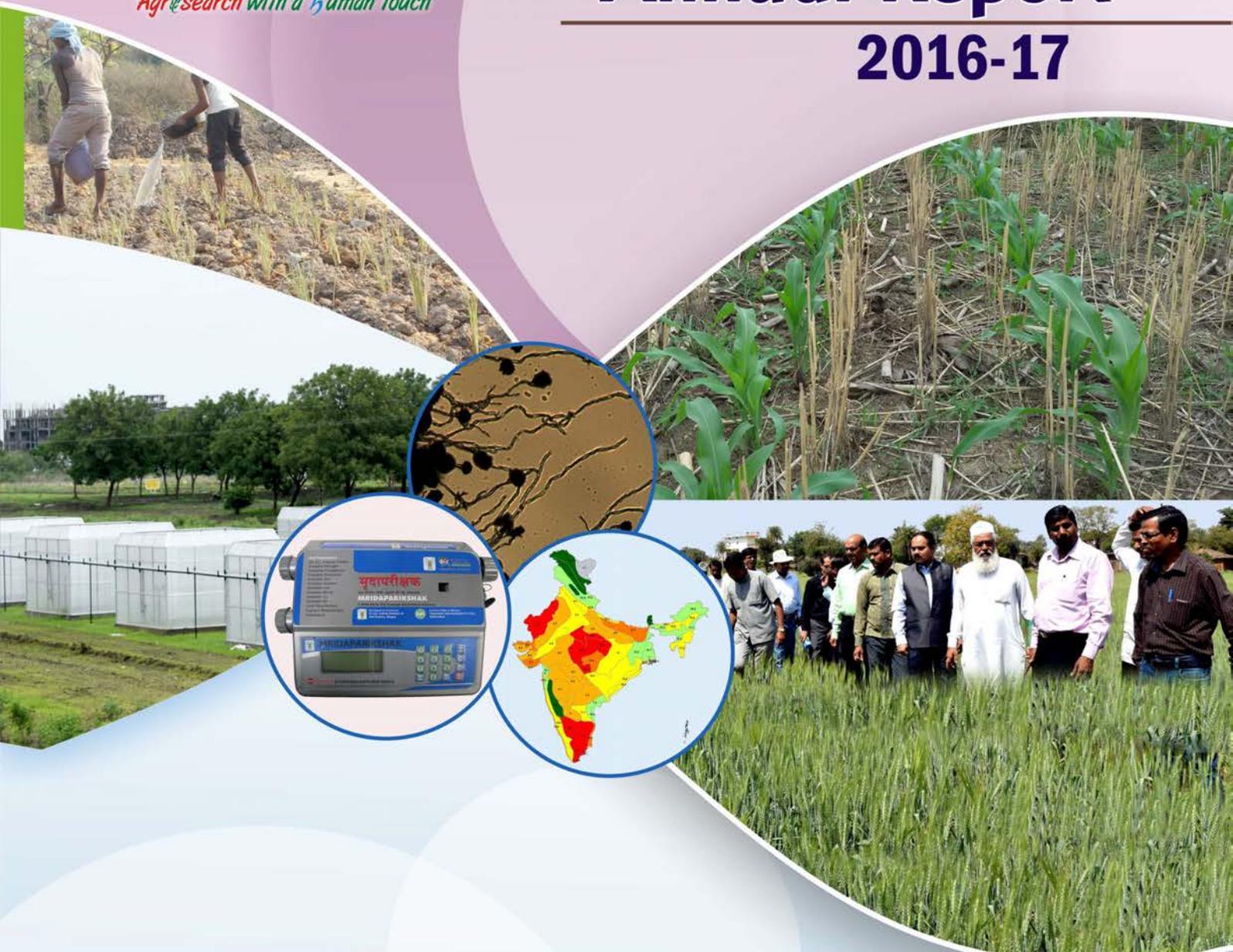हर कदम, हर डगर
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वार्षिक प्रतिवेदन
Annual Report
2016-17

भा.कृ.अनु.प.–भारतीय मृदा विज्ञान संस्थान
ICAR-Indian Institute of Soil Science

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2016-17

ICAR-INDIAN INSTITUTE OF SOIL SCIENCE
Nabibagh, Berasia Road, Bhopal – 462038 (M.P.)

