating different organic inputs for rice (compost, enriched compost, green manure and azolla dual culture with or without biofertilizers-root dipping in *Azospirillum* and PSB) for suitable organic package, application of enriched compost @5t ha^{-1} (rock phosphate primed with biofertilizers) with biofertilizers exhibited highest grain yield of 3.71 t ha^{-1} compared to application of only enriched compost (3.52 t ha^{-1}). Likewise, azolla dual culture, compost and green manure in conjugation with biofertilizer yielded 3.50, 3.37 and 3.22 t ha^{-1} respectively indicating 9-15% yield increase over corresponding non-biofertilizer treatments (AAU, Jorhat).

PGPR in alfisol

Biofertilizer strains with PGPR activity that are able to withstand abiotic stresses were identified. Under field conditions in alfisol, inoculation of *Azotobactor* AZT-21+ *Pseudomonas sp.* P-7 improved fodder yield (22%) and grain yield (15%) of sorghum and grain yield of pigeonpea (17%) over uninoculated control treatment (CRIDA, Hyderabad).

Sweet Sorghum

Application of chemical fertilizers upto 100% RDF (80:60:40 kg N, P_2O_5 , K_2O ha^{-1}) along with dual inoculation of *Azospirillum* + *Gluconacetobacter* significantly increased the green stalk yield (15.1%), millable cane yield (13.1%), grain (30.2%) and juice yield (30.2%) of sweet sorghum over control. 100% RDF alongwith dual inoculation of *Azospirillum* + *Gluconacetobacter* also improved the juice quality (TSS, fermentable sugars) and nutrient uptake by the crop up to significant level (MAU, Parbhani).

Soybean, chickpea, wheat in Vertisols

Inoculation of the *Rhizobium* (R33, R35) of soybean in field gave 17 % increase in seed yield, however best PGPR strains (P3, P10 and P25) gave 23% increase and the combinations of rhizobia and PGPR gave 28% increase in seed yield in Vertisols. In chickpea, the rhizobial strains (R40, R56, R58) gave an average increase of 7.6 % increase in seed yield; best PGPR strains (P3, P10 and P25) gave 9.7 % increase and the combinations of rhizobia and PGPR gave 14.5 % increase in seed yield. In wheat, the PGPR strains gave 11.3 % increase when inoculated individually, or 16.0% in any two combinations and 26.0 % when all three were inoculated as consortia (JNKVV, Jabalpur).

Biofertilizers for Blackgram

Tweleve bradyrhizobial strains of blackgram were isolated and screened in pot culture. The mix of BLG 121, BLG 127 and BLG 130 along with PSB, PGPR and AM Fungi gave 210 kg ha^{-1} extra seed yield than 100% RDF (ANGRAU, Amaravathi).

Millet based cropping for acid soils

Ragi-berseem-green gram were grown in sequence with addition of fertilizers and bioinoculation *(Azotobacter* + *Azospirillum* + PSB). After the harvest, the residues of respective crops were incorporated in respective treated soils. `Aswagandha' crop was grown thereafter without addition of nutrients. All the crops were benefited by bioinoculation (greengram (30.2%), ragi (29.1%), berseem (23%), aswagandha (6.6 %) compared to no BI. Liming of acid soil (pH 5.1) increased the efficiency of bioinoculants further. Influence of bioinoculation was more beneficial with vermicompost application to ragi and berseem crops but with FYM for greengram and aswagandha (OUAT, Bhubaneswar).

Biofertilizers for coastal acid saline soils

Bioinoculation in integrated nutrient management package increased the economic yields of sunflower, groundnut and potato crops by 11.8, 5.7 and 10.1 % compared to no inoculation package of practice in coastal acid saline soils (OUAT, Bhubaneswar).

Bt Cotton

In studies on effect of transgenic cotton on yield and soil health parameters it was observed that Bt cotton yielded significantly more seed yield (1977 kg ha^{-1}) over non-Bt (1692 kg ha^{-1}). Dual inoculation of *Azotobacter* + PSB was found to increase yield significantly (2156 kg ha^{-1}) over single inoculation of *Azotobacter* (1805 kg ha^{-1}) or PSB (1865 kg ha^{-1}) cotton. Single inoculation of either *Azotobacter* or PSB was superior over uninoculated control (1505 kg ha^{-1}). Significantly better effect was observed when biofertilizers were applied to cotton by mixing in compost (2151 kg ha^{-1}) as compared to seed treatment (1612 kg ha^{-1}). Average population of bacteria in soil in Bt-cotton rhizosphere (2.35 CFU x 10^{-8}) was comparable to non-Bt cotton rhizosphere soil (3.25 CFU x 10^{-7}) (MAU, Parbhani).

Biofertilizer Technology

Biofertilizer delivery for groundnut

Different delivery systems of application of the consortium of beneficial bacteria (PGPR: *Pseudomonas sp*. C185; *Pseudomonas sp*. ACC3; PSM: *Pseudomonas sp*. ACC 10 + B. *megaterium*; and groundnut rhizobia: TAL 1000 and NRCG 22) were tested in field. The delivery comprised application of consortia through irrigation water, as seed treatment through carriers like sterile farm soil, talcum powder, kaoline, charcoal, and FYM. Sterile soil was the best carrier resulting in significantly higher pod yield (14.7%) of groundnut over uninoculated control with cultivar TG 37A besides improvement of root and shoot length, plant biomass, and shelling out-turn (DGR, Junagadh).

Liquid biofertilizer formulations

Liquid inoculants with 50% RDF gave maximum nodule number and dry wt in pigeon pea and supported the maximum population of all microbial groups in the rhizosphere of pigeon pea at 90 DAS. A complex medium, MGM3 capable of supporting the growth of *Azospirillum*, PSB, and PGPR ((log 9.0 CFU/ml of each organism) and MGM8 supporting the growth of *Rhizobium*, PSB and PGPR (log 8.9 CFU/ml of each) was formulated. In pot experiments, growing of each organism separately and mixing at the time of application or growing together in a complex medium and applying to crop resulted in yields that were statistically at par (ANGRAU, Amaravathi).

Evaluation of different carriers for the promising cyanobacterial consortium

Eight carriers [paddy straw compost, kaolin, sodium alginate, hydrogel, vermiculite: kaolin (1:1), vermiculite: compost (1:1); soil: charcoal (1:3); liquid formulation] were tested for their utility as carriers for the selected cyanobacterial consortium (BF1+BF2+BF3+BF4). vermiculite : compost (1:1), vermiculite: kaolin (1:1) and compost proved to be the most promising carriers, in terms of biomass up to 90 d storage at room temperature (IARI, New Delhi).

Diversification of Biofertilizers

Temperate Horticulture

PGPR from cauliflower identified by 16S r DNA analysis as *Bacillus pumilus*. 10 bacterial isolates associated with Capsicum in H.P., selected from screening for PGP traits and antagonism against major fungal diseases i.e., damping off (*Pythium sp.*) blight (*Phytophthora sp.*) and anthracnose fruit rot (*Colletotrichum sp.*). Screened 27 efficient PGPR isolates associated with tomato for multifarious plant growth promoting traits. Efficient PGPR isolate from medicinal plant Valeriana identified and characterized as *Aneurinibacillus aneurinilyticus* and P solubilizer as *Bacillus subtilis* (YSPUHT, Solan)

Field demonstrations of developed technology (application of *Bacillus pumilus* and 75% recommended doses of chemical fertilizer) resulted in 30% increase in curd yield in cauliflower besides saving 30 kg N and 20g P ha^{-1} (YSPUHT, Solan).

Application of liquid formulation of single strain multi-functional biofertlizer and biocontrol agent *Bacillus lichiniformis* CKA1, on 10 year old white root rot infected apple trees in orchard resulted in significant improvement in plant health and vigour. Rejuvenation of fresh and healthy shoots was observed for the third year also and increased the fruit yield by 43 to 70%. In healthy orchards the yield increase was 35-45% (YSPUHT, Solan).

4.7.3 Consequences of transgenic cotton on soil microbial diversity

Soil samples from rhizosphere were collected from the transgenic as well as non transgenic cotton fields. Samples were anlaysed for biological parameters on major Bt and non-Bt cotton based cropping system, like soybean, red gram, wheat and vegetables in Vertisol of Nagpur districts, Maharastra. It was observed that Bt-cotton based cropping system as compare to non-Bt-cotton system had maximum impact on soil biological and biochemical activities such as soil microbial biomass carbon, soil respiration, dehydrogenase and glomalin protein content followed by cotton-red gram, cotton-wheat, cotton-vegetables and cotton-fallow. In general, it is proved that all properties showed the highest activities under Bt cotton as compared to non-Bt cotton based cropping system (Table 4.7.1). Soil biological activities were significantly correlated with soil active pools of carbon (water soluble carbon, carbohydrates and microbial biomass carbon). Experimental results showed that the greater microbial activities in Bt- cotton based cropping system was due to substantial improvement of soluble phase of carbon through rhizodeposition, root biomass and leaf-fall which acted as a source of bio-energy for soil microbes. Heterotrophic bacterial population was found the highest followed by associate nitrogen fixers and P solubilisers. Log cfu g^{-1}soil of these beneficial microbes was found higher in case Bt- cotton than non-Bt based cropping system (Fig. 4.7.1).

Table 4.7.1 Effect of transgenic cotton based cropping on rhizospheric soil biological and biochemical activity in Vertisol

Cropping system	SMBC (mg kg^{-1})		SR (mg kg^{-1} 10 d^{-1})		DHA (μg TPF g^{-1}h^{-1})		FDA (μg fluorescin g^{-1} h^{-1})		Alkaline phosphatase (μg PNP g^{-1} h^{-1})		Glomalin (mg kg^{-1})	
	Bt	Non-Bt	Bt	Non-Bt	Bt	Non-Bt	Bt	Non-Bt	Bt	Non-Bt	Bt	Non-Bt
Cotton - soybean	369.8	298.0	225.2	198.2	32.0	31.3	27.2	19.4	295.6	265.0	123.2	62.2
Cotton - redgram	310.4	275.6	177.0	158.8	25.5	22.4	18.8	17.2	260.6	246.2	79.4	65.0
Cotton - wheat	276.4	268.0	159.2	153.2	19.7	18.3	14.7	14.8	229.2	221.2	70.4	56.0
Cotton - vegetables	265.8	236.8	210.4	191.2	18.0	16.2	17.7	17.3	270.0	198.4	52.6	44.2
Cotton - fallow	269.2	242.4	194.6	174.0	22.6	17.5	16.2	13.5	234.4	201.0	41.0	40.0

SMBC- Soil microbial biomass carbon, SR- Soil respiration, DHA- Dehydrogenase activity, FDA- Fluorescein di-accetate activity, Alkaline phosphatase

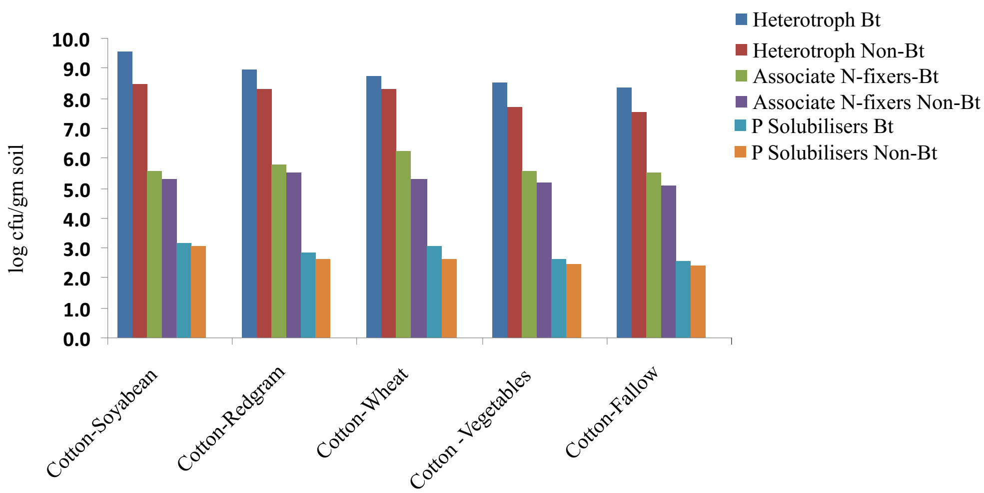


Fig. 4.7.1 Soil heterotrophs, associate N fixers and P solubilisers population under the Bt and non Bt cotton cropping system

4.7.4 Methanogenesis in Vertisols under long term fertilizer management agroecosystem

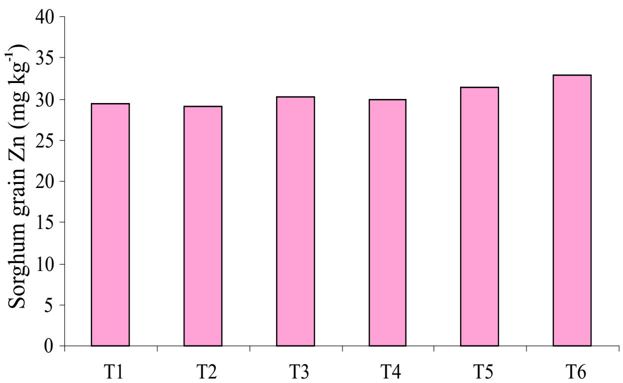
There is worldwide concern over the increasing concentration of methane (CH_4) from agriculture. Atmospheric CH_4 concentration is increasing by about 0.7% per year contributing 15% of the enhanced global warming. There are still uncertainties in CH_4 emission estimates from tropical soils and factors governing the process of methanogenesis. Further, CH_4 oxidation plays an important role in the process of CH_4 emission, but its importance is little understood. Our potential for control of the soil CH_4 sink lies primarily in our ability to change land-use practices. The better targeting of fertilizer application and land conversion could help to avoid the destruction of large soil methane sinks unnecessarily. The present study is concerned with investigating the effect of fertilizer application on CH_4 oxidation potential in Vertisols. Soils from all India network project on organic farming experiment located at the Indian Institute of Soil Science, Bhopal were investigated for its potential in CH_4 production and consumption rate in relation to the microbial population. CH_4 was quantified using gas chromatograph equipped with FID (Flame ionization detector) and microbial population was estimated by cultivation dependent approach. Results revealed that CH_4 production was substantially low in this type of soil while there is high CH_4 oxidation potential. CH_4 oxidation at 60 and 100% moisture level was differentially exhibited and soils amended with organic sources oxidized higher CH_4 than inorganic and integrated fertilizer managed soils. Soil moisture played significant role in regulating microbial metabolism relevant to atmospheric regulation of CH_4. Methanotrophic microbial activity was more pronounced in 60% MHC (moisture holding capacity) than 100% MHC while the responses of ammonium oxidizers were stimulated at higher moisture level. Results provided explicit information on the greenhouse gas production and its mitigation in different agricultural practices in tropical Vertisols.

4.8 Biofortification

4.8.1 Biofortification of grain sorghum & finger millet varieties with Zn through agronomic measures

This ongoing experiment aimed at bio-fortification aspects of different varieties of sorghum and finger millet based on the Zn content in grain. The experiment during 2010-11 has been conducted with six Zn treatments *viz*. T_1 : Absolute control (No fertilizer), T_2 : Control (NPK), T_3 : NPK + 50% N, T_4 : $ZnSO_4$ 100 kg ha^{-1} (single application), T_5 : 0.5% $ZnSO_4$ for spray at three growth stages and T_6 : $T_4 + T_5$ for 15 varieties each of sorghum and finger millets.

In finger millet the plant height ranged between 80 – 120 cm, while in the sorghum it was 200 to 370 cm during crop growth stage. In finger millet the days to 50% flowering were 51 to 78, while it was 70-84 for sorghum. In finger millet grain the Zn concentration ranged from 19 to 36 mg kg^{-1}, while it was 18-52 mg kg^{-1} in sorghum which showed the probable potential of fortification (Fig. 4.8.1). Overall, the T_4 treatment has better response in ragi, while the T2 has better in sorghum yield. In finger millet the grain yields ranged between 450 – 1300 kg ha^{-1} while it was 300 and 2000 kg ha^{-1} in sorghum. Similarly in finger millet the harvest index ranged between 0.2 to 0.6 while it was ranged between 0.2 to 0.4 in sorghum. Overall sorghum showed slightly higher zinc content.



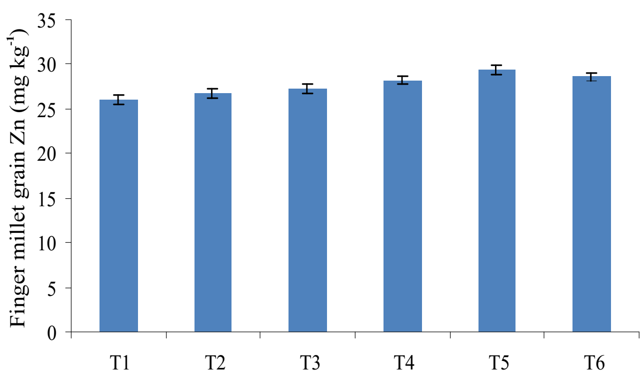


Fig. 4.8.1 Zinc content in grain of sorghum and finger millet under different Zn treatments

Both soil and foliar application has significant effect in sorghum grain Zn, while foliar application of Zn has higher effect in millet. Overall, the extra application through any means of Zn has positive effect in grain Zn. The varieties like CSV 21 F and Pant chari 3 was found to content the highest Zn in sorghum grain, while in millet Paiyur 1, MR 1 and MR 6 were the highest. Overall, variations in grain Zn content seemed to be less than the control (T1). However, the variations in vegetative parts were more. It probably indicated the variation in translocation efficiency of the varieties. The above findings were correlated well with physiological parameters – carbon exchange rates, nitrate reductase activities, membrane stability index.

4.8.2 Identification of micronutrient efficient and inefficient cultivars of major food crops in India

Cultivars of major food crops were screened to identify micronutrient efficient cultivars by assessing micronutrient uptake efficiency and micronutrient yield efficiency index. The genetically micronutrient inefficient cultivars are virtually agronomically efficient for enhancing micronutrient content in seeds. Thus, the efficient cultivars may be utilized by breeders for QTL identification and developing high yielding micronutrient enriched cultivars (genetic biofortification) while the inefficient cultivars may be used for agronomic biofortification to dense the grains of highly responsive cultivars with micronutrients. Efficient and inefficient cultivars of different crops identified for further physiological study has been given (Table 4.8.1).

Table 4.8.1 Micronutrient efficient and inefficient cultivars of different crops

Name of centre	Crop	Micro-nutrient	Genetically efficient	Genetically inefficient (agronomically efficient)
IISS, Bhopal	Pigeon pea	Zn	ICPL 87119	Hisar HO2 -60
			T 15-15	Hisar Paras
			Virsa Arhar 1	Hisar Manak
	Wheat		GW 322	HW 2004
			JW 3211	JW 17
			HI 8627	C 306
ANGRAU, Hyderabad	Rice	Zn	Erramallelu	MTU 1001
			WGL 32100	NLR 33892
			NLR 30491	JGL 11727
	Maize		Super 9681	Ashwini
			DHM 117	Lakshmi 4950
			DHM 111	NK6240
GBPUAT, Pantnagar	Rice	Zn	Pant Dhan 18	Jaya
			Pant Sugandh Dhan 17	Pant Dhan 19
				Pant Sankar Dhan 1
			Pusa Sugandh 4	
	Wheat		UP 2565	UP 262
			UP 2628	PBW 590
			PBW 502	VL 804
PAU, Ludhiana	Rice	Mn	PAU 201	3140
			3047	3141
			PR 116	Pusa 44
	Wheat		PBW 636	PDW 291
			BW 8989	PDW 314
			PBW 550	BW 9022
AAU, Anand	Pigeon pea	Fe	DT 23	BP 1-96
			AAUT 2007-4	C 11
			PKV Trombay	BSMR 853
	Gram		GJG 506	ICCC 4
			GG 1	GAG 839
			GAG 838	GJG 305
RAU, Pusa	Rice	Fe	RAU 759	Boro 3
			Sanwal Basmati	Rajendra Kasturi
			Swarna Sub-1	Rajendra Subhashni
	Maize		Debaki	Shaktiman 3
			Hemant	CM 400
			Rajendra hybrid Makka 1	Shaktiman 4

4.9 Amelioration of Contaminated Soils

4.9.1 Impact assessment of continuous fertilization on heavy metals, and microbial diversity in soils under long term fertilizer experiment

Application of NPK+FYM moderated the soil reaction (pH) of Barrackpore was found to be 7.85. Electrical conductivity of soil indicates the soluble salts status of the soil. The EC value for most of the soils irrespective of treatments was below 0.25 mmhos cm^{-1} in all the soil depths *viz*. 0- 5, 5-15, 15-30, 30-45 and 45-60 cm. The highest value of acid phosphatase activity (Fig.4.9.1) was recorded in surface horizon of the 100% NPK + FYM plot. Acid phosphatase activity decreased with an increase in soil depth. As compared to control (unfertilized plot) acid phosphatase activity was increased up to 87 and 111 % in 100% NPK, and 100% NPK +FYM, respectively. Similarly, the highest value of alkaline phosphatase activity (Fig.4.9.2) was recorded in surface horizon of the 100% NPK + FYM. The highest Fluorescein diacetate activity (FDA) values (50 µg Fluorescein g^{-1} hr^{-1}) were observed in 0 – 5 cm soil depth as compared to other soil profile. The maximum value of FDA (Fig. 4.9.3) was recorded in 100% NPK + FYM (48.7 µg Fluorescein g^{-1} soil hr^{-1}). As compared to control (unfertilized plots). FDA increased up to 46 and 71% in 100% NPK and 100% NPK +FYM, respectively. Dehydrogenase activity (Fig. 4.9.4) followed the same trend of FDA activity. Amongst the treatment addition of fertilizer at higher doses (100% NPK , 150% NPK, 100% NPK+ lime), increased the DTPA Pb content from 0.94 to 1.30 ppm, DTPA Ni content from 0.08 to 0.12 ppm, DTPA Co content from 0.04 to 0.28 ppm, DTPA Cd content from 0.03 to 0.12 ppm in soils of Barrackpore centre. Higher microbial biomass carbon (Fig. 4.9.5) was observed in treatments where balanced fertilization was practiced and also in FYM amended treatment. Basal soil respiration (Fig. 4.9.6) followed the same trend to that of SMBC. A perusal of data in Table 4.9.1 revealed that fertilizer is a source of heavy metals which supplies heavy metals in varying quantity. Amongst the fertilizers, SSP and DAP supplied higher quantity of Pb, Cr, Ni and Cd. Farmyard manure also contains higher quantity of Cr (14.25 ppm) and Ni (51.75 ppm).