International Decade of Soils 2015-2024

ICAR-IISS

Preface

Soil, the thin outermost layer of our earth is a scarce natural resource which sustains the vast diversity of terrestrial ecosystem of the globe. The ecology of the soil beneath is truly fascinating and interesting to our understanding in many aspects. In India, the food production and the associated agricultural enterprises have to be carried out in the 141±1 million hectare of finite agricultural land which is diminishing at faster rate owing to land degradation and various anthropogenic activities. Soil degradation is devastating crop yields and contributing to malnourishment in many corners of the globe particularly in India. Hence, the improvement and maintenance of the health of the soils is indispensable for sustaining agricultural productivity. This warrants regular monitoring of our soil resources and providing suitable technological interventions for enhancing soil health.

This Annual Report vividly illustrates the multi-scale approach in the area of soil health & input use efficiency; conservation agriculture & carbon sequestration; soil microbial diversity & genomics; soil pollution, remediation & environmental security. It also describes the work done on integrated nutrient management, balanced fertilization, nutrient enriched compost and manure preparation, farmers' participatory research and demonstration of the technologies at farmers' fields under the aegis of various AICRP centers across the length and breadth of the country.

During the period, some new technologies and methodologies were developed and refined by the institute *viz*. a mini lab named *Mridaparikshak* which can estimate 15 important soil parameters *viz*., pH, EC, organic carbon, available N, P, K, S, Zn, B, Fe, Cu, Mn, gypsum requirement (GR), lime requirement (LR) and calcareousness; development of prediction models for SOC using MIR spectroscopy, production of fertilizer through nanotechnological interventions like nano zinc fertilizer from sphalerite mineral, nano potassic fertilizer from gluconite etc., mixed biofertilizer consortium of actinomycetes isolates along with consortia of Rhizobia and PGPR for wheat and chickpea; a bioreactor for accelerated decomposition of biodegradable wastes; preparation of standard reference soil material for heavy metal analysis.

On the basic research front, bacterial and archaeal diversities were identified in bioenergy crop and identification and delineation of simultaneous deficiencies of more than one micronutrient were also done. Sub-optimal level of Fe fertilizer in nano form has shown positive influence on root growth. Also, the copper oxide nano particles showed remarkable antibacterial activity in soil. Consortia of microorganisms applied along-with slurry, starter nitrogen, molasses and curd accelerated the *in-situ* decomposition of rice and wheat residues completing the process within 30 days. Critical limits of heavy metals *viz*. lead and chromium, were established in different soil types.

Further, this report presents a glimpse of all the important activities undertaken by the institute during the period reported upon. During the year, construction was initiated for two laboratories namely, Soil & Produce Quality Laboratory and Nano Technology

International Decade of Soils 2015-2024

Laboratory at the institute, which will be equipped with sophisticated equipments. Two international collaborative projects were initiated with the University of Oxford, UK and Centre for Biotechnology and Molecular Biology, Argentina. The institute is organizing regular training programmes on soil health assessment for strengthening the personnel from KVKs, SAUs, farmers, and students. It is thus, a great pleasure for me to bring out the Annual Report 2016-17 of the ICAR-Indian Institute of Soil Science.

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

I place on record, my sincere appreciation to Dr. R. Elanchezhian, Dr. A.K. Tripathi, Dr. Tapan Adhikari, Dr. N.K. Lenka, Dr. J. Somasundaram, Dr. N.K. Sinha and Dr. B.P. Meena for their dedicated efforts in bringing out this Annual Report.

I acknowledge with deep sense of gratitude and respect to Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR and Dr. K. Alagusundarm, I/c Deputy Director General (NRM), ICAR for their guidance, encouragement and continuous support which helped the institute for all round growth and development. I am highly thankful to Dr. S.K. Chaudhari, Assistant Director General (S&WM), for his constant support, active involvement and constructive suggestions in carrying out various activities for overall progress of the institute.