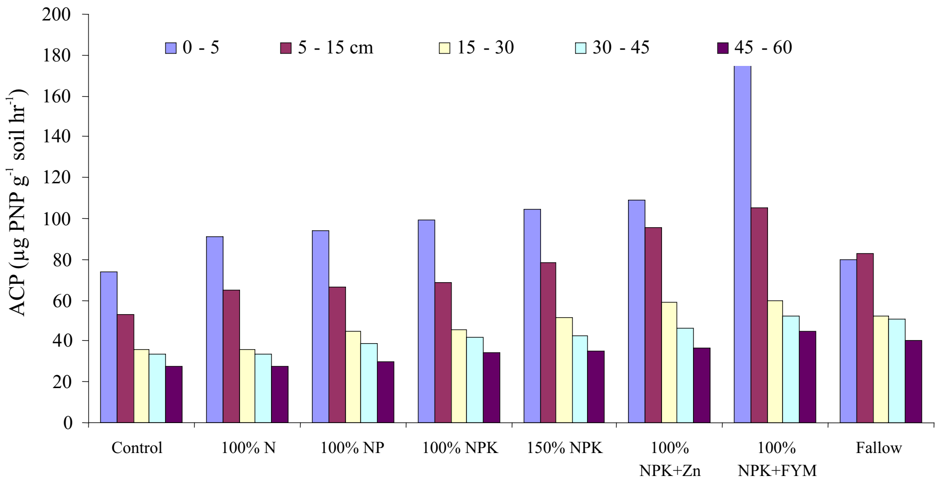


Fig. 4.9.1 Acid phosphatase activity (ACP) of soils under management options at Barrackpore LTFE centers

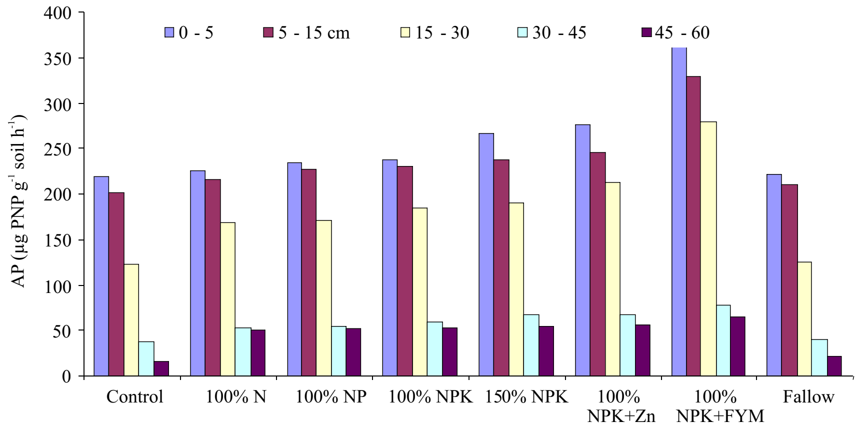


Fig. 4.9.2 Alkaline phosphatase activity (AP) of soils under management options at Barrackpore LTFE centre

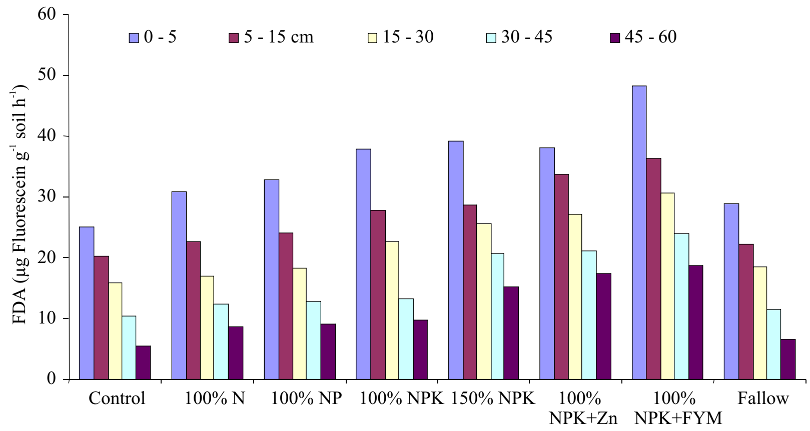


Fig. 4.9.3 Fluorescein diacetate hydrolysis activity (FDA) of soils under different management options at Barrackpore LTFE centre

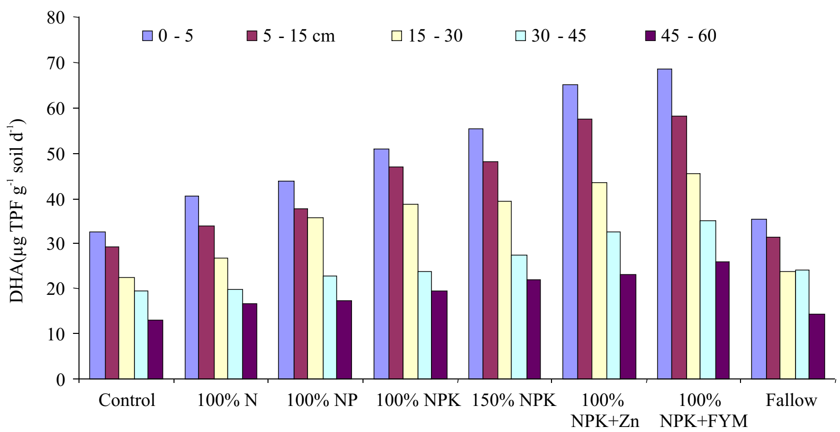


Fig. 4.9.4 Dehydrogenase activity (DHA) of soils under different management options at Barrackpore LTFE Centre

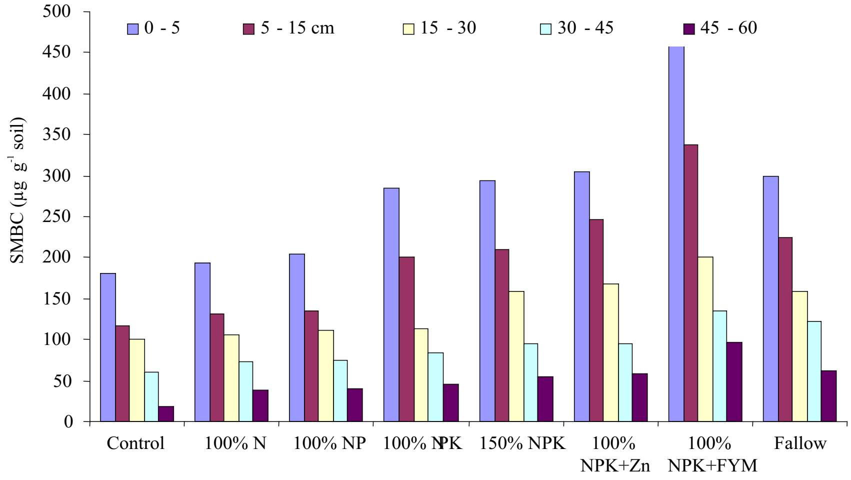


Fig. 4.9.5 Soil microbial biomass carbon (SMBC) of soils under different management options at Barrackpore LTFE centre

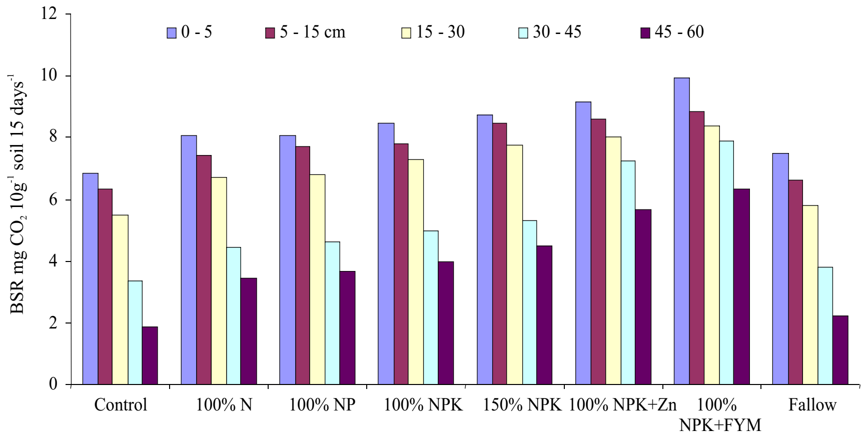


Fig. 4.9.6 Basal soil respiration (BSR) of soil under different management options at Barrackpore LTFE centre

Table 4.9.1 Heavy metals content (mg kg^{-1}) in fertilizers used in Barrackpore LTFE center

S. No.	Fertilizers	Pb	Cr	Ni	Cd	Co
1	SSP	5.85	7.55	12.50	2.25	5.00
2	$ZnSO_4$	8.56	4.89	5.75	0.75	3.25
3	FYM	9.20	14.25	51.75	1.25	25.00
4	DAP	4.25	13.62	25.00	9.00	21.50
5	Urea	0.95	4.35	1.85	0.50	0.32
6	MOP	1.65	3.65	4.98	0.12	0.45

4.9.2 Phytoremediation of Cd with different varieties of Tuberose

The potential of three varieties of tuberose (Prajwal, Shringar and Mexican single) for phytoremediation of soil contaminated with cadmium was evaluated by subjecting the plants to five levels of Cd (0, 25, 50, 75 and 100 mg kg^{-1} soil). Application of 100 mg Cd kg^{-1} soil did not show any toxicity symptoms in all three varieties of tuberose. However, there was a significant reduction in photosynthesis rate at higher levels (beyond 50 mg Cd kg^{-1} soil) in Prajwal and Mexican single. The variety Prajwal recorded the highest photosynthesis rate followed by Shringar and Mexican single (Table 4.9.2). At higher levels of applied Cd, there was a marginal decrease in the total dry matter weight in all the three varieties (Table 4.9.2).

Table 4.9.2 Effect of different levels of Cd on some physiological parameters in different varieties of tuberose

Levels of Cd (mg kg^{-1})	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1}) Prajwal	Photosynthetic rate Shringar	Photosynthetic rate Mexican single	TDW (g pot^{-1}) Prajwal	TDW Shringar	TDW Mexican single	Plant height (cm) Prajwal	Plant height Shringar	Plant height Mexican single
0	14.45	14.45	13.80	69.19	61.91	64.11	103	79	143
25	14.35	13.90	12.95	68.59	58.91	61.81	93	68	122
50	14.45	13.90	11.50	66.49	58.36	56.23	82	65	100
75	12.70	12.95	11.40	66.19	56.16	56.16	78	62	88
100	11.95	12.10	9.90	65.64	55.93	56.14	65	54	72
CD (0.05)	1.92	NS	2.35	NS	NS	NS	19.63	9.82	15.95

**NS: Non significant*

The partitioning of Cd in different plant parts is shown in (Fig.4.9.7). The Cd concentration in tissues of all the three varieties of tuberose increased significantly with increasing Cd concentration in soil. Most of the Cd absorbed by the plants was accumulated in the shoots and slightly lower concentration was found in bulbs and spikes.

The variety Prajwal recorded the highest Cd content (163 µg g DW^{-1}) in shoot (Fig. 4.9.7a) and was followed by Mexican single (119 µg gDW^{-1}) (Fig. 4.9.7b) and Shringar (110 µg gDW^{-1}) (Fig. 4.9.7c). Further, the present study clearly showed that all three varieties of tuberose possessed the typical ability of Cd hyper accumulation characterized by (1) accumulation of Cd in shoots of the plant exceeding the critical judging standard i.e.,100 µg gDW^{-1} and (2) by ratio of Cd in the shoots to bulbs > 1 (Table 4.9.3). Among the three varieties, Prajwal recorded the highest uptake of Cd (5.51 mg pot^{-1}) at highest concentration i.e., 100 mg Cd kg^{-1} soil followed by Mexican single (5.41 mg pot^{-1}) and Shringar (4.45 mg pot^{-1}) (Fig. 4.9.8). When the fraction of Cd removed from the total soil Cd was calculated, highest average fraction was observed in Prajwal (1.30 %) and more or less similar trend was observed in Shringar (1.22 %) and Mexican single (1.23%) (Table 4.9.3). It was concluded that all three varieties of tuberose showed greater tolerance to Cd and exhibited strong ability to accumulate Cd (Plate 4.9.1).

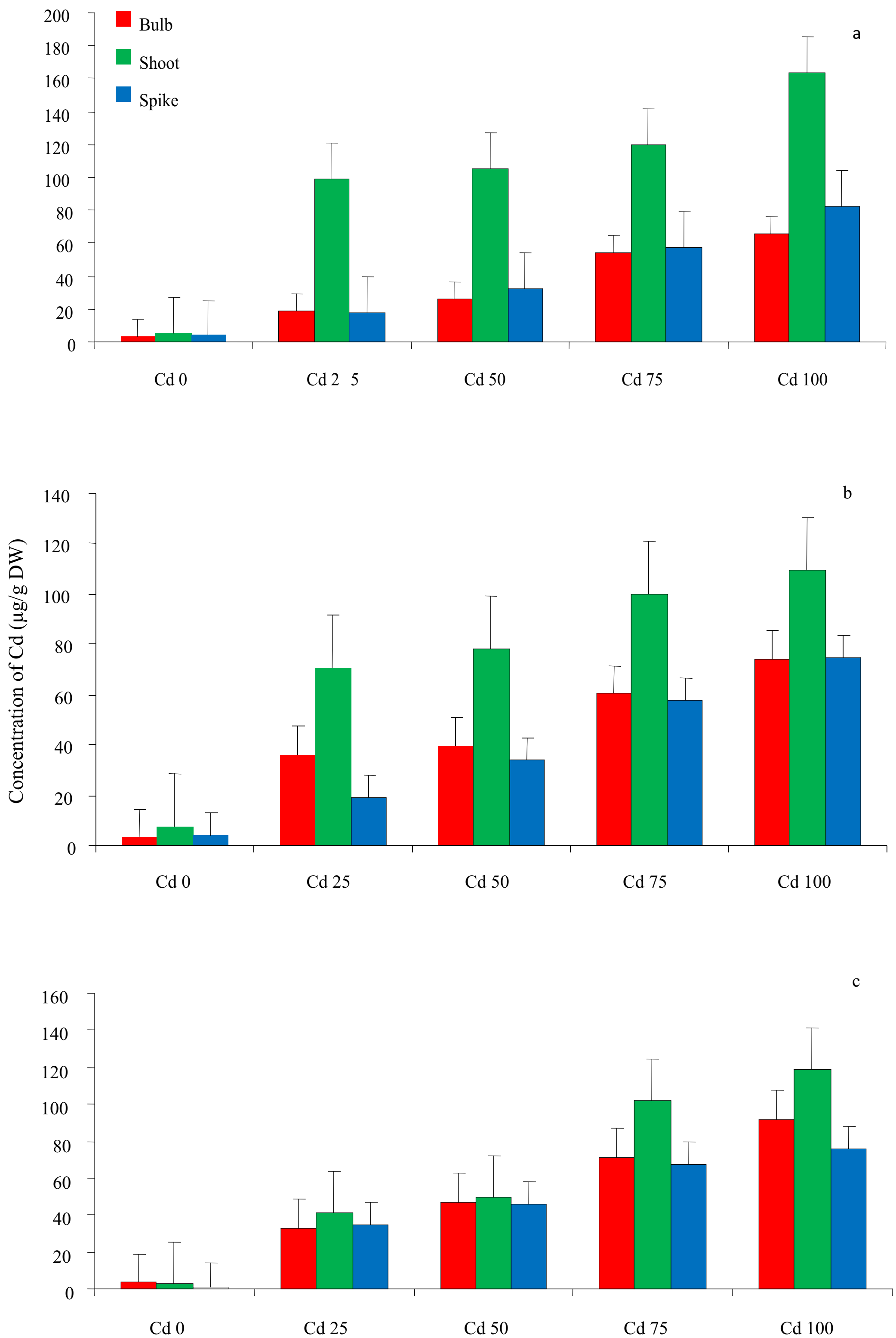


Fig. 4.9.7 Partitioning of Cd in different varieties of tuberose (a) Prajwal (b) Shringar and (c) Mexican single

Table 4.9.3 **Fraction of total Cd removal (%) and shoot/bulb ratio of Cd in three different varieties of tuberose**

Levels of Cd (mg kg^{-1})	Fraction of total Cd removal (%)			Shoot/ bulb ratio of concentration of Cd		
	Prajwal	Shringar	Mexican single	Prajwal	Shringar	Mexican single
25	1.73	1.93	1.61	5.33	1.96	1.27
50	1.15	1.05	1.07	4.08	1.97	1.06
75	1.22	0.99	1.15	2.22	1.66	1.44
100	1.10	0.89	1.08	2.48	1.48	1.29

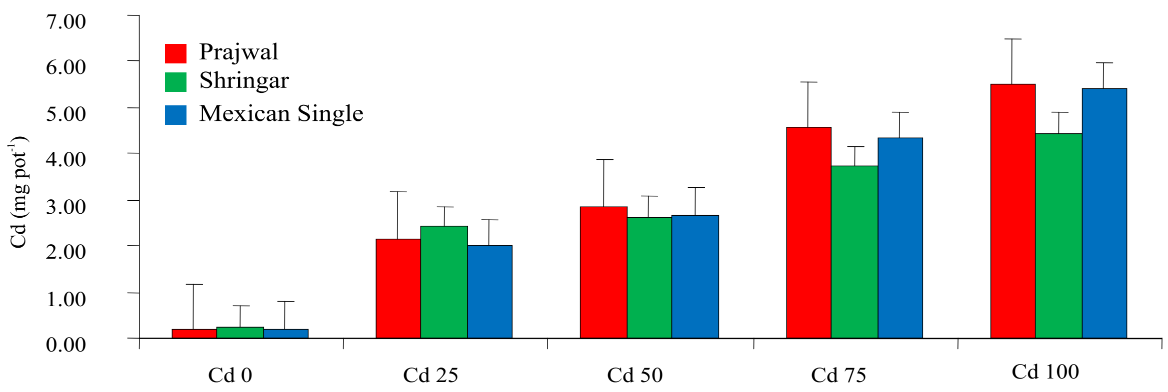


Fig. 4.9.8 Total uptake of Cd by different varieties of tuberose

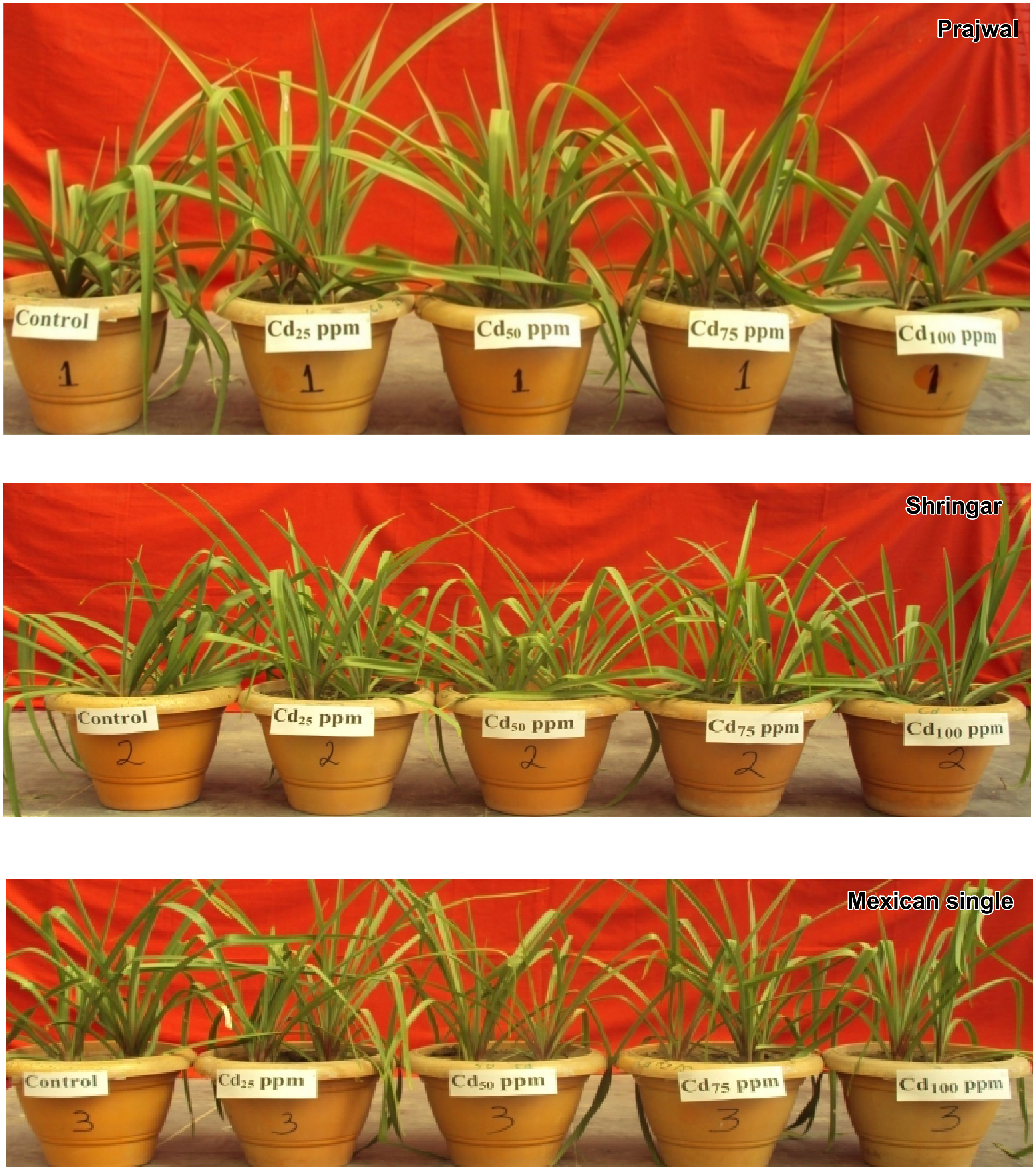


Plate 4.9.1 Effect of different levels of Cd on tuberose varieties

4.9.3 Non point sources of phosphorus loading to Upper Lake, Bhopal

An investigation was carried out to study the non point sources of phosphorus loading to Upper Lake, Bhopal. Geo-referenced sediment and water samples collected from 11 sampling points at pre-monsoon stage were analyzed for different fractions of P using the standard procedure. The results showed that the total P in the sediment of pre-monsoon stage samples ranged from 0.03% to 0.07% with a mean value of 0.04%. The mean sediment inorganic phosphorus (SIP) and the sediment organic phosphorus (SOP) was 68.01 % and 31.98% 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 86.32 to 96.97% of total sediment inorganic P followed by Fe bound P (2.10 to 11.51%) and loosely sorbed P (LSP) (0.39% to 5.66%). The total P value in the water samples ranged from 0.28 to 0.47 mg $L^{-1}$with a mean value of 0.39 mg L^{-1}. The total dissolved P, total reactive P and dissolved reactive P ranged from 0.08 to 0.17 mg L^{-1}, 0.05 to 0.09 mg L^{-1} and 0.008 to 0.04 mg L^{-1} with a mean value of 0.13, 0.08 and 0.03 mg L^{-1}, respectively. The mean total dissolved P (TDP), total reactive P (TRP), dissolved reactive P (DRP), dissolved organic P (DOP) and particulate P (PP) was 31.05%, 20.31%, 10.39%, 18.73% and 68.94% of TP, respectively.

4.10 Recycling and Rational Usage of Different Wastes in Agricultural Soils

Characterization of heavy metals in municipal solid wastes compost

Distribution of different size fractions in MSW composts of Indian cities

Compost samples produced in 12 different cities through different types of feedstock material were used for this study. The MSW compost samples were separated into different size fractions (> 500 µm, 250 – 500 µm, 125-250 µm, 75-125 µm and 10-75 µm) through wet sieving method. Different size fractions were dried and analyzed for total metal content (using di-acid method) as well as for metals extracted by 0.1 N HCl and 0.1 N NaOH. Results showed that major fraction of the MSW compost belongs to > 500 µm size group (71.9%) and smaller size groups had about 3 to 7% of the total weight (Fig. 4.10.1). MSW compost samples produced from segregated biodegradable wastes (BWC) contained maximum material (82% by weight) in the > 500 µm size group followed by those produced from partially segregated wastes (PSWC) (69%) and those produced from mixed wastes (MWC) (68%).

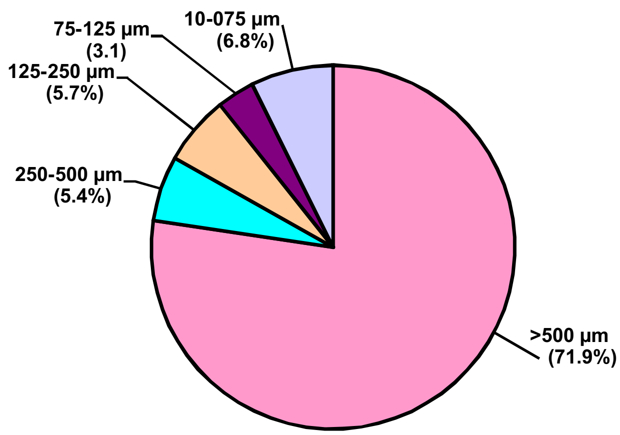


Fig. 4.10.1 Average distribution of weight of material (expressed as % of total) in different size fractions of MSW compost

Heavy metal contents in different size fractions of MSW composts

Mean concentration of all heavy metals was the minimum in biggest size fraction (> 500 µm) and maximum in smallest size fraction (10 - 75 µm). Metal concentrations, in general, increased with decrease in size fractions (Fig. 4.10.2). On an average, 68, 70, 63, 70, 59, and 66% of total Cd, Cr, Cu, Ni, Pb and Zn respectively, were present in the largest size fraction (> 500 µm) of the MSW compost followed by 12.8, 13.8, 18.1, 12.0, 14.8, and 17.1% in the smallest size fraction (10 - 75µm) (Fig. 4.10.3). Heavy metals contents in the smallest size fraction of compost prepared from BWC were lower as compared to those prepared from partially segregated wastes or mixed wastes.

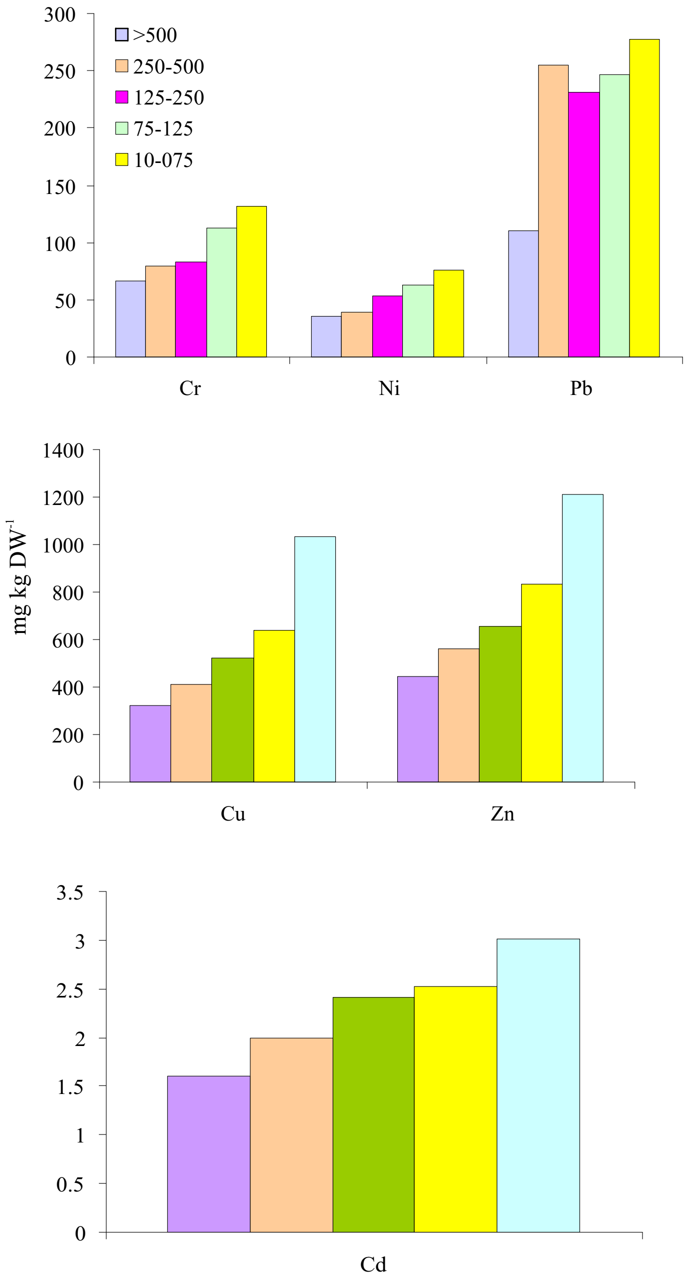


Fig. 4.10.2 Distribution of heavy metals in different size fractions (µm) of MSW compost

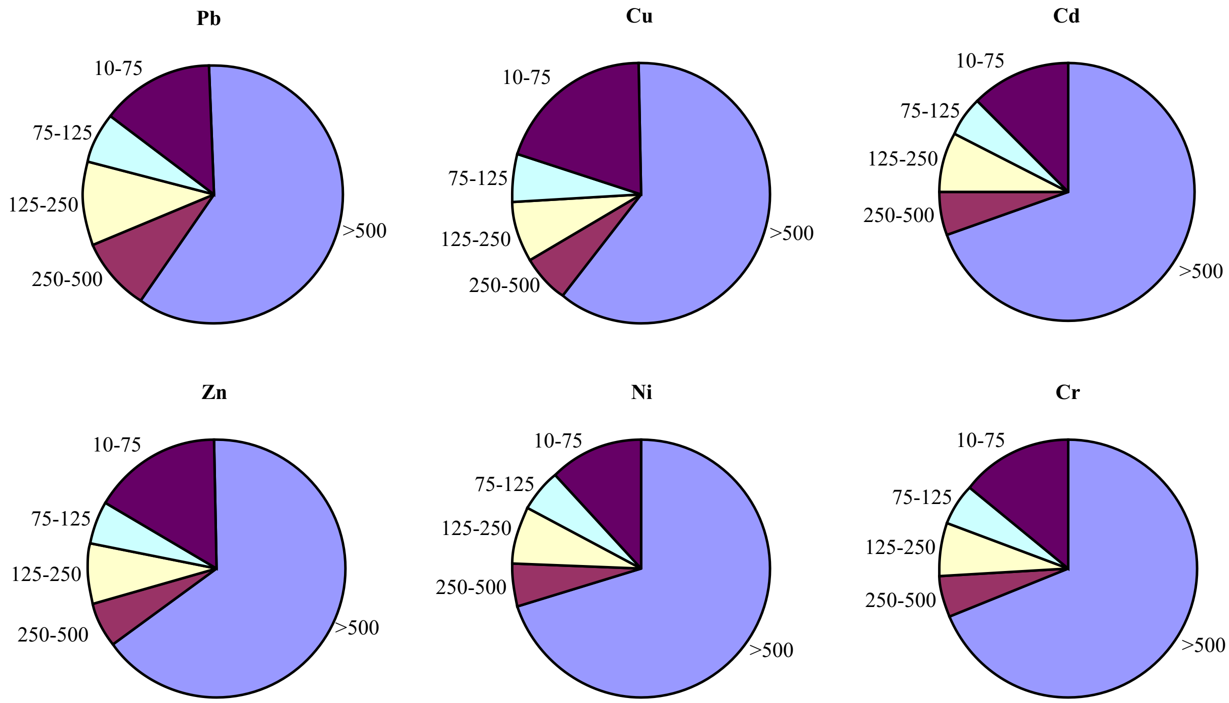


Fig. 4.10.3 Proportional distribution of heavy metals in different size fraction (μm) of MSW composts

Dilute acid extractable fraction of heavy metals in different size fractions of MSW compost

Dilute HCl (0.1N) extracts were primarily inorganic fraction of heavy metals in the compost. On an average, dilute acid extracted 60.7% Cd, 10.0% Cr, 31.7% Cu, 28.0% Ni, 46.4% Pb and 56.0% Zn from the total heavy metals in the compost (Fig. 4.10.4). Results showed that proportions of the total heavy metals (except Cd) extracted by HCl were more where MSW composts were prepared from either mixed wastes or partially segregated wastes as compared to those prepared from segregated biodegradable wastes. In general, inorganic fraction of Cd, Cu, and Zn were more in finer fractions as compared to bigger size fraction of MSW composts. In case of MWC and PSWC, there were no significant differences among the different size fractions in the proportion of HCl extractable Cr, Ni and Pb (Fig. 4.10.5). In BWC, however, extent of all the metals extraction by HCl increased progressively with decreasing size fractions.

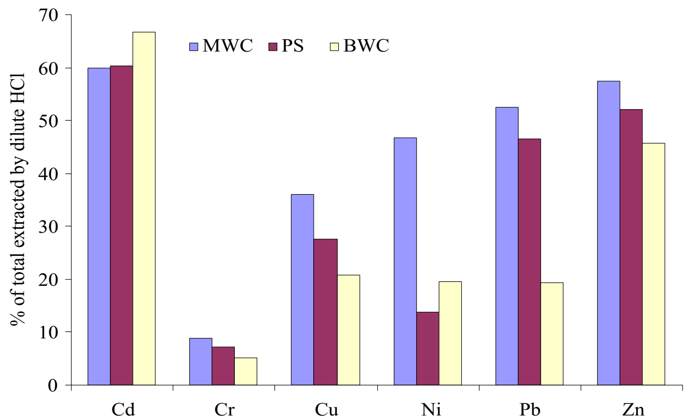


Fig. 4.10.4 Effect of feedstock type on the dilute acid extractable fraction of heavy metals in the MSW compost

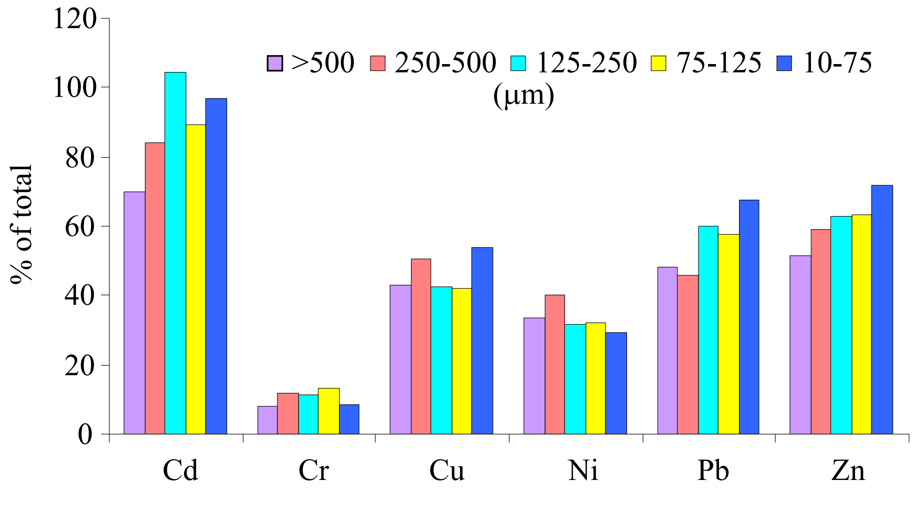


Fig. 4.10.5 Extraction of heavy metals by dilute HCl from different size fractions (m) of MSW compost

Efficiency of different reagent solution in extracting heavy metals from different MSW compost

Several organic acids and chelating reagents (Table 4.10.1) were evaluated for their efficiency in extracting heavy metals from MSW compost. Among these, only 0.01 M EDTA extracted about 40% Zn and 56% Cd from the MSW compost. Extraction of other metals was low.

Table 4.10.1 Removal of heavy metals from MSW composts by different reagent solution

Extractant	Total metals (%) extracted from compost					
	Zn	**Cu**	**Cd**	**Pb**	**Cr**	**Ni**
0.01 *M* Na_2-EDTA	43.1	4.6	50.0	13.0	0.3	4.7
0.01 M Na_2-EDTA dissolved in untreated spent wash	37.9	8.7	61.6	17.1	0.5	8.8
0.01 *M* HCl	0.6	0.3	3.3	0.0	0.2	1.2
0.05 *M* Citric acid	3.8	0.3	5.0	0.0	0.9	1.8
0.05 *M* Tartaric acid	1.0	0.3	3.5	0.0	0.2	1.2
0.05 *M* Citric acid dissolved in 0.01 *M* HCl	3.5	0.2	5.0	0.0	0.7	1.4
0.05 *M* Tartaric acid dissolved in 0.01 *M* HCl	1.1	0.3	3.7	0.0	0.2	0.9
Water	0.6	0.3	2.5	0.0	0.2	1.3

4.11 Organic Farming

Microbiological evaluation of biodynamic and organic preparations

Enumeration of different group of microbes were done from panchagavya, BD500 and cow dung manure. Population of plant growth promoting bacteria like aerobic nitrogen fixer, P solubilizers and pseudomonas were found to be the highest in panchagavya (Fig.4.11.1).

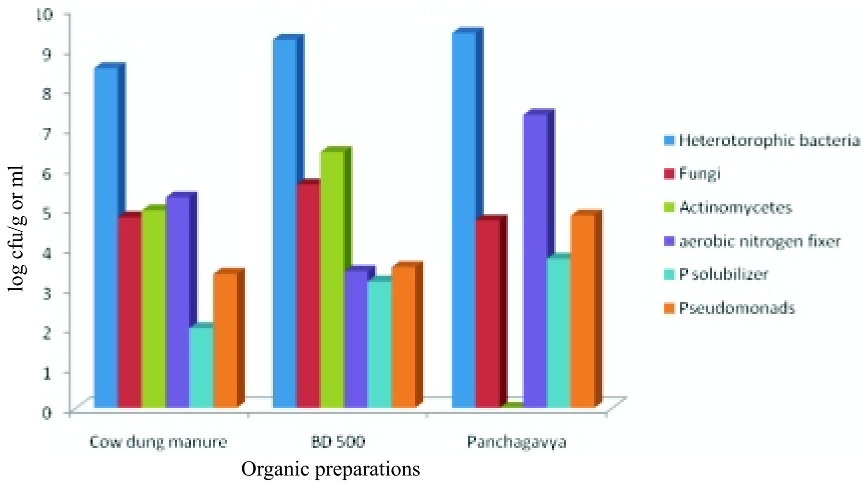


Fig. 4.11.1 Microbial population in panchgavya, biodynamic (BD 500) and cow dung manure

4.12 Crop Adaptability to Climate Change

Changing climatic factors influence on the nutrient acquisition, utilization and recovery of soybean and chickpea germplasm lines/genotypes on a black soil of central India

In the *rabi* season 2010, 12 varieties of chickpea were raised in field in two sowing dates. The varieties selected

Table 4.12.1 Yield (q ha^{-1}) of varieties in first and second sowing

No	Variety	First Sowing	Second Sowing
1	JG130	13.34	11.92
2	SAKI 9516 (JG 16)	17.60	12.26
3	JG11	20.32	10.74
4	JAKI 9218	16.58	13.38
5	JG315	17.50	13.82
6	JG6	16.54	10.00
7	JG74	15.54	10.50
8	JG 412	12.80	12.90
9	JG 226	13.34	12.56
10	JG 218	19.58	12.86
11	IG 593	11.52	8.64
12	Vishal	16.64	11.38

were JG130, SAKI 9516, JG11, JAKI 9218, JG315, JG6, JG74, JG 412, JG 226, JG 218, IG 593, Vishal. All the varieties performed relatively better in the first sowing compared to second sowing (Table 4.12.1 and 4.12.2). The time taken for germination in the second sowing was more and it was expressed in terms of yield also. Since the crop was entirely rainfed, the moisture availability was the deciding factor for the overall performance of the crop. The varieties JG 6, JG 11, JG 16, JG 74, JG 315, JG 218 and Vishal performed well in terms of yield in timely sowing condition. The varieties JG 130, JAKI 9218, JG 412, JG 226, and IG 593, recorded similar yield compared to other varieties in both the sowing dates.

Table 4.12.2 100 seed wt in first and second sowing

No	Variety	First Sowing	Second Sowing
1	JG130	23.47	22.81
2	SAKI 9516	18.19	15.92
3	JG11	21.92	18.59
4	JAKI 9218	22.48	21.08
5	JG315	15.85	13.46
6	JG6	31.14	26.73
7	JG74	17.48	14.79
8	JG 412	26.48	24.74
9	JG 226	15.14	13.96
10	JG 218	20.28	16.27
11	IG 593	30.90	20.39
12	Vishal	26.54	18.46

From overall performances of the soybean plants under two different sowing dates in first year, four varieties were selected for second year experiment. In second year these varieties were raised in two sowing dates with four P treatments. It was found that all the varieties performed well in the first sowing and the P treatment giving good yield also. But in the second sowing except one variety all others failed to give good yield even in the P treatment plots. The variety JS 9752 was surviving better in both the sowing dates. The short duration varieties failed in the late sowing due to different kinds of stress.

4.13 On-farm Research and Impact Assessment

4.13.1 On farm production and evaluation of vermi-compost and enriched compost

To assess the various methods of preparation of vermicompost, enriched compost and to know its quality in the farmer's field situations using local resources available at the farm itself, field experiments on the farmer's fields of Misrod and Parwalia villages in Bhopal (M.P.) were initiated during *kharif* – 2009 and are continuing till date. Two farmers's each from Misrod and parwalia village have been selected for the experimentation. Vermicompost, enriched compost and ordinary compost prepared on the farmer's field were analysed for various physical, chemical and biological properties (Table 4.13.1, 4.13.2 and 4.13.3). Based on the phosphate contents in the vermicompost and enriched compost, imposition of treatments were made in soybean crop and subsequent wheat crop was grown by applying recommended dose of fertilizers. Soybean crop was sown in the month of July and harvested in the month of October. Seed yield of soybean at different farmer's field varied significantly among various treatments (Table 4.13.4). The highest seed yield of soybean was recorded with vermicompost treatment followed by enriched compost, farmer's practice and the lowest with 100% NPK treatments at all the farmer's field. Straw yield of soybean followed the similar trend (Table 4.13.5). Wheat was grown on the same plots after harvest of soybean with 100% recommended dose of fertilizers. Seed yield of wheat (Table 4.13.6) did not vary significantly between vermicompost and enriched compost treatments but it did vary significantly between farmer's practice and 100% NPK treatment. The lowest seed yield of wheat was recorded with 100% NPK treatment compared to all other treatments. Straw yield of wheat followed the similar trend as that of grain yield (Table 4.13.7). The results of soil samples analyzed for available NPK status after two years of cropping revealed that available NPK status in Misrod village was higher compared to Parwalia village (Table 4.13.8, 4.13.9 and 4.13.10).

Table 4.13.1 Chemical composition of ordinary compost

Parameters	Farmer-1	Farmer-2	Farmer-3	Farmer-4
pH	7.3	7.2	7.7	7.4
TOC (%)	24	23	25	24
Total N (%)	0.68	0.71	0.75	0.73
Total P_2O_5 (%)	0.58	0.65	0.55	0.63
Total K (%)	0.79	0.80	0.88	0.85
Zn (ppm)	49	51	42	48
Cu (ppm)	19	18	16	21
Fe (ppm)	923	970	950	942
Mn (ppm)	180	210	195	215
WS carbon (%)	0.28	0.31	0.32	0.39
DHA (mg TPF kg^{-1} compost hr^{-1})	43	42	39	41
CEC (cmol (p^+) kg^{-1}	67	63	65	68
Biodegrability Index	3.01	2.99	3.04	3.06

Table 4.13.2 Chemical composition of phospho compost

Parameters	Farmer-1	Farmer-2	Farmer-3	Farmer-4
pH	7.5	7.4	7.7	7.8
TOC %	28	29	25	27
Total N (%)	1.2	1.3	1.2	1.1
Total P_2O_5 (%)	3.79	3.92	4.03	3.85
Total K (%)	0.83	0.88	0.85	0.89
Zn (ppm)	58	67	42	58
Cu (ppm)	21	18	19	16
Fe (ppm)	1010	1083	919	932
Mn (ppm)	192	219	201	209
WS carbon (%)	0.35	0.37	0.38	0.37
DHA (mg TPF kg^{-1} compost hr^{-1})	45	47	42	43
CEC (cmol (p^+) kg^{-1}	72	75	78	76
Biodegrability Index	3.18	3.23	3.08	3.16

Table 4.13.3 Chemical composition of vermicompost

Parameters	Farmer-1	Farmer-2	Farmer-3	Farmer-4
P^H	7.30	7.00	7.20	7.10
TOC %	26	28	27	30
Total N (%)	1.5	1.3	1.6	1.4
Total P_2O_5 (%)	0.89	0.91	0.86	0.85
Total K (%)	0.62	0.64	0.69	0.60
Zn (ppm)	65	70	60	72
Cu (ppm)	34	35	29	31
Fe (ppm)	3100	3345	3033	3150
Mn (ppm)	410	465	455	475
WS carbon (%)	0.37	0.39	0.41	0.43
DHA (mg TPF kg^{-1} compost hr^{-1})	48	47	49	51
CEC (cmol (p^+) kg^{-1}	79	77	78	77
Biodegrability Index	3.17	3.21	3.19	3.33

Table 4.13.4 Soybean seed yield (kg ha^{-1}) under different nutrient management options

Treatment	Farmer-1	Farmer-2	Farmer-3	Farmer-4
Farmer's practice	1645	1681	1548	1503
100%NPK	1505	1562	1433	1413
Enriched compost	1742	1758	1643	1608
Vermicompost	1919	1883	1779	1705
CD (P=0.05)	101	115	87	97

Table 4.13.5 Soybean straw yield (kg ha^{-1}) under different nutrient management options

Treatment	Farmer-1	Farmer-2	Farmer-3	Farmer-4
Farmer's practice	3415	3519	3373	3375
100%NPK	3210	3323	3113	3215
Enriched compost	3608	3673	3490	3437
Vermicompost	3925	3621	3673	3643
CD (P=0.05)	102	114	109	108

Table 4.13.6 Wheat grain yield (kg ha^{-1}) under different nutrient management options

Treatment	Farmer-1	Farmer-2	Farmer-3	Farmer-4
Farmer's practice	4222	4115	3915	4081
100%NPK	4173	4381	4071	3981
Enriched compost	4519	4679	4287	4115
Vermicompost	4628	4617	4317	4278
CD (P=0.05)	135	98	145	148

Table 4.13.7 Wheat straw yield (kg ha^{-1}) under different nutrient management options

Treatment	Farmer-1	Farmer-2	Farmer-3	Farmer-4
Farmer's practice	6231	6275	6179	6078
100%NPK	6414	6591	6214	5978
Enriched compost	6681	6825	6328	6272
Vermicompost	6871	6781	6478	6396
CD (P=0.05)	131	189	123	151

Table 4.13.8 Available N (kg ha^{-1}) after two years of cropping cycle

Treatment	Farmer-1	Farmer-2	Farmer-3	Farmer-4
Farmer's practice	280.3	279.2	218.7	234.8
100%NPK	283.4	298.3	225.3	245.5
Enriched compost	291.4	275.7	221.4	219.9
Vermicompost	295.6	287.9	217.4	242.7

Table 4.13.9 Available P (kg ha^{-1}) after two years of cropping cycle

Treatment	Farmer-1	Farmer-2	Farmer-3	Farmer-4
Farmer's practice	25.2	26.2	20.3	17.2
100%NPK	26.3	28.3	19.2	18.3
Enriched compost	23.2	29.2	17.1	18.1
Vermicompost	29.3	28.1	18.3	19.2

Table 4.13.10 Available K (kg ha^{-1}) after two years of cropping cycle

Treatment	Farmer-1	Farmer-2	Farmer-3	Farmer-4
Farmer's practice	615.2	585.8	423.7	443.2
100%NPK	595.8	598.7	473.3	421.3
Enriched compost	575.5	591.3	478.4	432.4
Vermicompost	621.3	633.6	463.8	437.5

4.13.2 Front line demonstrations of STCR technology on farmers' fields

Agricultural production systems at the current level of yields are not sustainable when there is a significant mining of plant nutrients from soil. Build-up and maintenance of soil fertility and consequent provision of balanced fertilization to crops are key to sustain long-term crop productivity. Nutrient supplying power of soils, crop responses to added nutrients and amendment needs can safely be assessed through sound soil testing programme. Monitoring of soil fertility against depletion and accumulation of certain elements in toxic proportions over time is possible through appropriate soil tests. Huge cost of fertilizers has become a big hurdle for the farmers to apply adequate fertilizers to crops. Soil test calibration that is intended to establish a relationship between the levels of soil nutrients determined in the laboratory and crop response to fertilizers in the field permits balanced fertilization through right kind and amount of fertilizers. The ICAR project on soil test crop response correlation has used the multiple regression approach to develop relationship between crop yield on the one hand, and soil test estimates and fertilizer inputs, on the other. Ready reckoners in the form of fertilizer prescription equations have been developed by different centres for facilitating users for profitable use of fertilizers based on soil test values and the same has been demonstrated through various multi-location / verification follow up trials as well as front line demonstrations.

Multi-location / verification follow up trials

Jute

Test verification trials conducted at Barrackpore with jute (cv. JRO-128) showed that in all the trials, targeted yield of jute (35 and 40 q ha^{-1}) was achieved within (+) 2.10 to 4.17 per cent yield deviation, proving the validity of the equations. Application of fertilizers as per soil test values and targeted yield of jute fibre with FYM (@ 5 t ha^{-1}), achieved the targeted yield of jute fibres with 7.62 and 7.50% yield deviations, respectively (Table 4.13.11).

Table 4.13.11 Verification of IPNS fertilizers prescription equations of jute (cv. JRO-128) in farmers' fields (mean value of three locations)

Treatments	Fertilizer dose ($kg\ ha^{-1}$) N	P_2O_5	K_2O	Fibre yield ($q\ ha^{-1}$)	Addnl. yield over control ($q\ ha^{-1}$)	Net return (Rs. ha^{-1})	Yield deviation (%)	B:C ratio
Control	0.0	0.0	0.0	26.8	-	16280	-	1.41
FP	23	59	59	34.6	8.63	30205	-	1.71
RDF	80	40	40	40.0	14.0	41864	-	1.99
ST-TY 35 q ha^{-1}	17.1	10	10	35.7	9.8	34541	(+) 2.10	1.85
ST–TY 35 q ha^{-1} +FYM_{5t}	15.1	10	10	37.7	11.7	38314	(+) 7.62	1.94
ST–TY 40 q ha^{-1}	53.7	10	19	41.7	15.0	46175	(+) 4.17	2.12
ST–TY 40 q ha^{-1} + FYM_{5t}	47.8	10	17	43.0	17.0	49061	(+) 7.50	2.19

Rice

Test verification trials conducted with rice (cv. MTU1010) showed that targeted yield (40 and 50 q ha^{-1}) was achieved within (+) 2.10 to (-) 1.11 per cent yield deviation, proving the validity of the equations. Application of fertilizers as per soil test values and targeted yield (40 and 50 q ha^{-1}) of rice with FYM (@ 5 t ha^{-1}), achieved the targeted yield of rice grain with (+) 11.1 and 4.3% yield deviations, respectively (Table 4.13.12).

Table 4.13.12 Verification of IPNS fertilizers prescription equations of rice (cv. MTU1010) In farmers' fields (mean value of three locations)

Treatments	Fertilizer doses ($kg\ ha^{-1}$) N	P_2O_5	K_2O	Grain yield ($q\ ha^{-1}$)	Addnl. yield over control ($q\ ha^{-1}$)	Response ratio ($q\ ha^{-1}$)	Net return (Rs. ha^{-1})	Yield deviation (%)	B:C ratio
Control	0.0	0.0	0.0	27.1	0.9	0.0	4245	-	1.17
FP	59	50	50	34.1	8.0	5.0	9643	-	1.35
RDF	80	40	40	36.2	10.0	6.2	11912	-	1.44
ST-TY 40 q ha^{-1}	17	10	10	41.1	15.0	40.9	18901	(+) 2.78	1.74
ST–TY 40 q ha^{-1} +FYM_{5t}	14	10	10	44.4	18.3	55.0	22539	(+) 11.1	1.89
ST–TY 50 q ha^{-1}	60	10	15	49.4	23.3	27.4	27370	(-)1.11	2.05
ST–TY 50 q ha^{-1} +FYM_{5t}	56	7.3	12	52.2	26.0	34.5	30422	(+) 4.31	2.17

Garden pea

Test verification trials were conducted with garden pea (cv. Azad P-3) showed that highest green pod yield was achieved under ST-TY treated plots over RDF and farmers practices with (-)15.4 to (-) 17.6 per cent yield deviation.Application of fertilizers as per soil test values and targeted yield (90 and 100 q ha^{-1}) of green pod with FYM (@ 5 t ha^{-1}) recorded highest yield over RDF and FP with (-) 17.7and 17.6% yield deviations, respectively (Table 4.13.13).

Table 4.13.13 Verification of IPNS fertilizers prescription equations of garden pea (cv. Azad P-3) in farmers' fields (mean value of three locations)

Treatments	Fertilizer dose (kg ha^{-1})			Green pod yield (q ha^{-1})	Extra yield over control (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	0	0	0	47.2	0.0	0.00	10433	-	1.42
FP	15	30	20	59.5	12.3	21.4	18629	-	1.72
RDF	30	60	50	69.8	22.5	19.8	25241	-	1.93
ST-TY 90 q ha^{-1}	43	18	56	76.2	28.9	34.4	30789	(-)15.4	2.17
ST–TY 90 q ha^{-1}+FYM_{5t}	29	12	45	74.1	26.8	44.5	29613	(-) 17.7	2.14
ST–TY 100 q ha^{-1}	65	24	69	82.4	35.1	29.5	34956	(-) 17.6	2.30
ST–TY 100 q ha^{-1}+ FYM_{5t}	50	18	59	82.4	35.1	35.8	35350	(-)17.6	2.33

Wheat

In order to evaluate and demonstrate the fertilizer calibration equations for wheat crop developed by Ludhiana centre, 10 follow up trials were conducted in five different districts (Jalandhar, Amritsar, Firozpur, Bathinda and Moga) of Punjab state. Six different treatments involved comparison among fertilizer recommendations based on STCR technology for target wheat grain yields of 45 and 55 q ha^{-1}, Farmers' practice, general recommended dose (GRD), soil test based recommended dose (STRD) and control. Analysis of data showed that in almost all the districts, the targeted yield of 55 q ha^{-1} was achieved within ± 5 per cent variation of the targeted yield (Table 4.13.14). Higher grain yields in Target 55 q ha^{-1} treatment were obtained as compared to FP, GRD and STRD, when fertilizer was applied on target yield basis at all the sites.

Table 4.13.14 Results of follow-up trials on wheat in Moga district of Punjab

Treatments	Fertilizer dose ($kg\ ha^{-1}$) N	P_2O_5	K_2O	Wheat grain yield ($q\ ha^{-1}$)
Village: Dusanj				
Control	0	0	0	30.5
FP	150	50	0	52.5
GRD	120	60	30	51.5
STRD	120	45	0	50.5
Target 45 $q\ ha^{-1}$	141	63	0	47.0
Target 55 $q\ ha^{-1}$	183	75	0	53.5
Village: Chuga Kalan				
Control	0	0	0	24.5
FP	150	90	0	51.0
GRD	120	60	30	49.0
STRD	120	45	0	51.5
Target 45 $q\ ha^{-1}$	147	79	0	46.5
Target 55 $q\ ha^{-1}$	190	90	0	50.5

Frontline demonstration on wheat based on soil test based balanced fertilizer recommendations of STCR for targeted yield of wheat conducted in village Partapur, district Gaziabad, (U.P.) registered grain yield of 47.5 and 45.7 q/ha with response ratio of 12.1 and 11.2, and net profit of Rs. 26554 and 24331per ha in soil test based fertilizer recommendations as compared to general recommended dose, respectively (Table 4.13.15).

Table 4.13.15 Frontline demonstrations at farmer's field on wheat

Treatment	Fertilizer dose ($kg\ ha^{-1}$) N	P_2O_5	K_2O	Yield ($q\ ha^{-1}$)	Extra yield ($q\ ha^{-1}$)	Cost of extra yield (Rs.)	Cost of fert. (Rs.)	Response rate (kg grain kg^{-1} nutrient)	Net profit (Rs. ha^{-1})
Village : Partapur									
Target 5 t ha^{-1}	150	20	50	47.5	26.5	29150	2596	12.1	26554
General dose	120	60	40	45.7	24.7	27170	2839	11.2	24331
Farmer's practice	131	57	0	44.5	23.5	25850	2418	12.5	23432
Control	0	0	0	21.0	-	-	-	-	-

Beetroot

Test verification trials conducted with beetroot showed that targeted yield could be achieved with (-) 1.25 to (-) 2.74 per cent yield deviation (Table 4.13.16).

Table 4.13.16 Mean root yield, per cent achievement, RR and BCR for verification trials on Beetroot (mean of six trials)

Treatments	Fertilizer dose (kg ha^{-1}) N	P_2O_5	K_2O	Mean Root yield (t ha^{-1})	Mean % achieve-ment	Mean RR (kg kg^{-1})	Mean B:C ratio
Control	0	0	0	23.13	-	-	8.1
Blanket	120	160	100	38.57	-	40.62	10.6
STCR-NPK alone - 40 t ha^{-1}	75-126	105-152	47-140	39.50	98.78	52.78	11.2
STCR-IPNS* - 40 t ha^{-1}	35-86	85-132	16-110	40.48	101.23	55.92	12.0
STCR-NPK alone -50 t ha^{-1}	139-190	157-204	51-200	49.98	99.97	56.35	12.6
STCR-IPNS* - 50 t ha^{-1}	99-150	137-184	17-170	51.37	102.80	59.23	13.6
Farmer's practice	100 150	100 125	50 90	34.03		38.17	9.8

Test verification trials conducted with Pigeon pea, paddy, field pea, gram and wheat conducted in montmorillonitic hypothermic Typic Hapulustert deep black taxonomically fine soil showed greater benefit of STCR technology over fertilizer application as general recommended dose or farmers' practice (Table 4.13.17).

Table 4.13.17 Economics of treatments included in FLDs on pigeon pea, paddy, field peagram and wheat conducted in montmorillonitic hypothermic Typic Hapulustert deep black soil

Treatment	Fertilizer dose (kg ha^{-1}) N	P_2O_5	K_2O	Response (kg ha^{-1})	Cost of fertilizer (Rs. ha^{-1})	Cost of prod. (Rs. ha^{-1})	Profit (Rs. ha^{-1})	Yard stick value
Pigeon pea (ICPH-2671), Village : Karakbel, Narsinghpur								
GRD	30	75	30	750	2219	22500	20281	5.56
T.Y. 2.5 t ha^{-1}	22	36	43	1180	1384	35400	34016	11.68
T.Y. 2.5 t + 5 t FYM ha^{-1}	22	36	43	1330	1384	39900	38516	5.00

Pigeon pea (ICPH-2671), Village : Boucher, Narsinghpur								
GRD	30	75	30	780	2219	23400	21181	5.78
T.Y. 2.5 t ha^{-1}	7	31	44	1250	1098	37500	36402	15.24
T.Y. 2.5 t + 5 t FYM ha^{-1}	7	31	44	1470	1098	44100	43002	5.95
Paddy (MR-219), Village : Urdawa, Jabalpur								
GRD	80	50	30	810	2300	7290	4990	5.06
T.Y. 30 q ha^{-1}	17	45	6	1360	1225	12240	11015	20.00
T.Y. 30 q + 5 t FYM ha^{-1}	17	45	6	1540	1225	13860	12635	6.61
Field Pea (P-3), Village : Simariya, Seoni								
GRD	30	75	30	689	2219	11024	8805	5.10
T.Y. 20 q ha^{-1}	19	54	35	1078	1671	17248	15577	9.98
T.Y. 20 q + 5 t FYM ha^{-1}	19	54	35	1190	1671	19040	17369	4.36
Gram (JG-130), Village : Simariya, Seoni								
GRD	30	60	30	320	1897	6400	4503	2.67
T.Y. 15 q ha^{-1}	17	49	3	530	1287	10600	9313	7.68
T.Y. 15 q + 5 t FYM ha^{-1}	17	49	3	640	1287	12800	11513	2.74
Wheat (JW-3279), Village : Karakbel, Narsinghpur								
GRD	100	50	30	650	2548	7150	4603	3.61
T.Y. 50 q ha^{-1}	128	26	77	1100	2747	12100	9353	4.76
T.Y. 50 q + 5 t FYM ha^{-1}	128	26	77	1400	2747	15400	12653	3.54
Wheat (JW-273), Village : Baghali, Jabalpur								
GRD	100	50	30	560	2548	6160	3613	3.11
T.Y. 50 q ha^{-1}	112	125	75	1020	4662	11220	6558	3.27
T.Y. 50 q + 5 t FYM ha^{-1}	112	125	75	1350	4662	14850	10188	2.83
Wheat (JW-273), Village : Simariya, Seoni								
GRD	100	50	30	590	2548	6490	3943	3.28
T.Y. 50 q ha^{-1}	122	130	72	1040	4869	11440	6571	3.21
T.Y. 50 q + 5 t FYM ha^{-1}	122	130	72	1310	4869	14410	9541	2.68

** 5 t FYM ha^{-1} = 25 kg N + 26.5 kg P_2O_5 + 31 kg K_2O*

Long Term STCR-IPNS Demonstration

Jute-rice-lentil cropping sequence

In a two year old STCR-IPNS long term demonstration under jute-rice-lentil sequence on alluvial soil at Barrackpore (Table 4.13.18), an average response ratio of 21.0, 19.6 and 19.1 kg kg^{-1} was recorded under STCR-IPNS over blanket recommendation farmers' practice (17.6 kg kg^{-1}) and FP (15.3kg kg^{-1}).

Table 4.13.18 STCR-IPNS effect on jute-rice-lentil sequence

Treatments	Fertilizer dose (kg ha^{-1})			Total fertilizer dose (kg ha^{-1})	Addnl. yield over control (q ha^{-1})			Total Add. Yield Over control q ha^{-1}	Response ratio (kg kg^{-1})			Total response ratio
	N	P_2O_5	K_2O		Jute	Rice	Lentil		Jute	Rice	Lentil	
Control	0	0	0	0	0.00	0.00	0.00	0.0		0	0	0.0
ST-TY-I*	247	234	294	775	17.29	15.85	6.95	40.1	7.00	6.76	2.36	16.1
ST-TY-II**	197	147	198	542	13.17	9.30	4.55	27.0	6.68	6.33	2.30	15.3
T3+FYM (5 t/ha)	178	140	179	497	14.41	11.15	5.40	31.0	8.10	7.99	3.02	19.1
T3+Azot+PSB	178	140	179	497	14.62	12.40	6.90	33.9	8.21	8.89	3.85	21.0
T4+Azot.+PSB	178	140	179	497	14.13	11.85	5.70	31.7	7.94	8.49	3.18	19.6
FYM @ 5 t ha^{-1}	0	0	0	0	1.93	5.10	3.45	10.5		-	-	0.0
T7+Azot.+PSB	0	0	0	0	4.26	6.70	4.70	15.7		-	-	0.0
RDF	160	160	90	370	9.89	12.90	3.00	25.8	6.18	8.06	3.33	**17.6**
FP	141	119	65	325	6.14	8.30	2.60	17.0	4.35	6.97	4.00	**15.3**

** Target of jute fibre 40 q ha^{-1}, ** Target of jute fibre 35 q ha^{-1},*
** Target of rice grain 50 q ha^{-1}, ** Target of rice grain40 q ha^{-1},*
** Target of lentil grain 15 q ha^{-1}, ** Target of lentil grain 20 q ha^{-1},*

Pearlmillet-wheat cropping sequence

In a nine year old STCR-IPNS long term demonstration (since -2003 year) under –pearlmillet - wheat sequence on *Typic Haplustept* soil at Delhi showed depletion of available N, P and K after pearlmillet in organic alone as well as control treatment (Table 4.13.19). Application through chemical fertilizer alone also depleted available N and K.

Table 4.13.19 Fertility status after harvest of pearl millet and wheat crop under long term experiment on pearlmillet–wheat cropping sequence

Treatments	After wheat			After pearlmillet		
	Available Nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})	Available Nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
Organic alone	221.0	28.4	243.9	190.5	26.4	195.0
Integrated	180.8	29.2	212.2	208.0	30.9	261.08
Chemical	218.8	27.9	240.6	175.5	28.4	219.3
Control	174.3	16.3	187.4	165.0	13.1	181.0
Mean	198.7	25.5	221.0	188.75	24.7	214.09
C.D. at 5%	5.9	1.6	6.7	8.9	1.9	12.4

Rice-wheat cropping sequence

Application of fertilizers to attain fixed yield targets computed from fertilizer adjustment equations helped in getting significantly higher wheat grain yields than that obtained with either general recommended dose (GRD) or soil test based recommendation (STRD) in Ludhiana. However, the actual yield obtained deviated by 7 and 6.7 per cent of the fixed yield targets of 45 and 55 q ha^{-1}, respectively. It is noteworthy that though the fertilizer additions were more than used in GRD or STRD, but the agronomic efficiency (kg grain/kg N applied) was 10.7 and 9 with fixed target of 55 or 45 q ha^{-1}, respectively as compared with STRD and GRD *ie* 6.1 and 6.4 kg grain/kg N applied, respectively. The approach took into account the contribution of integrating plant nutrients from available biomass with inorganic fertilizers and computing fertilizer doses for fixed yield targets. The data given in table 4.13.20 and 4.13.21 clearly indicate that not only sizeable part of nutrients can be saved but significantly higher grain yield of wheat can also be obtained over other approaches of N management in wheat in rice-wheat cropping system. The yields obtained with IPNS target yield approach only deviated by 5.1 percent from fixed target of 55 q ha^{-1}. The agronomic efficiency with use of IPNS target yield approach technology almost doubled than as that obtained with only fixed target yields.

Table 4.13.20 Effect of addition of fertilizers using different approaches of fertilizer recommendations on the grain yield of rice (q ha^{-1})

Treatments	Fertilizer dose (kg ha^{-1})			Grain yield (q ha^{-1})	Per cent deviation from fixed target	Agronomic efficiency (kg grain kg^{-1} N applied)
	N	P_2O_5	K_2O			
Control	0	0	0	43.0	-	-
GRD	120	30	30	60.3	-	14.4
STRD	150	0	30	59.2	-	10.8
Target(70 q ha^{-1})	103	29	33	57.8	17.4	14.4
Target(75 q ha^{-1})	125	33	37	67.0	10.7	19.2
Target (70 q ha^{-1}) with FYM	74	18	0	62.2	11.1	25.9
Target (75 q ha^{-1}) with FYM	100	24	0	66.5	11.4	23.5
LSD (0.05)				6.0		

Table 4.13.21 Effect of addition of fertilizers using different approaches of fertilizer recommendations on the grain yield of wheat (q ha^{-1})

Treatments	Fertilizer dose (kg ha^{-1})			Grain yield (q ha^{-1})	Per cent deviation from fixed target	Agronomic efficiency (kg grain kg^{-1} N applied)
	N	P_2O_5	K_2O			
Control	0	0	0	28.3	-	-
GRD	120	60	30	36.0	-	6.4
STRD	150	45	30	37.5	-	6.1
Target (45 q ha^{-1})	168	41	33	43.5	7.0	9.0
Target (55 q ha^{-1})	216	73	43	51.3	6.7	10.7
Target (45 q ha^{-1}) with residual FYM	130	32	20	45.0	0.0	12.8
Target (55 q ha^{-1}) with residual FYM	165	55	31	52.2	5.1	14.4
LSD (0.05)				3.6		

Maize-wheat cropping sequence

Plate 4.13.1 Long term field experiment: view of wheat crop

Experiments conducted at Palampur centre (Plate 4.13.1) revealed that the pre- fixed targets where FYM was applied consumed less nutrients but produced more grain yield and simultaneously resulted in more net returns compared to the other two pre- fixed targets where FYM was not used. However, the benefit cost ratio was found to be higher in case of non IPNS yield targets owing to additional cost of FYM and was highest (4.4) in treatment comprising of 35 q ha^{-1}. So, to maintain/sustain soil health and for getting higher returns, application of FYM based on STCR concept may be suggested to the farmers. Overall, results (Table 4.13.22) clearly reveal the superiority of prescription based fertilizer application. Yield target concept based fertilizer application excelled all other approaches in terms of yield and net returns and benefit cost ratio.

Table 4.13.22 Long term target yield experiment in maize-wheat cropping (wheat cv. HPW 42)

Treatment	Fertilizer dose (kg ha^{-1})			Grain yield (q ha^{-1})	Per cent deviation	Cost of yield (Rs. ha^{-1})	Cost of fertilizers + FYM (Rs. ha^{-1})	Net gain over control (Rs. ha^{-1})	B:C ratio
	N	P_2O_5	K_2O						
Control	0	0	0	12.0	-	12000	-	12000	-
Farmers' Practice*	40	0	0	14.0	-	13800	2771	11029	
GRD	120	60	40	17.2	-	17200	4110	13090	4.2
STB	150	45	30	16.0	-	16000	3714	12286	4.3
T_{25}	123	107	18	26.0	4.0	26000	5980	20020	4.3
T_{25} FYM_5	88	84	0	27.3	9.2	27300	6812	20488	4.0
T_{35}	184	144	56	37.5	7.1	37500	8449	29051	4.4
T_{35} FYM_5	146	128	30	39.5	12.8	39500	9554	29946	4.1

**Farmers applied FYM @ 5t ha^{-1}*

Demonstration on wheat at Palampur showed close agreement ($\pm$10%) between targeted and observed yields for the pre-fixed yield targets of 25 and 35 q ha^{-1} under both IPNS and non-IPNS situations (Table 4.13.23) . The lowest yield of 10.6 q ha^{-1} was recorded in control plots followed by farmers' practice (13.6 q ha^{-1}). Wheat yield under IPNS and non-IPNS situations of 25 and 35 q ha^{-1} targets was within the permissible range, as the percent deviation was within $\pm$10. The net benefits over control were higher under prescription based fertilizer applications using IPNS equations and highest (Rs 34344 ha^{-1}) was in the treatment comprising of 35 q ha^{-1} with FYM. The marginal benefit cost ratios were also found to be > 2, thus clearly reflecting the superiority of prescription based fertilizer applications under both IPNS as well as non- IPNS situations for achieving higher returns.

Table 4.13.23 **Target yield experiment (involving IPNS based equations) in wheat (cv. HPW 155) on farmers' fields (Typic Hapludalf) in wet temperate zone of H.P.(Average of 5 locations)**

Treatment	Fertilizer dose (kg ha^{-1}) N	P_2O_5	K_2O	Seed yield (q ha^{-1})	Per cent deviation	Cost of yield (Rs.)	Cost of fertilizers + FYM (Rs.)	Net gain over control (Rs.)	MBCR
Control	0	0	0	10.6	-	10594	-	-	-
Farmers' practice	40	0	0	13.6	-	13594	2820	3000	4.82
GRD	120	60	30	33.1	-	33063	2747	22469	12.04
Targets (q ha^{-1})									
25	48	69	24	24.3	-2.8	24313	6128	13917	3.97
35	101	110	53	32.5	-7.1	32500	7765	21906	4.19
25 +IPNS	127	131	67	37.9	-5.2	37938	8583	27344	4.42
35 +IPNS	180	172	96	44.9	-10.1	44938	10220	34344	4.40

It can be concluded that relevant IPNS based equations hold true up to 35 q ha^{-1} target in wheat. As far as net gains over control are concerned, application of fertilizers following STCR concept increased the grain yields appreciably. Yield targets of 25 and 35 q ha^{-1} returned additional gains of Rs. 13917, 21906, and 27344 and 34344 over the control under non- IPNS and IPNS situations, respectively (Plate 4.13.2).

Plate 4.13.2 Follow up trials on wheat (HPW-155) at farmers' field

Front line demonstrations on oilseeds

Front line demonstrations conducted with oilseeds (mustard var. B-9) in Karimpur block, district Nadia (W.B). The results had clearly brought out the superiority of STCR-IPNS recommendations over blanket and farmer's practice. In all the trials, targeted yield (12 and 15 q ha^{-1}) was achieved within (-)1.14 to 7.60 per cent yield deviation, proving the validity of the equations (Table 4.13.24).

Table 4.13.24 Front line demonstrations of fertilizers prescription equations of mustard (var. B-9) in Karimpure, District. Nadia (mean value of four FLD)

Treatments	Fertilizer dose (kg ha^{-1})			Grain yield (q ha^{-1})	Addnl. yield over control (q ha^{-1})	Response ratio (q ha^{-1})	Net return (Rs. q ha^{-1})	Yield deviation (%)	B:C ratio
	N	P_2O_5	K_2O						
Control	0	0	0	7.00	0.00	0.00	3919	-	1.26
FP	40	30	25	8.68	1.69	2.57	7752	-	1.48
RDF	70	40	40	10.29	3.30	3.22	11765	-	1.69
ST-TY 12 q ha^{-1}	100	32	55	11.92	4.93	3.79	15969	(-)1.14	1.93
ST–TY 15 q ha^{-1}	120	46	71	13.52	6.53	3.86	19389	(-)7.60	2.08

A total of six Front line demonstrations were conducted with oilseeds (mustard var. B-9) in Panchkania village, Haringhata, District- Nadia (W.B). The results had clearly brought out the superiority of STCR-IPNS recommendations over blanket and farmer's practice in respect of yield, net returns and B: C ratio. In all the trials, targeted yield (12 and 15 q ha^{-1}) could not achieved within (±) 10.0 per cent yield deviation due to severe attack of aphid (Table 4.13.25).

Table 4.13.25 Front line demonstrations of fertilizers prescription equations of mustard (cv. B-9) in village Panchkania, Haringhata, District Nadia (mean value of six FLDs)

Treatments	Fertilizer dose (kg ha^{-1})			Grain yield (q ha^{-1})	Addnl. yield over control (q ha^{-1})	Response ratio (q ha^{-1})	Net return (Rs. q ha^{-1})	Yield deviation (%)	B:C ratio
	N	P_2O_5	K_2O						
Control	0	0	0	5.66	0.00	0.00	839		1.06
FP	40	30	20	6.38	0.73	1.03	1576		1.10
RDF	60	40	40	7.12	1.47	1.45	3036		1.18
ST-TY 12 q ha^{-1}	100	22	65	7.48	1.83	1.48	3792	(-) 37.7	1.22
ST–TY 15 q ha^{-1}	120	35	82	7.83	2.18	1.39	4119	(-) 47.8	1.23

Front Line Demonstrations conducted with oilseeds (mustard) in Upper Gangetic Plains zones clearly brought out the superiority of STCR-IPNS recommendations over blanket and farmer's practice. The grain yield obtained was 25.1 and 19.6 q ha^{-1} with net profit of Rs. 39233 and 26738 ha^{-1} in soil test based fertilizer recommendations as compared to general recommended dose, respectively (Table 4.13.26).

Table 4.13.26 Economics of treatments included in FLDs on mustard

Treatments	Fertilizer dose (kg ha^{-1}) N	P_2O_5	K_2O	S	Yield (q ha^{-1})	Addnl. yield over control (q ha^{-1})	Response ratio (q ha^{-1})	Net return (Rs. ha^{-1})	Net profit (Rs. ha^{-1})
Control	0	0	0	0	8.1	-	-	-	-
Target (2.5 t ha^{-1})	40	30	20	20	25.1	17.0	7.2	1576	39483
RDF	60	40	40	0	19.6	11.5	7.2	3036	26738
Farmer's practice	81	58	0	0	15.4	7.3	3.4	18250	15629

Test verification trials conducted with soybean, niger and linseed in montmorillonitic hypothermic Typic Hapulustert deep black taxonomically fine soil showed greater benefit of STCR technology over farmers' practice or blanket application of fertilizer (Table 4.13.27).

Table 4.13.27 Economics of treatments included in FLDs on soybean, niger and linseed

Soybean (JS 97 52), Village : Simariya, Seoni									
GRD	20	60	20	350	1694	7000	5306	3.13	3.50
T.Y. 2.5 t ha^{-1}	29	89	18	590	2414	11800	9386	3.89	4.34
T.Y. 2.5 t + 5 t FYM ha^{-1}	29	89	18	660	2414	13200	10786	4.47	2.19
Niger (PCN-8), Village : Guriya, Jabalpur									
GRD	10	20	10	151	632	5738	5106	8.08	3.78
T.Y. 5 q ha^{-1}	48	2	18	264	778	10032	9254	11.89	3.88
T.Y. 5 q + 5 t FYM ha^{-1}	48	2	18	289	778	10982	10204	13.11	1.24
Niger (PCN-8), Village : Ghughri, Jabalpur									
GRD	10	20	10	185	632	7030	6398	10.12	4.63
T.Y. 5 q ha^{-1}	54	15	37	250	1281	9500	8219	6.42	2.36
T.Y. 5 q + 5 t FYM ha^{-1}	54	15	37	300	1281	11400	10119	7.90	1.11
Niger (PCN-8), Village : Pitkuchi, Jabalpur									
GRD	10	20	10	125	632	4750	4118	6.51	3.13
T.Y. 5 q ha^{-1}	53	26	37	175	1505	6650	5145	3.42	1.51
T.Y. 5 q + 5 t FYM ha^{-1}	53	26	37	210	1505	7980	6475	4.30	0.75
Linseed (J 23), Village : Bhinjawada, Seoni									
GRD	60	40	20	390	1759	13650	11891	6.76	3.25
T.Y. 16 q ha^{-1}	8	30	15	560	862	19600	18738	21.75	10.57
T.Y. 16 q + 5 t FYM ha^{-1}	8	30	15	670	862	23450	22588	26.21	3.07

Frontline demonstrations with soybean and toria conducted in low hills sub-montane zone of Himachal Pradesh covering the districts of Hamirpur and Una for two pre- fixed yield targets of 20 and 25 q ha^{-1} for soybean and 10 and 15 q ha^{-1} for *toria*. The following fertilizer adjustment equations developed for both the crops by Palampur centre were used in front line demonstrations on farmers' fields with soybean and toria.

Soybean (cv. Bragg)	Toria (cv. Bhawani)
FN=20 kg N ha^{-1}	FN =5.33 T-0.06SN
FP_2O_5=6.97 T-6.30SP	FP_2O_5=3.67 T-0.73 SP
FK_2O=4.36 T-0.36 SK	FK_2O=5.63 T-0.69 SK

FN, FP_2O_5 & FK_2O are fertilizer nutrient /doses in kg ha^{-1}
T= Yield target in q ha^{-1}
SN, SP and SK are Soil test values in kg ha^{-1} for available N, P and K.

In case of soybean, the lowest yield was obtained under farmers' practice (8.5 q ha^{-1}) followed by farmers' practice (13.6 q ha^{-1}). The treatments based on STCR concept out yielded control as well as farmers' practice. The yield obtained under GRD was at par with that obtained under pre- fixed target of 20 q ha^{-1}. However the desired agreement between targeted and observed yields could not be achieved in case of both the pre- fixed targets of 20 and 25 q ha^{-1} (Table 4.13.28), as the percent deviations in both the cases were higher (>10) and on the negative side. However, the net benefits over farmers' practice and GRD were higher justifying the usefulness of targeted yield concept based fertilizer application. The benefit cost ratio was highest (5.5) in the treatment comprising of target 25 q ha^{-1} as against the farmers' practice where it was comparatively low (3.5).

Table 4.13.28 Fertilizer demonstrations on soybean (cv. Bragg) on farmers' fields (Entisol) in low hills sub-montane zone of Himachal Pradesh (Average of 4 locations)

Treatments	Fertilizer dose (kg ha^{-1})			Yield (q ha^{-1})	Per cent deviation	Cost of yield (Rs.)	Cost of cultivation (Rs.)	Net returns (Rs.)	B:C ratio
	N	P_2O_5	K_2O						
Control	20	0	0	8.5	-	18590	7200	11390	-
FP	20	0	0	13.6	-	29865	8621	21244	3.5
GRD	25	56.3	45	16.0	-	35090	9063	26027	3.9
Target									
20 q ha^{-1}	20	0	41.3	16.3	-18.6	35805	7749	28056	4.6
25 q ha^{-1}	20	7.1	63.1	19.9	-20.3	43835	7922	35913	5.5

In toria, application of fertilizers as per target yield concept, in general, resulted in higher yield of *toria* in comparison to farmers' practice and general recommended dose (Table 4.13.29). At the same time the amount of NPK fertilizers used under target yield concept were considerably lower resulting in saving of the fertilizers, thereby giving more profit. The per cent deviations under both the pre-fixed targets were quite high (> 10) due to the severe damage caused to the crop by heavy hailstorm (during flowering stage). Inspite of the damage to the crop, higher yield, net returns and benefit cost ratio under prescription based fertilizer application were obtained over general recommended dose, farmers' practice and control treatment. The results advocate that STCR equations can be successfully used for raising toria crop and harnessing better profits.

Table 4.13.29 Fertilizer demonstrations on *toria* (cv. Bhawani) on farmers' fields (Entisol) in low hills sub-montane zone of Himachal Pradesh (Average of 7 locations)

Treatments	Fertilizer dose (kg ha^{-1})			Yield (qha^{-1})	Per cent Deviation	Cost of yield (Rs.)	Cost of cultivation	Net returns (Rs.)	B:C ratio
	N	P_2O_5	K_2O						
Control	0	0	0	3.1		7600	7200	400	
FP	20	0	0	6.3		12677	7410	5267	1.71
GRD	75	30	48.6	7.7		15414	9078	6336	1.70
Target 10 q ha^{-1}	42.8	12.1	5.6	8.4	-11.5	16729	7985	8743	2.09
Target 15 q ha^{-1}	69.4	30.4	28.5	11.8	-22.4	23600	8867	14733	2.66

Frontline demonstrations on Raya (cv. RLM 619) crop in farmers' fields in Moga and Ludhiana districts of showed that yields obtained under STCR technology varied from their respective targets (20 q ha^{-1}and 25 q ha^{-1}) at the most by 5.5% (Table 4.13.30). A comparison of seed yields vis-à-vis soil nutrient status suggested the importance of K in Raya nutrition.

Table 4.13.30 Frontline demonstrations on oilseeds (Raya RLM-619) at farmers' fields

Treatment	Fertilizer dose (kgha^{-1})			Grain Yield (q ha^{-1})
	N	P_2O_5	K_2O	
Village : Dosanjh, District : Moga				
GRD	100	30	15	18.8
Target 20 q ha^{-1}	109	6	25	19.2
Target 25 q ha^{-1}	152	30	49	24.0
Farmer's practice	120	30	0	19.2
Control	0	0	0	8.4
Village : Chugga Kalan, District : Moga				
GRD	100	30	15	18.2
Target 20 q ha^{-1}	107	16	23	19.1
Target 25 q ha^{-1}	150	40	47	24.6
Farmer's practice	100	30	0	17.3
Control	0	0	0	8.2

GRD	100	30	15	18.0
Target 20 q ha^{-1}	98	0	44	19.1
Target 25 q ha^{-1}	141	24	68	24.6
Farmer's practice	120	30	0	18.1
Control	0	0	0	9.3
Village : Dosanjh, District : Moga				
GRD	100	30	15	19.0
Target 20 q ha^{-1}	100	6	24	19.2
Target 25 q ha^{-1}	143	30	48	24.4
Farmer's practice	100	30	20	19.2
Control	0	0	0	8.3
Village : Raoke Kalan, District: Moga				
GRD	100	30	15	18.0
Target 20 q ha^{-1}	102	0	22	18.9
Target 25 q ha^{-1}	145	24	46	24.1
Farmer's practice	120	28	0	16.8
Control	0	0	0	8.6

In Southern Agroclimatic zone of Tamil nadu, front line demonstrations were conducted with groundnut variety TMV 7 in two locations viz., C. K. Valasu and Perumalkoilpatti on red sandy clay loam soil. The treatments were control, farmer's practice, blanket recommendation, STCR recommendation for 25 q ha^{-1} and STCR recommendation under IPNS for 25 q ha^{-1}. In both the locations, the soil was low in available N and high in P status. The available K status was high in C.K.Valasu and medium in Perumalkoilpatti. Based on the initial soil test values, the fertilizer doses were calculated for STCR treatments. For STCR-IPNS treatment, FYM @12.5 t ha^{-1} was applied. The results revealed that the highest pod yield of 2400 kg ha^{-1} was recorded in the STCR-IPNS treatment followed by 2210 kg ha^{-1} in STCR-fertilizers alone treatment (Table 4.13.31). The highest response ratio of 15.93 kg kg^{-1} was recorded for STCR-IPNS treatment followed by STCR fertilizer alone (13.85 kg kg^{-1}). Both the treatments surpassed the yield and response ratio recorded in blanket recommendation (1990 kg ha^{-1} and 9.90 kg kg^{-1} respectively).

Table 4.13.31 Front line demonstration on groundnut (cv. TMV 7) at farmers' field

Treatments	Fertilizer dose (kg ha^{-1}) N	Fertilizer dose (kg ha^{-1}) P_2O_5	Fertilizer dose (kg ha^{-1}) K_2O	Pod yield (kg ha^{-1})	RR (kg kg^{-1})
Village : C.K.Valasu, District Dindigul					
Control	0	0	0	950	-
Blanket	17	34	54	1990	9.90
STCR-25 q ha^{-1} yield target	47	17**	27**	2210	13.85
STCR-IPNS* 25 q ha^{-1} yield target	17	17**	27**	2400	15.93
Farmer's Practice	25	15	50	1600	7.20

Fertilizer Prescription Equations: $FN = 6.54\,T - 0.56\,SN - 0.69\,ON$; $FP_2O_5 = 3.80\,T - 3.32\,SP - 0.77\,OP$; $FK_2O = 8.35\,T - 0.65\,SK - 0.87\,OK$

At Perumalkoilpatti, results revealed that the highest pod yield of 2571 kg ha^{-1} was recorded in the STCR-IPNS treatment followed by 2380 kg ha^{-1} in STCR-fertilizers alone treatment (Table 4.13.32) while control and farmer's practice recorded relatively lower yields. The highest response ratio of 12.0 kg kg^{-1} was recorded for STCR-IPNS treatment followed by STCR fertilizer alone (10.7 kg kg^{-1}). Both the treatments recorded higher yield and response ratio when compared to blanket recommendation (1513 kg ha^{-1} and 6.08 kg kg^{-1} respectively).

Table 4.13.32 Front line demonstration on groundnut (cv. TMV 7) at farmers' field

Treatments	Fertilizer dose (kg ha^{-1})			Pod yield (kg ha^{-1})	Response ratio (kg kg^{-1})
	N	P_2O_5	K_2O		
Village : Perumalkoilpatti; District Dindigul					
Control	0	0	0	875	-
Blanket	17	34	54	1513	6.08
STCR-25 q ha^{-1} yield target	35	17**	89	2380	10.70
STCR-IPNS* 25 q ha^{-1} yield target	10	17**	46	2571	12.00
Farmer's practice	30	20	45	1470	6.20

Fertilizer Prescription Equations : $FN = 6.54\,T - 0.56\,SN - 0.69\,ON$; $FP_2O_5 = 3.80\,T - 3.32\,SP - 0.77\,OP$; $FK_2O = 8.35\,T - 0.65\,SK - 0.87\,OK$

In Southern zone of Tamil Nadu, one front line demonstration was conducted with sunflower at Gujiliamparai, Dindigul Dt. on sandy clay loam soil. The soil was low in available N and high in available P and K status. The treatments were control, blanket recommendation, STCR recommendation (Fertilizers alone) and STCR recommendation under IPNS and farmer's practice. Based on the initial soil test values, the fertilizer doses were calculated for STCR treatments. For STCR-IPNS treatment, FYM @12.5 t ha^{-1} was applied. From the yield data and fertilizer doses applied, the response ratio (RR) was calculated. The results revealed that the highest seed yield of 2150 kg ha^{-1} was recorded in the STCR-IPNS treatment followed by 1895 kg ha^{-1} in STCR-fertilizers alone treatment (Table 4.13.33). The highest response ratio of 5.41 kg kg^{-1} was recorded for STCR-IPNS treatment followed by STCR fertilizer alone (4.30 kg kg^{-1}). Both the treatments recorded highest yield and response ratio while comparing with blanket recommendation (1589 kg ha^{-1} and 3.23 kg kg^{-1} respectively) and proved the superiority of STCR base fertilizer recommendation.

Table 4.13.33 Front Line Demonstration on Sunflower (Hybrid: Ravi Kiran 1) at farmers' field

Treatments	Fertilizer dose ($kg\ ha^{-1}$) N	P_2O	K_2O	Pod yield ($kg\ ha^{-1}$)	Response ratio ($kg\ kg^{-1}$)
Control	0	0	0	910	-
Blanket	60	90	60	1589	3.23
STCR-2 t ha^{-1} yield target	120	33	76	1895	4.30
STCR-IPNS* 2 t ha^{-1} yield target	90	23**	36	2150	5.41
Farmer's practice	45	75	55	1410	2.85

Fertiliser Prescription Equations : $FN = 9.60\,T - 0.49\,SN - 0.68\,ON$; $FP_2O_5 = 4.20\,T - 1.87\,SP - 0.80\,OP$; $FK_2O = 9.24\,T - 0.45\,SK - 0.64\,OK$

In North Western zone of Tamil Nadu, one front line demonstration was conducted with gingelly at Thoppur village on sandy clay loam soil. The treatments include control, blanket recommendation, STCR recommendation (Fertilizers alone) and STCR recommendation under IPNS. Based on the initial soil test values, the fertilizer doses were calculated for STCR treatments. For STCR-IPNS treatment, FYM @12.5 t ha^{-1} was applied. The soil was low in available N, high in available P and medium in K status. From the yield data and fertilizer doses applied, the response ratio (RR) was calculated. The results revealed that the highest pod yield of 990 kg ha^{-1} was recorded in the STCR-IPNS treatment followed by in STCR-fertilizers alone treatment (920 kg ha^{-1}), blanket recommendation (740 kg ha^{-1}), farmer's practice (650 kg ha^{-1}) and control (450 kg ha^{-1}). The highest response ratio of 4.50 and 3.92 kg kg^{-1} were also recorded in STCR-IPNS and STCR fertilizer alone treatments respectively (Table 4.13.34).

Table 4.13.34 Front line demonstration on gingelly (Hybrid: Subhiksha) at farmers' field

Treatments	Fertilizer dose ($kg\ ha^{-1}$) N	P_2O_5	K_2O	Pod yield ($kg\ ha^{-1}$)	Response ratio ($kg\ kg^{-1}$)
Control	0	0	0	450	-
Blanket	35	23	23	740	3.58
STCR-1 t ha^{-1} yield target	57	12**	51	920	3.92
STCR-IPNS* 1 t ha^{-1} yield target	27	12**	21	990	4.50
Farmer's practice	20	20	20	650	3.33

Fertiliser Prescription Equations : $FN = 13.7\,T - 0.46\,SN$; $FP_2O_5 = 6.3\,T - 1.79\,SP$; $FK_2O = 12.8\,T - 0.47\,SK$

Front line demonstrations conducted with groundnut at C.K.Valasu, Perumalkoilpatti and Kannurpatti), sunflower (Gujiliamparai), and gingelly (Thoppur) in Southern and North Western zone of Tamil Nadu had clearly brought out the superiority of STCR-IPNS fertilizer recommendation for groundnut, sunflower and gingelly over blanket recommendation and farmer's practice (plate 4.13.3).

Jute

Rice

Oilseed

Plate 4.13.3 Front line demonstration in Tamil Nadu on different crops

5. TECHNOLOGY ASSESSED/TRANSFERRED

Technology Dissemination Events

- Two training camps were organized by Dr. R. S. Chaudhary, Head, Division of Soil Physics, in the two villages viz. Parwalia of Bhopal district and Vaidakhedi of Sehore district of Madhya Pradesh in which 30 selected farmers were trained for preparing the Soil Health Cards of their fields by themselves.

Demonstration of field method for evaluating soil health

- The demonstrations conducted in the district of Kandhamal, with bioinoculant as integral component of INM practice increased the pod yield of cowpea by 60%, maize cob yield by 31%, green gram seed yield by 51%, arhar seed yield by 73%, potato tuber yield by 18 % and garden pea pods by 18%, compared to uninoculated and unintegrated treatments (OUAT, Bhubaneswar).
- Biofertilizer production from the effective microbial cultures of the project during 2011-12 at 5 centres generated a revenue of Rs. 100 lakhs.

Farmers' trainings conducted at the Institute

Name of the Institute/ Organization	Number of Farmers	Coordinator	Title of training	Duration of the training
Katihar District, Bihar under ATMA Project	25	Dr. A. B. Singh	Organic farming and soil health	8 days (20-27 April, 2011)
Purvi Champaran District, Bihar under ATMA Project	25	Dr. A. B. Singh	Organic farming and soil health	6 days (16-21 September, 2011)
Gaya District, Bihar under ATMA Project	25	Dr. A. B. Singh	Organic farming and soil health	6 days (26 September - 01 October, 2011)
Saran District, Bihar under ATMA Project	25	Dr. A. B. Singh	Organic farming and soil health	6 days (10-15 October, 2011)
Darbhanga District, Bihar under ATMA Project	25	Dr. A. B. Singh	Organic farming and soil health	6 days (1-6 December, 2011)
Diara Development Project, Patna, Bihar	25	Dr. A. B. Singh and Dr. A. K. Tripathi	Organic farming and soil health	5 days (26-30 December, 2011)
Supoul District, Bihar under ATMA Project	25	Dr. A. B. Singh	Organic farming and soil health	6 days (15-20 January, 2012)
Darbhanga District, Bihar under ATMA Project	25	Dr. A. B. Singh	Organic farming and soil health	6 days (2-7 February, 2012)
Raisen District, Madhya Pradesh under ATMA Project	25	Dr. A. B. Singh And Dr. A. K. Tripathi	Organic farming and soil health	5 days (15-19 March, 2012)

6. EDUCATION AND TRAINING

6.1 Training Attended

Participant	Title	Name of Organization	Duration
Dr. (Ms.) Asha Sahu	Current approaches and applications of bioinformatics in agricultural research.	CTCRI, Kerala	28 Mar-6 April, 2011
Dr. Sanjay Srivastava	Data mining and GIS for decision support in agriculture under management development programme (MDP).	IIM, Lucknow	28 March – 08 April, 2011
Dr. Asit Mandal	Holistic foundations for assessment and regulation of genetic engineering and genetically modified organisms.	CSA, Hyderabad	2-7 May, 2011
Dr. A. K. Shukla	Leadership development	NAARM, Hyderabad	01–06 July, 2011
Miss. Neenu, S.	Climate change mitigation strategies-planning for implementing the mitigation practices in India.	ESCI campus, Gachi Bowli, Hyderabad	12-14 July, 2011
Dr. M. Vassanda Coumar	Techno scientific management for scientist.	ASCI, Hyderabad	1-12 August, 20011
Mr. S.Rajendiran	National training on "Nanocellulose and its composites in agriculture".	CIRCOT, Mumbai	10-24 October, 2011
Dr. N. K. Lenka	USDA seminar "Challenges of natural resource management for small - holder farmer's on marginal lands".	Des Moines, Iowa, USA	12 October, 2011
Dr. Sanjay Srivastava	Training programme on "Enhancing the input application efficiency by Using precision farm machines, remote & ground sensor".	PAU, Ludhiana	14-23 November, 2011
Dr. Nishant K. Sinha	National training on "Recent trends of geoinformatics in land Resource Database Management for Sustainable agriculture".	NBSSLUP, Nagpur	15-28 November, 2011

Dr. Sangeeta Lenka	National training programme on "Climate change, carbon sequestration and carbon trading".	CSWRI , Avikanagar, Rajasthan	24-25 November, 2011
Miss. Neenu, S.	Forecast modelling in crops.	IASRI, New Delhi	3-12 August, 2011
Dr. S. K. Behera	MS power p oint (MSPP) 2007 .	ISTM, New Delhi	18-19 August, 2011
Dr. Sanjay Srivastava	Enhancing the input application efficiency by using precision farm machines, remote & ground sensor.	PAU, Ludhiana	14-23 November, 2011
Dr. Nishant K. Sinha	Recent trends of geoinformatics in land resource d atabase management for sustainable agriculture.	NBSSLUP, Nagpur	15-28 November, 2011
Dr. K. Ramesh	Applications of nanotechnology in agriculture.	CIRCOT , Mumbai	02-12 January, 2012
Dr.(Ms) Asha Sahu	Effective enhancement programme for women scientists.	IMTR, Goa	16–20 January, 2012
Drs. S.R. Mohanty, K. Bharati and K. Ramesh	Refresher course on agricultural research m anagement.	NAARM, Hyderabad	19 Jan-8th February, 2012
Dr. Nishant K. Sinha	Website design, development, hosting & m anagement.	IIFM, Bhopal	30 January - 1 February, 2012
Dr. M. Vassanda Coumar	Environmental impact assessment: Cases, issues and applications of remote sensing, GPS & GIS techniques .	MANIT, Bhopal	23-28 February, 2012
Dr. Nishant K. Sinha	Predicting soil carbon sequestration in view of global warming and climate c hange.	NBSSLUP, Nagpur	24 February – 8 March, 2012

6.2 Trainings Organized for students

Coordinating Scientist & Division at IISS	Training Programme	Name of the Trainee and Degree Programme	Name of the Institution / College	Duration of the Training
Dr. S. Kundu	CO_2 Mineralization of hard wood and soft wood biochar	Dr. Hamudu (Post Doctoral Fellow under "C. V. Raman Visiting Fellow")	Rwanda	3 months
Dr. S. R. Mohanty	Effect of nano-particles on soil microbial community dynamics	Ms. D. Chourasiya (M.Sc.Microbiology)	S N Govt P.G. College, Khandwa.	2 months
Dr. M.C. Manna	Long-term effect of fertilizer and manure on soil microbial activities in Vertisol	Ms. Yamini (M.Sc. Microbiology)	S.N. Govt. P.G. College, Khandwa.	2 months
Dr. S. R. Mohanty	Methanotrophic activity in tropical upland soils of India	Monika Patidar (M.Sc. Microbiology)	S N Govt P.G. College, Khandwa.	2 months
Dr. S. R. Mohanty	Responses of methanogenic and methane oxidising microorganisms to fertilizer amendment in tropical soils	Ms. Davista Afreen (M.Sc. Microbiology)	Barkatullah University, Bhopal.	6 months
Dr. S. R. Mohanty	Nanomaterial impact on methanotrophic bacteria	Ms. Suchitra Singh	Barkatullah University, Bhopal.	6 months
Dr. S. R. Mohanty	Impact of organic, inorganic and integrated system of crop cultivation on biological and physical healthof soil	Ms. Sabiha khan (M.Sc. Biotechnology)	Safia college, Bhopal, MP.	1month

Dr. S. R. Mohanty	Impact of organic , inorganic and integrated system of crop cultivation on biological and physical health of soil	Ms. PriynakaSharma (M.Sc. Biotechnology)	Safia college, Bhopal.	1month
Dr. S. R. Mohanty	Impact of organic , inorganic and integrated system of crop cultivation on biological and physical health of soil	Ms. Farzana (M.Sc. Biotechnology)	Safia College, Bhopal.	1month
Dr. K. Bharati	Methanotrophic activity under elevated CO_2 and temperature in tropical soils	Ms. K Manjusha (B.Sc. Biotechnology)	Bapatla Engineering College, AP.	1 month
Dr. K. Bharati	Impact of elevated CO_2, temperature and soil aggregate size on CH_4oxidation activity in Vertisols	Ms. Akansha Joshi (M.Sc. Microbiology)	S N Govt College, Khandwa.	2 months
Dr. Asit Mandal	Assessment of microbial activity and diversity under cotton in Vertisol	Ms. Neha Sankle (M.Sc. Microbiology)	S N Govt College, Khandwa.	2 months

Dr. (Ms.) Asha Sahu	Exploring bioaccumulation efficacy of *Trichoderma viride*: an alternative bioremediation of cadmium and lead	Ms. Rachna Mali (M.Sc. Microbiology)	S N Govt College, Khandwa.	2 months
Dr. J.K. Thakur	Functional characterization of microbes present in Panchagavya for their PGPR activities	Ms. Neeta Rathore (M.Sc. Microbiology)	S N Govt College, Khandwa	2 months
Dr. Asit Mandal	Consequences of transgenic cotton on rhizosphere soil enzymes and microbial activity under Vert isol	Ms. Anuradha Panthi (M.Sc. Biotechnology)	Barkatullah University, Bhopal.	1 month
Dr. Asit Mandal	Effect of transgenic cotton on cultural diversity of soil microorganisms	Ms. Ekta Hedau (M.Sc. Biotechnology)	Barkatullah University, Bhopal.	1 month
Dr. Asit Mandal	Effect of transgenic cotton on glomalin protein in Vertisol	Ms. Hemlata Malviya (M.Sc. Biotechnology)	Barkatullah University, Bhopal.	1 month
Dr. (Ms.) Asha Sahu	Influence of artificially spiked nickel and chromium on growth and biomass production of *Trichoderma viride*	Ms. Rubeena Khanam (M.Sc. Biotechnology)	Barkatullah University, Bhopal.	1 month

Dr. (Ms.) Asha Sahu	Artificially spiked copper and zinc affects biomass production of *Trichoderma viride* under laboratory condition	Ms. Priya Gaur (M.Sc. Biotechnology)	Barkatullah University, Bhopal.	1 month
Dr. J.K. Thakur	Assessment of soil microbial enzyme activity under different crop management practices	Ms. Padma Parmar (M.Sc. Biotechnology)	Barkatullah University, Bhopal.	1 month
Dr. J.K. Thakur	Enumeration of microflora from organic manure and BD500 and evaluation of antifungal activities of actinomycetes isolated from organic manures	Ms. Priya Geete (M.Sc. Biotechnology)	Barkatullah University, Bhopal.	1 month
Drs. R. S. Chaudhary and S. R. Mohanty	Internship training on impact of organic, inorganic and integrated system of crop cultivation on biological and physical health of soil	Sabiha Khan, Farzana Lityani Priyanka Sharma	Saifia College, Bhopal.	1 month
Drs. J. Somasundaram and R. S. Chaudhary	Internship training on impact of conservation tillage and various cropping systems on biological and physical health of soil	Shumaila Maqsood, Sabba Khan Shobha Sunderasia.	Saifia College, Bhopal.	1 month

Dr. Ajay	Biochemical Analysis of different varieties of finger millet plant material through Zinc biofortification at post-flowering stage	Mr. Krishna Gokhle (M.Sc. Bioscience)	Barkatullah University, Bhopal.	3 months
Dr. Ajay	Biochemical Analysis of different varieties of finger millet seed material through Zinc biofortification at post-flowering stage	Mr. Jacky Shakul (M.Sc. Bioscience)	Barkatullah University, Bhopal.	3 months
Dr. Ajay	Biochemical analysis of different varieties of sorghum plant material through Zinc biofortification at post-flowering Stage.	Ms. Sarita Tripathi (M.Sc. Bioscience)	Barkatullah University, Bhopal.	3 months
Ms. Neenu S.	Methods of soil analysis.	Neha Arya, Mamta Choudhary, Ankita Diwan , Madhuri Choudhary, M.Sc. Chemistry	Barkatullah University, Bhopal.	5 days
Dr. M. Vassanda Coumar	Characterization of oilseed processing industrial effluent and its effect on soil quality.	Mr. Aejaz Yousof (M.Sc. Environmental Science)	Barkatullah University, Bhopal	3 months

Dr. M. Vassanda Coumar	Effect of metal processing industrial effluent irrigation on physico-chemical and biological properties of soil	Mr. Bilal Ahmad Rather (M.Sc. Environmental Science)	Barkatullah University, Bhopal	3 months
Dr. M. Vassanda Coumar	Physico-chemical characterization of water and sediment from Lower lake, Bhopal	Mr. Irfan Ahmad (M.Sc. Environmental Science)	Barkatullah University, Bhopal	3 months
	Physico-chemical characterization of water and sediment from Shahpura lake, Bhopal.	Mr. Nisar Ahmad Mir (M.Sc. Environmental Science)	Barkatullah University, Bhopal	3 months

6.3 Foreign Visits

- Dr. K. Ramesh visited Ohio State University, OSU South Centers, Piketon, to undergo USDA Norman E Borlaug International Agricultural Science & Technology fellowship program under the guidance of Dr. Rafiq Islam, Research Scientist during July 14 to September 09, 2011.
- Dr. N.K. Lenka visited Ohio State University, Columbus, USA to undergo Borlaug fellowship program under the guidance of Dr Rattan Lal, Distinguished University Professor during October 10, 2011-January 8, 2012.
- Ms. Neenu S. visited Kathmandu, Nepal from September 19 to 23, 2011 to attend Capacity building workshop on “Using climate scenarios and analogues for designing adaptation strategies in agriculture”.

Dr. N.K. Lenka receiving Certificate of Recognition from Prof. Rattan Lal at Ohio State University, Columbus, USA

Dr. . K. Ramesh presenting seminar at College of Ohio State University, OSU South Centers, Piketon, USA

7. AWARDS/HONOURS/RECOGNITIONS

7.1 Awards

- Dr. S. Ramana received **“Bharat Jyothi Award-2012”** of India International Friendship Society.
- Dr A. K. Shukla received **“JSP Yadav Memorial Team Award-2011”** of Indian Society of Soil Science, New Delhi for excellence in soil science research.
- Dr. A. Subba Rao, Director and Dr. K. Sammi Reddy, Principal Scientist received **“Hari Om Ashram Trust Award”** for the biennium 2008-09 of Indian Council of Agricultural Research (ICAR), New Delhi for their outstanding contribution in the field of Natural Resource Management.
- Dr. Y. Muralidharudu, Project Coordinator (AICRP-STCR), received **“Chaudhary Devi Lal Outstanding All India Coordinated Research Project Award (AICRP) – 2010”** of Indian Council of Agricultural Research (ICAR), New Delhi for site-specific nutrient management .
- Dr. Pramod Jha received **"Golden Jubilee Commemoration Young Scientist Award-2011"** of Indian Society of Soil Science, New Delhi.

Drs. A. Subba Rao, Y. Muralidharudu and K.S. Reddy confered ICAR Award

Dr. Pramod Jha receiving Young Scientist Award (ISSS) at UAS, Dharwad

7.2 Best Poster Awards

- Ramana, S., Biswas, A.K., Singh, A.B., Ajay and Ahirwar, N.K received best poster award on “Phytoextraction of chromium by some floriculture plants” during National Seminar of Plant Physiology from November 24-26, 2011 held at Ramnarain Ruia College, Matunga.
- Kundu, S., Vassanda Coumar, M., Saha, J.K., Biswas, A.K. and Reddy, K.S. received best poster award on “ Effect of biochar, FYM and lime on microbial resilience of degraded acid soil under copper stress” during 76th Annual Convention of Indian Society of Soil science from November 16 - 20, 2011 held at UAS, Dharwad.
- Tapan Adhikari, Kundu, S., Biswas, A.K., Tarafdar, J.C. and Subba Rao, A. received best poster award on ““Nano rock phosphate: Synthesis and application to crops” during 4th Bangalore Nano Symposium from December 8-9, 2011 held at The Lalit Ashok Hotel, Banglore.

7.3 Recognitions

- Dr. Pradip Dey, Dr. Tapan Adhikari and Dr. Brij Lal Lakaria elected as Councillor of Indian Society of Soil Science, New Delhi.
- Dr. Tapan Adhikari elected as Councillor of Clay Mineral Society of India, Nagpur.

8. LINKAGES AND COLLABORATIONS IN INDIA AND ABROAD

The institute has strengthened linkages with national, international agencies, and the extension and development agencies, as well as with ICAR institute and SAUs located throughout the country. Linkages have been strengthened by organizing workshops/ meetings of AICRP 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 post graduate students by the institute scientists. 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 Indian Institute of Soil Science has established research linkages and collaborations with other ICAR institutes and State Agriculture Universities (SAUs) through its network of NAIPs and AICRPs and their co-ordnating centers. All the three AICRPs and one Network Project's co-operating units located at IISS, Bhopal have 56 cooperating centers spread over in almost all the SAUs.

Two network projects on the following aspects are being operated in the institute.

1. Network project on organic farming (NPOF)
2. Assessment of quality and resilience of soils in diverse agro-ecosystems.

In a NAIP project on Nano-technology, institute has collaboration with CAZRI, Jodhpur. There is collaboration with CRRI, Cuttack in another NAIP project on “Soil Organic Carbon Dynamics and Climate Change”. AMAAS funded research project on “Improving Yields and Nutrient Uptake of Selected Crops through Microbial Inoculants in Vertisols of Central India” was initiated in the year 2008 in collaboration with NBAIM, Mau.

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

S. No	All India Coordinated Research Projects	No. of co-operating centres		
		ICAR	SAUs/ SGUs	Total
1.	AICRP on Long Term Fertilizer Experiments to Study Changes in Soil Quality, Crop Productivity and Sustainability (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, Palampur, Kanpur.	0	16	16
4.	Network Project on Biofertilizers (BNF): Jorhat, New Delhi, Hisar, Jabalpur, Parbhani, Amarawathi, Bhubaneshwar, Junagarh, Coimbatore, Pusa, Solan, Ranchi, Udaipur, Hazaribagh, Hyderabad, Dharwad, Delhi, Trichur, Vellayani	4	15	19
	Total	9	60	69

9. LIST OF PUBLICATIONS

9.1 Research papers

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Adhikari, Tapan and Kumar, Ajay (2012). Phytoaccumulation and tolerance of *Riccinus Communis* L. to Nickel. *International Journal of Phytoremediation* **14**(5): 481-492.

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Singh, Muneshwar and Wanjari, R.H. (2012). Annual Report 2010-11. All India Coordinated Research Project on Long Term Fertilizer Experiments to Study Changes in Soil Quality, Crop Productivity and Sustainability, **114p.**

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9.3 Book Chapters

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Hati, K.M. (2011). Soil properties in relation to profile water transmission and water harvesting. **In** Training Manual of Summer School on *'Sensor based application for precision farming to improve input use efficiency'* from July 05-25, 2011 *at CIAE, Bhopal. Technical Report No. CIAE/AMD/SS-73A/2011/387*. **pp. 211-216.**

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Ramesh, K., Singh, A.B., Ramana, S., Ramesh, P., Lakaria, Brij Lal, Singh, D. and Solanki, K. (2012). Soybean ki Jaivik Kheti. **In** *Javik Kheti Evam Mrida Swasthya* (Singh, A. B., Tripathi, A.K., Subba Rao, A. Eds). Indian Institute of Soil Science, Bhopal, **pp. 54-60.**

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9.4 Review/Popular Articles

Ajay and Dotaniya, M.L. (2012). Detergents: a Blessing or a Curse- *AGROBIOS Newsletter* **X**(11): 61-62.

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9.5 Invited Lecture/ Lead Papers Published

A. K. Shukla

- Delivered T.D. Biswas memorial lecture entitled " Micronutrient Research in India: Current Status and Future Strategies" at CSAUT, Kanpur on October, 2011.
- Delivered invited lecture entitled "Micro and secondary nutrients in crop productivity and human health" at PAU, Ludhiana on 07th December, 2011.
- Biswas, A.K. Pramod Jha and Lakaria, Brij Lal (2011) Organic matter in improving soil health and productivity: Chemical aspects during workshop on "Improving Soil Productivity in Rain-fed Areas" jointly organized by Watershed Support Services and Activities Network (WASSAN), Hyderabad and Indian Institute of Soil Science at IISS, Bhopal during 28-29 June, 2011.

D.L.N. Rao

- Delivered a lecture on "Interventions for Promotion of Biofertilizers" in Agribusiness Development Camp on Biofertilizers organized by Business Planning and Development Unit, JNKVV, Jabalpur, Jan 10, 2012.
- Delivered a lecture "Interventions for Promotion of Biofertilizers" at the DSR (ICAR)-Industry Interface on sharing of technologies for soy bean processing industry, farm machineries and biofertilizer on Feb 2, 2012.
- Delivered a lecture on "Recent advances in Biological Nitrogen Fixation Research" at Centre for Advanced Faculty Training (CAFT) programme on "Biotic and abiotic resources management for

ecofriendly and sustainable Agriculture" at the Department of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur, October 15, 2011.

- Delivered a lecture on "Soils, organic matter and soil biodiversity concerns in integrated soil management" during brain storming session on "Sustaining agricultural productivity through integrated soil management" at NAAS, New Delhi.
- Delivered a lecture on "Recent advances in nitrogen-fixing microorganisms" during brain storming session on "Microorganisms in Sustainable Agriculture" at INSA, New Delhi.

Muneshwar Singh

- Presented Dr. M.N. De Memorial Lecture on 'Nutrient Management on Long Term Basis: A Key To Sustainable Productivity and Soil Health' at Annual Convention of Indian Society of Agriculture & Chemist at GBPUAT Pantnagar, November 25-26, 2011.

Subba Rao, A.

- Subba Rao, A. Jha, P. and A.K. Biswas (211) Carbon Sequestration in Agricultural Soils: Issues and Streategies in National Symposium on Agro-forestry for Environmental Services, Livelihood Security and Climate Resilient Agriculture: Challenges and Opportunities, December 3-5, 2011 Jhansi
- Subba Rao, A. Singh, A.B. and Ramesh, K. (2011) Nutrient Management Strategies for Organic package and Practices" International Organic Bihar during June 22-24, 2011Patna.

10. LIST OF APPROVED ON-GOING PROJECTS

Sl. No	Title of the Research Project
Programme I : Nutrient Management and Fertility Improvement	
(A)	**In-house Projects**
1	Long-term evaluation of integrated plant nutrient supply modules for sustainable productivity in Vertisol *Muneshwar Singh, K. Sammi Reddy, A.K. Biswas, A.B.Singh and R.S. Chaudhary*
2	Transformation and phyto-availability of zinc and boron in selected bench mark acid soils amended with lime and farmyard manure *Sanjib Kumar Behera and M.V.Singh*
3	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*
4	Study on nanoporous zeolites for soil and crop management *K. Ramesh, K. Sammi Reddy and I. Rashmi*
5	Efficacy of soil sampling strategies for describing spatial variability of soil attributes *Neenu S, S. Srivastava, and B.N. Mandal*
6	Participatory integrated nutrient management for improving the productivity and quality of soils of Nagaland *Brij Lal Lakaria, N.K. Lenka, R.H. Wanjari and A.K. Biswas*
7	Studies on soil resilience in relation to soil organic matter in selected soils *N.K. Lenka, Sangeeta Lenka, Brij Lal Lakaria, Asit Mandal, S.K. Behera, A.K.Biswas and A. Subba Rao*
8	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, I. Rashmi and J. Somasundaram*
9	Biofortification of grain sorghum and finger millet varieties with zinc through agronomic measures *Ajay, M.V. Singh, M. Vassanda Coumar, J.K. Saha, S. Kundu and S.K. Behera*
10	Development of phosphorus saturation indices for selected Indian soils *I. Rashmi, J.S.V Tenshia, K. Sammi Reddy, A.K. Biswas and A. Subba Rao*
11	Biochar on soil properties and crop performance *Brij Lal Lakaria, Pramod Jha, A.K. Biswas, K.M. Hati, Jyoti Thakur, Vassanda Coumar A.K. Dubey and S. Gangil*
(B)	**Externally funded projects**
12	Nano-technology for enhanced utilization of native phosphorus by plants and higher moisture retention in arid soils *Tapan Adhikari, A.K. Biswas and S. Kundu*
13	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) *A. K. Shukla, S. K. Behera, Muneshwar Singh, P. C. Mishra and Tapan Adhikari*

14 Evaluation of Allwin wonder (aw) and Allwin top (at) for their effects on maize productivity and soil fertility
K. Ramesh and S. Ramana

15 GPS and GIS based model soil fertility maps for selected districts for precise fertilizer recommendations to the farmers of India
A. Subba Rao, Y. Muralidharudu, M..V.Singh, Muneshwar Singh, K.N. Singh, R.H. Wanjari, S.K. Behera and A. Rathore

16 Efficiency of Bio-release micronutrient fertilizer Zinc (Micromac) on yields and zinc nutrition of different crops in India
A. K. Shukla, S. K. Behera, R. H. Wanjari, B. L. Sharma

17 Evaluation of efficiency of Patentkali-PMS fertilizer for potash, magnesium and sulphur nutrition and yield of different crops in India

A. K. Shukla, Sanjib Kumar Behera

Programme II : Management of Soil physical Components

(A) In-house Projects

18 8tudy of Long-term tillage management with differential nitrogen on soybean-wheat cropping system in Vertisols
K.M. Hati and R.K. Singh

19 Tillage and manure interactive effects on soil aggregate dynamics, soil organic carbon accumulation and bypass flow in Vertisols
Sangeeta Lenka, M.C. Manna, Brij Lal Lakaria, K.M Hati, R.K. Singh, S.K. Rautray and B.K. Garg

20 Tillage effect on weed dynamics in soybean-wheat system on Vertisol
Blaise D'Souza, R.H. Wanjari, and R.K. Singh

21 Detection of water and nitrogen stress and prediction of yield of soybean and maize using hyper-spectral reflectance and vegetation indices
K.M. Hati, R.K. Singh, Blaise D'Souza

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

23 Evaluating conservation tillage on various sequences/ rotations for stabilizing crops productivity under erratic climatic conditions in black soils of Central India
J. Somasundaram, Blaise D'souza and R. S. Chaudhary

24 Impact of crop covers on soil and nutrient losses through runoff in Vertisol
R.K. Singh, R.S. Chaudhary, J. Somasundaram and I. Rashmi

25 Characterizing rooting behaviors, soil water patterns and nutrient uptake of soybean - chickpea under different tillage and water regimes in Vertisols
N. K. Sinha, M. Mohanty, K. M. Hati, R. Saha, J. Somasundaram and I. Rashmi

26 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, S. Lenka, K. S. Reddy, Pramod Jha, Neenu, S., R. S. Chaudhary and A. Subba Rao

27 Evaluating conservation agriculture for stabilizing crop productivity and carbon sequestration by resilient cropping system/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

Programme III : Soil Qualities for Sustainable Productivity

(A) In-house Projects

28 Quality assessment of crops under different nutrient management systems in long term experiment
A.B. Singh, P. Ramesh, Muneshwar Singh, A.K. Tripathi and A. Subba Rao

29 On farm production and evaluation of vermi-compost and enriched compost
A. K. Tripathi, M.C. Manna, A.B. Singh, Ranjit Kumar

30 Structural and functional diversity of microbes in soil and rhizosphere

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

31 Consequences of transgenic cotton on soil microbial diversity
Asit Mandal, J. K. Thakur, Asha Sahu, M. C. Manna, D. L. N. Rao and A. Subba Rao

32 Actinomycetes diversity in Deccan plateau, hot, arid region and semi arid eco-sub-region (AER 3 and 6) and evaluation of their PGPR activity.
T.K. Radha and D.L.N. Rao

33 Developing technique for acceleration of decomposition process using thermophilic organisms
Asha Sahu, J. K. Thakur, Vinod Kumar Bhargav (CIAE), H. L. Kushwah (CIAE), Asit Mandal, M. C. Manna and A. Subba Rao

34 Chemical and microbiological evaluation of biodynamic and organic preparations.
J. K. Thakur, Asha Sahu, Asit Mandal and A. B. Singh.

(B) Externally funded projects

35 Improving yields and nutrient uptake of selected crops through microbial inoculants in Vertisols of central India
D.L.N. Rao and M.C. Manna

36 Soil organic carbon dynamics and climatic changes and crop adaptation strategies
M.C. Manna, S. Ramana, K. Sammi Reddy, A.K. Tripathi, Muneshwar Singh, K.N. Singh and S. R. Mohanty

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

38 Assessment of quality and resilience of soils in diverse agro-ecosystems (NAIP).
S. Kundu, A. Subba Rao, Muneshwar Singh, Y. Muralidharudu, J.K. Saha, A.K. Biswas, A.K. Tripathi, K. Sammi Reddy, R.H. Wanjari, K.M. Hati, Tapan Adhikari and M. Vassanda Coumar.

39 Metagenomic characterization and spatio-temporal changes in the prevalence of microbes involved in nutrient cycling in the rhizoplane of bioenergy Jatropha curcas crop
S R Mohanty, K. Bharti and Asit Mandal

Programme IV : Minimizing Environmental Pollution

(A) In-house Projects

40 Developing database on extent of soil and water contamination in India
J.K. Saha, Tapan Adhikari , S. Ramana, A.K. Biswas, S. Srivastava, S. Kundu and M.L. Dotaniya

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

42 Soil resilience and its indicators under some major soil orders of India
Ritesh Saha, K.M. Hati, P. Jha, M. Mohanty, M. Vassanda Coumar, R.S. Chaudhary, A. Subba Rao and Badegaonkar

43 Non point sources of phosphorus loading to upper lake, Bhopal.
M. Vassanda Coumar, M.L. Dotaniya, J. Somasundaram, J.K. Saha, K.S. Reddy and S. Kundu

44 Soil quality assessment for enhancing crop productivity in some tribal districts of Madhya Pradesh
S. Rajendiran, M. L. Dotaniya, M. Vassanda Coumar, N. K. Sinha, S. Srivastava, A. K. Tripathi, S. Kundu

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

(B) Externally funded projects

46 Impact assessment of continuous fertilization on heavy metals and microbial diversity in soils under long-term fertilizer experiment.
Tapan Adhikari, R.H. Wanjari, A. K. Biswas, Muneshwar Singh, S. Kundu and A. Subba Rao

47 Quantifying green house gases (GHGs) emissions in soybean-wheat system of M. P.
Sangeeta Lenka, N. K. Lenka, S. R. Mohanty, S. Kundu, A. Subba Rao

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

Consultancies, Contractual services, patent, commercialization of technology

Sl. No.	Title	Project Team	Sponsored by
1.	Contractual research network project on "Evaluation of efficiency of patenkali – PMS fertilizer for potash, magnesium and sulphur nutrition and yield of different crops in India".	A. K. Shukla, S. K. Behera, R. H. Wanjari, K.P. Patel P. Stalin, A.K. Pal, S. P. Sharma, S. Kundapur	M/s Indian Potash Ltd., New Delhi
2.	Contractual research network project on "Efficiency of Bio-release micronutrient fertilizer Zinc (Micromac) on yields and zinc nutrition of different crops in India".	A. K. Shukla, S. K. Behera, R. H. Wanjari, B. L. Sharma, P. Stalin and Ramkala	M/s Sowbhagya Amino Inputs Pvt. Ltd., Hyderabad
3	Evaluation of Allwin wonder (aw) and Allwin top (at) for their effects on maize productivity and soil fertility	K. Ramesh and S. Ramana	Sree Ramcides Chemicals P. Ltd, Chennai

12. IRC, IMC, RAC, IBC, IPC, IJSC

(Institute Research Council, Institute Management Committee, Research Advisory Committee, Institute Building Committee, Institute Purchase Committee, Institute Joint Staff Council Committee)

Institute Research Council

During the year 2011-12, Institute Research Council (IRC) met two times under the chairmanship of Dr. A. Subba Rao, Director for reviewing the progress of on-going research projects and discussed new research proposals. First IRC Meeting was held 2-7 June, 2011 under the chairmanship of Dr. A. Subba Rao, Director, IISS, Bhopal. The Chairman in his opening remark pointed out that despite having finished large number of projects, we are not able to show our impact, hence, all the scientists need to convert their research output in to meaningful outcomes in ICAR News Letter or other national media. In the concluding remark, the Director drew attention towards the input of one and all for preparing EFC memo for 12th plan.

The second IRC meeting was held during 12th -15th December 2011 under the Chairmanship of Dr. A. Subba Rao, Director, IISS, Bhopal. Welcoming the members of IRC, Dr. S. Kundu requested all the members to summarize their presentation in a brief manner so as to highlight significant achievements. The Chairman in his opening remark pointed out that the ongoing research activity at this institute covers some important theme areas namely conservation agriculture, organic farming, soil pollution, biodiversity and nano-technology and therefore we need consolidation of research knowledge in those areas. In view of the forthcoming silver jublee celebration of the Institute we need to publish that information in the form of bulletins, booklets or pamphlets. The chairman urged upon the scientists to inculcate self motivation towards research to excel and achieve desired goals. He stressed that the scientists will have to develop inquisitive attitude and should be ready to take up challenging research. All the projects were discussed thoroughly. Remaining projects were discussed in was held on 29th March in which two new proposals, two ongoing projects and one final report (RPF III) were discussed.

Institute Management Committee (IMC)

Name	Designation	Position
Dr. A. Subba Rao	Director	Chairman
Dr. A.K. Shukla	Project Coordinator (Micro & Secondary Nutrients)	Member
Dr. Obi Reddy	Sr. Scientist (GIS), NBSS&LUP, Nagpur	Member
Dr. K.L. Sharma	Pr. Scientist & National Fellow, CRIDA, Hyderabad	Member
Dr. D.K. Painuli	Pr. Scientist, CAZRI, Jodhpur	Member

The XXXIIIrd and XXXIVth meeting of IMC was held on 28.05.2011 and 14.02.2012, respectively under the chairmanship of Dr. A. Subba Rao, Director, IISS, Bhopal. During this meeting, IMC recommended purchase of tractor trolley and high energy ball mill, replacement of two old photocopiers and postal franking machine, proposal for creation of an additional AAO post, proposal for completion of various works such as boundary wall, construction of building for soil biodiversity laboratory and soil, water and produce quality laboratory etc. Subsequently, ICAR has approved all the proposals of IMC subjected to the availability of sanctioned funds and administrative approval.

Research Advisory Committee (RAC)

Sl.No.	Name of the RAC members	Designation	Position
1.	Dr. V.S Tomar	Vice -Chancellor, RVRS Agriculture University, Gwalior	Chairman
2.	Dr. N.S. Pasrisha	Ex-Director, Potash Research Institute of India, Ludhiana	Member
3.	Dr. B.N. Johri	Barkatullah University, Bhopal	Member
4.	Dr. H.C. Joshi	Head, Division of ESS, IARI, New Delhi	Member
5.	Dr. P.S. Minhas	ADG (Soils), ICAR, New Delhi	Member
6.	Dr. A. Subba Rao	Director, IISS, Bhopal	Member
7.	Shri Shivnarayan Patel	Farmer	Member
8.	Shri Radheshyam Patidar	Farmer ,	Member

The 17th meeting of Research Advisory Committee (RAC) was held during 12-13 July, 2011 under the chairmanship of Dr.V.S.Tomar, Vice-Chancellor, Rajmata Vijayaraje Scindia Agricultural University, Gwalior. All the members except Dr. P. K. Aggarwal and Dr. R. K. Gupta attended the meeting.

In his introductory remarks, the Chairman Dr.V.S. Tomar emphasized the need for under taking basic research work for long-term use and for interpretation of the results of work done for developing new technology. He suggested the scientists to identify the soil related problems like deterioration in physical, chemical and biological properties of soil. The Chairman also mentioned, as an example, that if there is a crust formation on the surface soil, there will be no germination. He suggested for better understanding of the soil system in terms of SOC, carbon sequestration and climate change. He expressed concern that some soils are highly dispersible and even some normal are eroded with sheet and rill erosions and gully erosion due to back flash of river water and thereby some fertile soils are lost. He advised the scientists to develop fertigation schedules for different crops like rice and pigeon pea etc. The Chairman cautioned that import of food and fertilizers are going to decrease because of their high cost and non-availability in other countries also. Therefore, the future soil productivity depends on soil biology and there is necessity for developing technology to convert organic matter into good quality compost in a short time. Later, Dr. A. Subba Rao, Director presented the major achievements of IISS, Bhopal during the year 2011-12. The RAC accepted the Action Taken Report on the previous RAC recommendations.

The Director, IISS briefly presented the achievements of the institute in the previous year in terms of research contributions, publication, reports, promotions and selection of personnels and awards received etc. The highlights of the achievements include:

- The institute has made a good progress in a research project of NAIP on soil quality and resilience.
- Improving input use efficiency through use of nanoporous zeolites and nano rock phosphate particles.

- Assessing the long term produce and soil quality
- Managing soil physical environmental through long-term tillage experiment, developing soil quality indices and studies on weed control.
- Improving soil biological conditions in vertisols under soybean –wheat rotation.
- Studies on microbial diversity and biofertilizers.
- Biofortification of crop seeds with micronutrients through soil and foliar application in field experiments. Amelioration of contaminated soils.
- On farm research in Raisen and Bhopal districts on balanced and integrated nutrient supply system to demonstrate benefits to the farmers.
- Organic farming and crop adaptability to climate change.

Institute Building Committee

1	Dr. A. Subba Rao, Director	Chairman
2	Dr. M. V. Singh, PC (MSN)	Member
3	Dr. Muneshwar Singh, PC (LTFE)	Member
4	Dr. Y. Muralidharudu, PC (STCR)	Member
5	Dr. A. K. Misra, Head, Division of Soil Physics	Member
6	Dr. S. Kundu, Head, Division of ESS	Member
7	Dr. D. L. N. Rao, PC (AINP on BNF)	Member
8	Shri. Rajesh Dubey, Assistant Finance & Accounts Officer	Member
9	Shri..N.R. Verma, Senior Administrative Officer	Member Secretary

Institute Purchase Committee

1	Dr. A.K. Biswas, Head (SC & F Division)	Chairman
2	Dr. K. Sammi Reddy, Pr. Scientist	Member
3.	Dr. Brij Lal Lakaria, Pr. Scientist	Member (optional)
4.	Shri. Rajesh Dubey, Assistant Finance & Accounts Officer	Member
5.	Shri. N.R. Verma, Senior Administrative Officer	Member

Institute Joint Staff Council

1	Dr. A. Subba Rao, Director	Chairman
2	Dr. Pramod Jha, Sr. Scientist	Scientific representative
3	Shri. N.R. Verma, Senior Administrative Officer	Administrative Staff
4	Shri. Rajesh Dubey, Assistant Finance & Accounts Officer	Administrative Staff
5	Shri. Anurag, Security Supervisor	Administrative Staff
6	Shri. Hukum Singh, Field Assistant (T-3)	Technical Staff
7	Shri. Harish Kumar Barmaiya, SSS	Supporting Staff

Project Prioritization, Monitoring and Evaluation (PME) Cell

1.	Dr. A. Subba Rao, Director	Chairman
2.	Dr. K. Sammi Reddy, Pr. Scientist	Member Secretary and Officer In charge (Till August)
3.	Dr. Brij Lal Lakaria	In charge (Sept. onwards)
4.	Dr. S. Ramana, Sr. Scientist	Member
5.	Dr. J. Somasundaram, Sr. Scientist	Member
6.	Dr. M.Vass anda Coumar, Scientist	Member

Results – Framework Documentation (RFD) committee

1	Dr. A. Subba Rao, Director	Chairman
2	Dr. Brij Lal Lakaria, Pr. Scientist	Nodal Officer
3	Dr. J. Somasundaram, Sr. Scientist	Member
4	Shri. N.R.Verma, SAO	Member
5.	Shri. P.S. Sun il Kumar, AAO	Member
6	Mrs. Yojana Meshram, Personal Assistant	Member

13. PARTICIPATION OF SCIENTISTS IN CONFERENCES/ MEETINGS/WORKSHOPS / SYMPOSIA

Name	Programme	Venue	Period
Dr. K. Ramesh	National symposium cum brain storming workshop on Organic agriculture.	CSK Himachal Pradesh Krishi Vishva Vidyalaya Palampur, Himachal Pradesh	19-20 April 2011
Dr. Nishant K Sinha	Organized by United State-India educational foundation.	IIFM, Bhopal	25 April, 2011
Drs. Muneshwar Singh and R.H. Wanjari	Consortium Advisory Committee (CAC) meeting of NAIP sub project entitled 'Assessment of quality and resilience of soils under diverse agro-ecosystems'.	IISS, Bhopal	May 10, 2011 27 July, 2011, 7 Feb., 2012
Dr. A.B. Singh	International conference on organic Bihar and launching of "Bihar Jai B."	Patna, Bihar	22-24 June, 2011
Drs. A.K. Biswas R.S. Chaudhary and J. Somasundaram	Improving soil productivity in rainfed areas jointly organized by IISS and WAS SAN.	IISS, Bhopal	28-29 June, 2011
Drs. Muneshwar Singh, A.K. Biswas, M. C. Manna, R.H. Wanjari, J.K. Thakur and M. L. Dotaniya	Mid-term review workshop of the project "GPS and GIS based model soil fertility maps for selected districts of the country".	IISS, Bhopal	28-31 July, 2011
Drs. J.K. Saha, M.C. Manna and Asha Sahu	2nd International conference on "Recycling and reuse of materials (ICRM 2011)".	IMSE, Kottayam, Kerala	5-7 August, 2011
Drs. A.K. Biswas and Tapan Adhikari	5th CAC, CIC, and CMU meeting of the NAIP nanotechnology project.	CAZRI, Jodhpur	24-29 August, 2011
Drs A. K. Shukla and S. K. Behera	Fifth CIC meetings of the NAIP subproject C4/C30022.	IISS, Bhopal	13 September 2011

Dr. D.L.N. Rao	Brainstorming session on "Microorganisms in sustainable agriculture".	Indian National Science Academy, New Delhi	13 September, 2011
Drs A. K. Shukla and S. K. Behera	Annual review meeting of network project entitled "Evaluation of efficiency of Patent Kali – PMS fertilizer for potash, magnesium and sulphur nutrition and yield of different crops in India".	IISS, Bhopal	14 September, 2011
Drs. M. Mohanty and Sangeeta Lenka	National stake-holders consultation on climate change platform.	CRIDA, Hyderabad	19-20 September, 2011
Drs A. K. Shukla and S. K. Behera	Fifth CAC meetings of the NAIP subproject C4/C30022.	IISS, Bhopal	4 -5 October, 2011
Dr. S. Kundu	National Dialogue for application of nanotechnology in agriculture.	CIFE, Mumbai	8-9 October 2011
Drs. A. Subba Rao and J.K. Saha	NAAS brainstorming session on "Sustaining agricultural productivity through integrated soil management".	NASC Complex, New Delhi	10 October, 2011
Drs A. K. Shukla and S. K. Behera	3rd International zinc symposium –"Improving crop production and human health".	Hyderabad	10-14 October, 2011
Dr. N. K. Lenka	World Food prize symposium events and laureate award ceremony.	Des Moines, Iowa, USA	12-14 October, 2011

Drs. A. Subba Rao and J.K. Saha	Stakeholders meeting on "National initiative on utilization of solid organic (agro- and municipal) wastes in agriculture' under ICAR knowledge platform on 'Waste (agro -and municipal)".	NASC Complex, New Delhi	13 October, 2011
Dr. A. K. Tripathi	NSFI global agri - connect-2011 conference cum exhibition .	Dr. B. B. Pal Auditorium, IARI, Pusa, New Delhi	14-16 October, 2011
Drs. J. Somasundaram and Nishant K. Sinha	National consultation/ brainstorming on water: research prioritization under ICAR water platform.	NBFGR, Lucknow	18 October, 2011
Dr. A.K. Biswas	Workshop – cum – exhibition, "India R&D 2011 –industry-academia linkages".	India Habitat Centre, New Delhi	2-3 November, 2011
Dr. A. B. Singh	International conference on innovative approaches for agricultural knowledge management: global extension experiences.	NASC Complex, New Delhi	9-12 November, 2011
Drs. Muneshwar Singh, Tapan Adhikari, Brij Lal Lakaria, Pramod Jha, K. Ramesh and M. Vassanda Coumar	76th Annual convention of Indian society of soil science.	UAS, Dharwad	16-19 November, 2011
Dr. S. Ramana	National seminar on plant physiology.	Ram Narain Ruia College, Matunga, Mumbai	24-26 November, 2011

Dr. Muneshwar Singh, M.C. Manna, and Asha Sahu	Annual convention of ISAC and national symposium on "Balanced fertilizer to sustainable soil health, crop production and food security".	GBPUAT, Pantnagar	25-26 November, 2011
Drs. Tapan Adhikari, S. Ramana and Sangeeta Lenka	Interaction meets with scientists trained abroad in frontier areas of agricultural sciences.	NASC complex, New Delhi	28-30 November, 2011
Dr. M. L. Dotaniya	National training on "Bioremediation of heavy metal and hazardous wastes contaminated soil and water ecosystem".	TNAU, Coimbatore	1-14 December, 2011
Dr. Pramod Jha	National symposium on agroforestry for environmental services, livelihood security and climate resilient agriculture: challenges and opportunities.	NRCAF, Jhansi	3-5 December, 2011
Dr. Tapan Adhikari	4th Bangalore nano symposium.	Lalit Ashok Hotel, Bangalore	8-9 December, 2011
Dr. M. Mohanty	National workshop on "Climate observation and regional modelling for multidisciplinary applications (CORMA)".	CSIR CMMACS, Bangalore	9-10 December, 2011
Dr. A. B. Singh	National symposium on "Resource utilization through integrated farming system and biodiversity conservation in drylands".	Bhuj, Gujarat	20-22 December, 2011
Dr. Sangeeta Lenka	M. P. women science congress.	Madahav Science College, Ujjain	22 December, 2011

All scientist of IISS	Meeting of the scientists of AICRP centres, HODs of SAUs, IISS and other stakeholders with chairman QRT and RAC of IISS, Bhopal.	IISS, Bhopal	4-5 January, 2012
Dr. D.L.N. Rao	AICRPs review meeting.	IISS, Bhopal	5-6 January, 2012
Drs. Asha Sahu, and M.C. Manna	National conference on recent advances in chemical and environmental engineering (RACEE -2012).	Chemical Engineering Department, National Institute of Technology, Rourkela, Orissa	20-21 January, 2012
Dr. Brij Lal Lakaria, J. Somasundaram	Sensitization workshop on half yearly progress monitoring (HYPM).	CIFE, Mumbai	2 February, 2012
Drs. Brij Lal Lakaria, J. Somasundaram, Sangeeta Lenka and M.M. Mohanty	International conference on "Climate cha nge, sustainable agriculture and public leadership".	NASC, IARI, New Delhi	7-9 February, 2012
Drs. Asha Sahu, and M.C. Manna	National conference on biodiversity assessment, conservation and utilization.	Department of Biodiversity, M.E.S., Abasaheb Garware College, Deccaan Gymkhana, Karve Road, Pune, Maharashtra	9-11 February, 2012
Drs. A.K. Shukla, J. K. Saha and S.K. Behera	26th biennial workshop of AICRP on micro and secondary nutrients and pollutant elements in soils and plants.	BCKV, Kalyani	10–12 February, 2012
Dr. KM Hati	Interaction meeting on "Soil health, conservation agriculture and climate change' organized by CASA, New Delhi.	NASC Complex, Pusa, New Delhi	14 February, 2012
Dr. D.L.N. Rao	IMC and RAC meetings.	NBAIM, Mau	14-15 February, 2012
Dr. D.L.N. Rao	QRT meeting.	NASC, New Delhi.	20 February, 2012

Dr. J. K. Saha	National seminar on 'Safe food for all'.	The Dept. of ASEPAN, Visva - Bharati	21-23 February, 2012
Drs. Asha Sahu, and M.C. Manna	International conference on environmentally sustainable for urban ecosystem.	Indian Institute of Technology (IIT), Guwahati, Assam	24-26 February, 2012
Dr. S. K. Behera	National symposium on rice - based farming system for livelihood security under changing climate scenario.	College of Agriculture, Odisha University of Agriculture and Technology, Chiplima, Sambalpur, Odisha	27-29 February, 2012
Dr. M.C. Manna, and Asha Sahu	I[st] Biennial international congress on urban green spaces.	New Delhi	5-7 March, 2012
Dr. A. K. Shukla.	FAI agricultural advisory board meeting.	FAI, New Delhi	13 March, 2012
Dr. K.M. Hati	National consultation on "Application technologies for harvested rainwater in ponds".	CRIDA, Hyderabad	19-20 March, 2012
Drs. S.R. Mohanty and K. Bharati	National seminar on "Sustainable Agriculture and Food Security : Challenges in Changing Climate".	CCS HAU, Hisar, Haryana	27-28 March, 2012

14. WORKSHOP/SEMINARS/SUMMER INSTITUTES/ GROUP MEETINGS/ FARMERS' DAY /WOMEN'S DAY ORGANIZED AT THE INSTITUTE

Model Training Course (MTC)

- Greenhouse Gas Mitigation Strategies in Agriculture: Microbes in Aid of Global Climate Change funded by Ministry of Agriculture and cooperation was organized at the IISS, Bhopal during Dec 12-19, 2011. Dr S R Mohanty was the Course director/coordinator and Drs K Bharati and M C Manna Course Co-Directors.

Participants and scientists involved in the model training course "Greenhouse gas mitigation strategies in agriculture: microbes in aid of global climate change" organized at the IISS, Bhopal during December 12-19, 2011

- Another MTC on "Soil Organic Matter Management for Climate Resilient Agriculture" was organized by the Division of Soil Chemistry and Fertility during 14-21 February, 2012 (Course Director: Dr. A.K. Biswas; Course Co-Director: Dr. Pramod Jha). Altogether 20 participants from different State Governments and ICAR Institutes participated in the MTC.

- *A Model Training Course (MTC) sponsored by* Directorate of Extension, Ministry of Agriculture, Government of India, New Delhi *on "*Best Soil and Water Management Practices for Resource Use Efficiency" was organized during 17 – 24 October 2011. Dr. K. Sammi Reddy and Dr. A.K. Biswas was the Course Director Course Coordinator, respectively. Dr A. Subba Rao, Director, IISS inaugurated the MTC on 17 Oct., 2011. Twelve agricultural/horticulture officers from different state departments of Agriculture had participated in the training.

Participants and scientists involved in the model training course "Soil Organic Matter Management for Climate Resilient Agriculture" was organized at the IISS, Bhopal during February 14-21, 2012

National Training

- National training programme on "Assessment of quality and resilience of soils" sponsored by NAIP (ICAR) was organized at the IISS, Bhopal during 9-13 January, 2012. Dr. S. Kundu was the Course director/coordinator and Drs. J. K. Saha and M. Vassanda Coumar were Course Co-Directors. Participants from different states of India participated in the training course. Training course was inaugurated by Dr. A. Subba Rao, Director IISS, Bhopal on 9 January, 2012. External faculty Dr. D. K. Benbi, National Professor, PAU, Ludhiana and Dr. T. Bhattachharya, Principal Scientist, NBSS&LUP and LUP, Nagpur delivered guest lectures. Director Dr. A. Subba Rao, IISS distributed certificates to trainees during valedictory function on 13 January, 2012.

- Organized and conducted 14 days National training on "Climate change, carbon sequestration and carbon trading" sponsored by NAIP, ICAR, New Delhi at IISS from 5th to 18th April 2011 and imparted training to 16 participants (scientist and lecturers from ICAR and SAU). Dr. Sangeeta Lenka (Course Director), Dr. N. K. Lenka, Senior Scientist and Dr. S. Kundu, HOD, ESS were resource persons. Dr. Keith Paustian, Professor, Natural Resource Ecological Laboratory, CSU, Fort Collins, USA, an International resource person, delivered lectures on Climate change, soil carbon models and related issues during the training programme.

Participants and resource persons of National Training Programme

CIC/NAIP project meeting

- Fifth CIC meeting of NAIP sub-project "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"

  The fifth CIC meeting of the NAIP subproject entitled "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" (C4/C30022) was held at IISS, Bhopal on 13 September 2011. The Director of IISS, Bhopal and Consortium leader, CPI and CCPIs of the subproject participated in the meetings. At the outset, Dr. Arvind K. Shukla, CPI welcomed all the participants of the meetings. All the CCPIs presented the progress of the work and technical and financial aspects of the project for respective centres. After presentation, a thorough discussion was held on technical programme and financial aspects of the project.

Fifth CIC meeting in progress

- **Annual review meeting of Network Project entitled "Evaluation of efficiency of Patent kali – PMS fertilizer for potash, magnesium and sulphur nutrition and yield of different crops in India**

The annual review meeting of the Network Project Entitled "Evaluation of Efficiency of Patent kali – PMS Fertilizer for Potash, Magnesium and Sulphur Nutrition and Yield of Different Crops in India" was held at IISS, Bhopal on 14 September, 2011. Dr. A. Subba Rao Director of IISS, Bhopal, Dr. Arvind K. Shukla, CPI, CCPIs of various centres, Dr. Bhisham Pal, Senior Manager, Indian Potash Limited, New Delhi and SAO and FAO of IISS, Bhopal participated in the meetings. At the outset, Dr. Arvind K. Shukla, CPI of the project welcomed all the participants of the meetings and briefed them about the project. In his opening remark, Dr. A. Subba Rao emphasized that the physical characteristics and chemical composition of new products should be assessed thoroughly before testing the efficacy of the products. Because once the product is included in FCO, it will be sold and used across the country. Moreover, each new product should be tested multilocationally for at least two years for better assessment of its functional efficiency. All the CCPIs presented the progress of the work project for respective centres. After presentation, a thorough discussion was held on results of the project and recommendations were finalized.

Annual review meeting in progress

- **Fifth CAC meeting of NAIP sub-project "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"**

The fifth CAC meeting of the NAIP subproject entitled "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" (C4/C30022) was held at IISS, Bhopal from 04^{th} to 05^{th} October, 2011. The CAC members, Consortium leader, CPI, CCPIs and associated scientists of the subproject participated in the meetings. At the outset, Dr. A. K. Shukla, CPI welcomed all the participants of the meeting. Dr. A. Subba Rao, Consortium leader, Dr. P. N. Takkar, Chairman CAC and Dr. A. Dabadghao and Dr. C. Chatterjee, Members CAC presented their views regarding importance of the project and execution and improvement of the technical program of the project. Dr. A. K. Shukla, presented the summary of research work done by all the centers before the house. Subsequently CCPIs of cooperating centres presented the research work of their respective centres. After each presentation, a thorough discussion was held on the reported research results, technical programme, financial aspects of the project and recommendations were formulated.

Fifth CAC meeting in progress

- **Twenty sixth Biennial Workshop of All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants**

The twenty sixth Biennial Workshop of All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants was organized from 10 to 12 February 2012 at BCKV, Kalyani which was inaugurated by eminent soil scientist and ex-Vice Chancellor BCKV, Kalyani, Professor L. N. Mandal. The inaugural function was presided by Professor S. K. Sanyal, Vice Chancellor, BCKV, Kalyani. Dr P. N. Takkar, Ex-Director IISS, Bhopal, Dr K. N. Tiwari, Ex-Director IPNI Indian Office, Dr A. Subba Rao, Director IISS Bhopal, Dr Arvind K. Shukla, Project Coordinator Micronutrient, scientists of the project from different centers, scientists from different ICAR institutes and personnel from Industries participated in the workshop. A brain storming session on "Micro and secondary nutrients and pollutant elements from soil-plant to soil-plant-animal/human continuum was also organized during the workshop. Ten learned speakers/panelists presented their views in the chairmanship of Dr A. K. Singh, DDG (NRM). It was concluded that some specific studies on micronutrients and pollutant elements in soil-plant-animal/human continuum should be taken in XIIth plan.

26th Biennial Workshop of All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants in progress

Chief Guest felicitating a progressive farmer

Dr. SK Dhyani, Director, NRC on AF, Jhansi distributing soil health cards to a farmer of ACIAR project

Host farmers of ACIAR project from Rangai village with Soil Health Cards

National Workshop

Workshop on "Improving Soil Productivity in Rain-fed Areas" was jointly organized by Watershed Support Services and Activities Network (WASSAN), Hyderabad and Indian Institute of Soil Science at IISS, Bhopal during 28-29 June 2011. The workshop was sponsored by the Network on Revitalizing Rainfed Areas (RRA). Dr.I.P.Abrol, Chairman, CASA, New Delhi inaugurated the workshop and Dr. J. Venkateswarlu, Former Director, CAZRI, Jodhpur presided over the inaugural function. Dr. A. Subba Rao, Director, IISS and Chairman, Local Organizing Committee welcomed the Chief Guest and other delegates. There were five technical sessions which included 15 invited lead papers by the experts. The valedictory session was chaired by Dr. I.P. Abrol and co-chaired by Dr. B. Venkateswarlu, Director, CRIDA, Hyderabad. The workshop recommended that the Government of India should launch a "Soil Health Mission" with an aim to produce large quantities of biomass for improving the soil health.

Felicitation

- A farewell was organized to felicitate Dr Blaise Desouza, Principal Scientist, Division of Soil Physics on his promotion as Head, Crop Production, CICR Nagpur (24.08.2011).
- Dr. Y Muraluidharudu, Project Coordinator (STCR) was also felicitated on 30th August, 2011 consequent upon his retirement.

Inaugural Session of Workshop

Events

IISS Foundation Day

IISS Foundation Day was celebrated on 16 April 2011. Dr. Pitam Chandra, Director, CIAE was the Chief Guest and Dr. S.K. Dhyani, Director, NRC on AF, Jhansi was the Guest of Honour during the celebrations. About 100 farmers participated in the function. On this occasion, the Institute felicitated eight progressive farmers who have been associated with the institute in conducting on-farm trials. One Hundred Soil Health Cards prepared under ACIAR Project were distributed to the farmers. Four lectures on Integrated Nutrient

Management, Organic Farming, Micro-nutrient Management and Bio-fertilizers were delivered to farmers. Mr. Anil Dhingra, State Marketing Manager, IFFCO, Bhopal attended the function and shared his on-farm experiences with the farmers.

Releasing of institute publication on the IISS Foundation Day

Independence Day

The Staff Recreation Club (SRC) celebrated the '*Independence Day*' on 15th August, 2011 in the Institute premises. The events like race for children and musical chair for the women and men were arranged for the staff. The program was concluded with the distribution of prizes to the winners by Mrs. Subba Rao, Dr A. Subba Rao, Director, IISS, Bhopal, Dr. A.B. Singh, President, SRC.

Hindi Workshop

One day hindi-workshop on 'Climate Change' was organized at IISS on 21st September, 2011.

Republic Day

The Institute celebrated the '*Republic Day*' with all gaiety and fervour. All the staff of IISS participated in various events with thrill and great enthusiasm. Activities include races, poem recitation, songs, drawing competition for children, and musical chair for the women and men. The program was concluded with the distribution of prizes to the winners by honorable madam Mrs. Subba Rao and Dr. A.B. Singh, President, SRC.

15. DISTINGUISHED VISITORS

- Dr. A.K. Singh, DDG (NRM) visited the institute on 3-5 January, 2011 and 5th April, 2011.
- Dr. J.S. Samra, CEO, Natioanl Rainfed Area Authority, New Delhi visited the institute on 15th November, 2011.
- Hon'ble Dr. S. Ayyappan, DG visited the institute on 15th June, 2011.
- Shri. Vasudev Acharya Chairman, Committee on Agriculture visited IISS along with members of Lok Sabha (Sh. S.K.MurulIslam, Sh. Hukumdeo Narayan Yadav., Sh. Nripendra Nath Roy and Sh. Naranbhai Kachhadia) and Rajya Sabha (Sh. Shashi Bhushan Behera, Sh. Satyavrat Chaturvedi, Sh. Upendra Kushwah and Sh. B.P. Parmar) on 1st March, 2012.

16. PERSONNEL

(Appointments, Promotions, Joining, Transfers etc.)

New Appointments

- Dr. R. S. Chaudhary, Pr. Scientist (Soil Physics) joined as Head of the Soil Physics Division on 24 August, 2011.
- Dr. Brij Lal Lakaria joined IISS as Principal Scientist on 3 June, 2011.
- Shri Sunny Kumar joined as Stenographer Gr. III on 21 December, 2011.
- Shri. Sanjay Kumar Kori joined as Stenographer Gr.III on 3 January, 2012

Joining

- Dr (Smt). Kollah Bharati, joined IISS on 5 April, 2011 as Sr.Scientist in the Division of Soil Biology
- Ms. K.C. Shinogi joined as Scientist on 05 September, 2011.
- Mr. Bharat Prakash Meena (Agronomy) joined as Scientist in the Division of Soil Chemistry and Fertility on 22 December, 2011.
- Mr.Hironmoy Das (Agricultural Statistics) joined as Scientist in AICRP (STCR) on 23 December, 2011.
- Mr. Vasudev Meena (Agronomy) joined as Scientist in the Division of Environmental Soil Science on 23 December, 2011.

Promotions

- Shri. Sanjay Katinga was promoted from SSS to LDC on 2 April, 2011
- Shri. Vinod Choudhary was promoted from Laboratory Assistant (T-2) to T-3 on 30 October, 2010.
- Shri. Hukum Singh was promoted from Field Assistant (T-2) to T-3 on 30 October, 2010.
- Dr. Ritesh Saha promoted as Sr. Scientist under CAS w.e.f. 26 November, 2008.
- Shri Jineshwar Prasad was promoted from LDC to UDC on 18 November, 2011.
- Shri O.P. Yadav was promoted from LDC to UDC on 18 November, 2011.

Transfers

- Dr. Blaise Desouza. Pr. Scientist on selection to the post of Head to CICR, Nagpur on 24 August, 2011.

Retired

- Dr. Y. Muralidharudu, Pr. Scientist & PC (STCR) retired from ICAR service on 31 August, 2011.

17. INFRASTRUCTURE DEVELOPMENT

17.1 Project Prioritization, Monitoring and Evaluation (PME) Cell

Achievements of the PME Cell during the report period are;

- Compiled the material related to the visit of parliamentary standing committee on agriculture, Meeting during 28 February, 2012.
- Compiled and submitted 2 scientist-wise Six Monthly Progress Reports, 4 Quarterly Reports, 4 Quarterly Performance Reports and 12 Monthly Reports for the Cabinet Secretariat.
- Edited IISS Annual Report (2011-12).
- Compiled/ prepared and submitted the replies to 20 Audit *Paras* given by the External Audit Party for the financial year 2011-12.
- Preparation of the XII Five Year Plan EFC Memo of IISS, which is under progress.
- Compiled the material for DARE Annual Report.
- Prepared Agenda Items for IRC Meetings and compiled IRC Proceedings.
- Prepared Action Taken Reports (ATR) on the recommendations of Directors' Meeting, Regional Committee Meetings and QRT recommendations.

17.2 Agriculture knowledge management unit

Updating PERMIS Net Database ICAR has developed application software, Personnel Management Information System Network (PERMISNet), to maintain the activities and records of its various institutes/research centers and their employees. The records are to be updated on monthly basis. ARIS Cell is doing the work regularly.

Maintenance of IT and Communication Systems

The agriculture knowledge management unit is looking after the Information Technology and Communication related activities of the institute. The AKMU is also looking after the institute's main server having Linux network operating system.

Internet & Other Facility: AKMU is equipped with broad band VSAT connectivity by ERNET India, which has been upgraded from 256 to 512 kbps during the reported period. The main server has been configured with e-mail server and connected with LAN. All divisions and sections are connected to the Internet through proxy server. Scientists and staff are having individual email accounts. A broad band (BSNL-BB) system has been connected to all the computers in ARIS Cell to provide better facilities staff. It also takes care of the maintenance of computers, printers and other electronic peripherals.

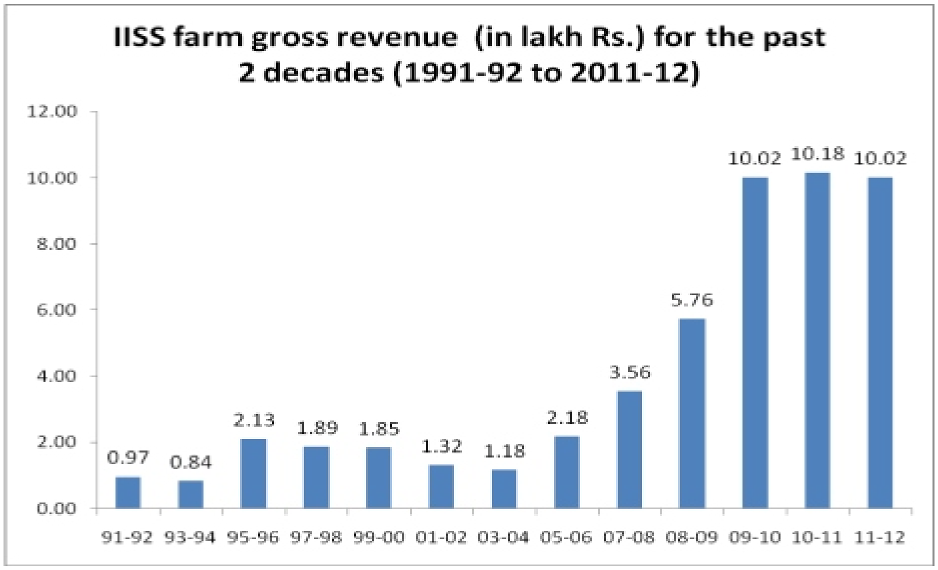
- Internet security for the network computers/servers: Internet Security software (Quick heal 10.0) have been installed to a total 75 computers. Two servers and 75plus network systems were efficiently managed and maintained through AMC/outsourcing service engineers from time to time.
- EPABX system: AKMU is also taking care of the internal communication needs of the institute by providing intercom telephone connection to all divisions and section through EPABX system. Regular updation of EPABX/intercom numbers has been done from time to time.

- Conference Hall: Well furnished conference hall with fully air conditioned with present state-of the-art technologies able to accommodate about 130 -140 members for various meetings/workshops/seminars.
- Updating Institute Website: The AKMU is also maintaining the Institute website (www.iiss.nic.in). The site contains complete information about the institute's R&D and other activities. It is updated from time to time as per the requirement of the institute. Recently the web pages were redesigned, updated and a new outlook to the home page is given. A user friendly soil fertility map like macronutrients and micronutrients (state & district-wise) has been kept in the website for display. RTI Act 2005, Photo Gallery, latest news, forthcoming events, other information, Search engine etc. have been incorporated in the present form to make it more informative.

17.3 Farm Development

During the year 2011, soybean (JS 9305 and JS 335) was cultivated in an area of 13.7 ha and 45.84 q of grain was harvested. Besides, 5.34 ha was sown with red gram var JKM 189. During rabi season, bulk sowing was not taken up due to paucity of rain/water. However, all the experiments were conducted with limited available water

A critical analysis of productivity of major crops (soybean, arhar and gram) over the years since 2004-05 has shown that soybean productivity has reached a maximum of 15-18 q ha^{-1} during 2008-09 and 2009-10 while rest of the years it hovered between 2.5 and 5.9 q ha^{-1}. In the shifting weather pattern scenario, alternate crops during *kharif* emerged to be maize and redgram. Although maize is cultivated in the farm in a small area, red gram is promoted in the *kharif* season (200-210 days). Among the red gram varieties var Asha (released from ICRISAT) yielded consistently 15 q/ha since 2008-09. During 2011-12, var JKM 189 (released from Agricultural University, Gwalior) was cultivated and has yielded 10.2 q ha^{-1}.



During the financial year, a mould board plough was added to the existing farm facility. The gross revenue of the farm has crossed Rs. 10 lakh consecutively for the past three years.

17.4 Library

During the period of report, the Institute library has acquired total documents categorized as listed below:

Documents	Additions during 2011-12	Total Holdings
Books	3	2497
Bound journals	00	2508
Annual reports	162	1766
Foreign journals subscribed	32	32
Indian journals subscribed	30	30

The Library is well maintained with facilities of document such as lending service, reference service, reprographic services, CD Rome Search service etc. The Library also exchanges the institute publications with the other ICAR Institutes, SAUs and renowned Scientists in the field of Soil Science.

DETAILS OF MANPOWER

Name	Designation
1. DIRECTOR'S CELL	
Dr. A. Subba Rao	Director
Mr. Thomas Joseph	PS to Director
Mrs. Geeta Yadav	Personal Secretary
Mr. Bhoilal Uikey	Lab. Attendant /SSS
2. DIVISION OF SOIL PHYSICS	
Dr. R. S. Chaudhary	Pr. Scientist & Head
Dr. Kuntal Mouli Hati	Sr. Scientist
Dr. J. Somasundaram	Sr. Scientist
Dr. Ritesh Saha	Sr Scientist
Mr. Manoranjan Mohanty	Scientist, Sr.Scale
Dr. R. K. Singh	Scientist, Sr.Scale
Dr. (Mrs.) Sangeeta Lenka	Scientist
Dr. Nishant Kumar Sinha	Scientist
Mr. R. K. Mandloi	Tech. Officer (T-6)
Mr. P. K. Chouhan	Field Asstt. (T-4)
Mr. Darash Ram	Lab. Attendant/SSS
3. DIVISION OF SOIL CHEMISTRY & FERTILITY	
Dr. A. K. Biswas	Pr. Scientist & Head
Dr. K. Sammi Reddy	Pr. Scientist
Dr. Brij Lal Lakaria	Pr. Scientist
Dr. Sanjay Srivastava	Sr. Scientist
Dr. N.K. Lenka	Sr. Scientist
Dr. K. Ramesh	Sr. Scientist
Dr. Pramod Jha	Sr. Scientist
Ms. I. Rashmi	Scientist
Ms. Neenu S.	Scientist
Dr. (Mrs.) J.S.Virgine Tenshia	Scientist
Mr. Bharat Prakash Meena	Scientist
Mr. Deepak Kaul	Tech. Officer (T-6)
Mr. K. S. Raghuvansi	
Mr. Hukum Singh	Field Asstt. (T-3)

4. DIVISION OF ENVIRONMENTAL SOIL SCIENCE

Dr. S. Kundu	Pr. Scientist & Head
Dr. J.K. Saha	Pr. Scientist
Dr. Ajay	Pr. Scientist
Dr. Tapan Adhikari	Pr. Scientist
Dr. M. Vassanda Coumar	Scientist
Dr. Mohan Lal Dotaniya	Scientist
Mr. S. Rajendiran	Scientist
Mr. Vasudev Meena	Scientist
Mrs. Seema Sahu	Tech. Officer (T-6)
Mr. S. K. Rai	T-2
Mr. Kalicharan	Lab. Attendant/SSS

5. DIVISION OF SOIL BIOLOGY

Dr. M. C. Manna	Pr. Scientist & Head
Dr. A. B. Singh	Pr. Scientist
Dr. A. K. Tripathi	Pr. Scientist
Dr. S. Ramana	Sr. Scientist
Dr. Santosh Ranjan Mohanty	Sr. Scientist
Dr.(Mrs.) Kollah Bharati	Sr. Scientist
Dr. Asit Mandal	Scientist
Dr.(Ms.) Asha Sahu	Scientist
Dr. Jyoti Kumar Thakur	Scientist
Mr. Vinodbabu Pal	Tech. Officer (T-5)
Mr. Vinod Choudhary	Lab Asstt. (T-3)
Mr. Ram Bharose	Lab Attendant/SSG.II

6. STATISTICS AND COMPUTER APPLICATION SECTION

Dr. (Mrs) Kollah Bharati	Sr. Scientist & I/c Section
Mrs. Kavita Bai	Sweeper/SSS

7. PROJECT COORDINATING UNITS

(a) Micronutrients

Dr. A.K. Shukla	Project Coordinator (MSN)
Dr. Sanjib Kumar Behera	Scientist
Mr. Sahab Siddque	Tech. Officer (T-5)
Mr. Jai Singh	Field Asstt (T-4)
Mr.Venny Joy	Personal Assistant
Mr. Harish Kumar Barmiya	Lab Attendant/SSS

(b) STCR

Dr. Pradip Dey	Project Coordinator (STCR)

Dr. Abhishek Rathore (On deputation)	Scientist (SS)
Mr. Hironmoy Das	Scientist
Mrs. Kirti Singh Bais	Personal Assistant
Mr. Janak Singh	Khalasi/SSS
Mr. Sanjay Narayan Gharde	Lab Attendant/SSS

(c) LTFE

Dr. Muneshwar Singh	Project Coordinator
Dr. R. H. Wanjari	Sr. Scientist
Mr. A. K. Mishra	Lab Attendant/SSS

(d) AINP ON BIOFERTILIZERS

Dr. D. L. N. Rao	Pr. Scientist & Network Coordinator
Miss. T.K. Radha	Scientist
Mr. Bhanwar Singh Yadav	Messenger/SSS

8. CENTRAL LAB

Dr. S.R Mohanty	Sr. Scientist & I/c Lab
Mr. Vinod Babu Pal	Tech. Officer (T-5)
Mr. Jagannath Gour	Lab. Attendant/SSS

9. TRAINING-CUM-REFERRAL SOIL TESTING LABORATORY

Dr. Pradip Dey	Project Coordinator (STCR)
Mr. Sanjay Ghaerde	Lab Attendant/SSS

10. LIBRARY, INFORMATION AND DOCUMENTATION UNIT

Mrs. Nirmala Mahajan	Tech. Officer (T-6) & I/c Library
Mr. Arun Bhojraj Mate	Lab. Attdt/SSS

11. AKMU

Dr. J.Somasundaram	Sr. Scientist & I/c ARIS Cell

12. PME CELL

Dr. Brij Lal Lakaria	Pr. Scientist & I/c PME Cell
Mrs. Yojana Meshram	Personal Assistant

13. FARM SECTION

Dr. K. Ramesh	Sr. Scientist & I/c Farm section
Mr. V. B. Andurkar	Farm Supdt. (T-9)
Mr. D. R. Darwai	Field Asstt. (T-4)
Mr. C. T. Wankhede	Electrician (T-4)
Mr. O. P. Shukla	Tractor Mechanic (T-4)
Mr. Bhagwat Prasad	Beldar/SSS

Mr. Lalaram Sahu	Beldar/SSS
Mr. Rakesh Sen	Beldar/SSS

14. ADMINISTRATION SECTION

Mr. N.R. Verma	Sr. Administrative Officer
Mr. G.D. Dubey	Finance and Accounts Officer
Mr. Rajesh Dubey	Assistant Finance & AO
Mr. P. S. Sunil Kumar	Assistant Administrative Officer
Mr. T. Ayodhya Ramaiah	Personal Assistant
Mr. Anupam S. Rajput	Assistant
Mr. M. S. Hedau	Assistant
Mrs. Babita Tiwari	Assistant
Mr. Bansilal Sersodia	Assistant
Mr. Anurag	Security Supervisor
Mr. Hiralal Gupta	U. D. C.
Mr. O. P. Yadav	U. D. C.
Mr. Jineshwar Prasad	U. D. C.
Mr. Sanjay Katinga	L. D. C.
Mr. Somnath Mukherjee	L. D. C.
Mr. L. N. Chouksey	Messenger/SSS
Mr. Dharm Raj Singh	Messenger/SSS
Mr. Amerjeet Singh	Watchman/SSS
Mr. Pramod Raut	Beldar/SSS
Mr. S. K. Batham	Messenger/SSS

15. VEHICLE SECTION

Dr. Jyoti Kumar Thakur	Scientist & I/c Vehicle
Mr. Naresh Yadav	Driver (T-3)
Mr. Sukhram Sen	Driver (T-2)

SOUL OF INFINTE LIFE