(Ashok K. Patra)
Director

Bhopal
30 June, 2017

CONTENTS

Annual Report 2016-17

International Decade of Soils 2015-2024

Healthy soils for a healthy life

कार्यकारी सारांश

विषयवस्तु I : मृदा स्वास्थ्य एवं आदान उपयोग दक्षता

मृदा उर्वरता मूल्यांकन

- भोपाल जिले के मेंगरा कला गाँव के किसानों के खेतों पर तीन वर्ष की अवधि (2013–2016) के लिए सोयाबीन–गेहूँ फसल चक्र प्रणाली में भा.कृ.अनु.प.–भारतीय मृदा विज्ञान संस्थान द्वारा विकसित तीन पादप पोषक तत्व प्रबन्धन तकनीकों जैसे समन्वित पादप पोषक तत्व आपूर्ति प्रणाली (आई.पी.एन.एस.–1), आई.पी.एन.एस.–2, और फसलों की लक्षित उपज के लिए मृदा परीक्षण आधारित उर्वरक अनुशंसा का मूल्यांकन के साथ प्रदर्शन किया गया। सोयाबीन–गेहूँ फसल प्रणाली के तीन फसल चक्रों के परिणामों में यह पाया गया कि सभी भा.मृ.वि.सं. प्रौद्योगिकियों ने संसाधनों में समृद्धि बड़े किसानों के खेतों पर अच्छा प्रदर्शन किया जबकि संसाधनों से कमजोर छोटे किसानों के खेतों पर मामूली अच्छा प्रदर्शन किया।

- आई.एन.एम. के विभिन्न मॉड्यूलों में मक्का के दानों एवं तनों में मृदा परीक्षण एवं शस्य अनुक्रिया आधारित 75 प्रतिशत ना.फा.पो. की खुराक के साथ 5 टन/है. गोबर की खाद के प्रयोग से अर्थपूर्ण रूप से वृद्धि हुई। विभिन्न कार्बनिक स्रोतों जैसे कुक्कुट खाद एवं शहरी कम्पोस्ट के साथ मृदा परीक्षण एवं शस्य अनुक्रिया आधारित 75 प्रतिशत ना.फा.पो. उर्वरक मॉड्यूल के एकीकरण के प्रयोग से मक्का की उत्पादकता भी बढ़ी है।

- विभिन्न संशोधित यूरिया सामग्री के प्रयोग से मक्का की उपज एवं नाइट्रोजन उपयोग दक्षता (एन.यू.ई) अर्थपूर्ण रूप से भिन्न पाई गई। विभिन्न संशोधित यूरिया सामग्रियों में नीम लेपित यूरिया (एन.सी.यू.) के प्रयोग से मक्का के दानों, तनों और कुल शुष्क भार उपज एवं नाइट्रोजन उपयोग दक्षता सर्वाधिक पाई गई और उसके बाद बायोचार लेपित यूरिया (बी. सी.यू.) और पाइन ओलियोरेजिन लेपित (पी.ओ.आर.) के तहत दर्ज की गई। एग्रोनामिक उपयोग दक्षता और आंशिक कारक उत्पादकता (पी.एफ.पी.एन.) भी अलग–अलग संशोधित यूरिया सामग्रियों के उपयोग से अर्थपूर्ण रूप से भिन्न पाई गई।

- परिणाम दर्शाते हैं कि संतुलित और समन्वित पोषक तत्वों के प्रयोग से सभी प्रकार की फसल प्रणालियों एवं मृदा प्रकारों में जैविक स्थिति में सुधार हुआ। ना.फा.पो. के अलावा गोबर की खाद के प्रयोग से मृदा जैविक गुणों में और अधिक सुधार हुआ।

- भारत के गंगा के मैदानों में मिट्टी की गुणवत्ता की निगरानी के लिए उत्तरप्रदेश के 15 जिलों के ए ई एस आर 4.3 और 9.2 क्षेत्रों से भू–संदर्भित मिट्टी के नमूनों को एकत्र किया गया और मिट्टी के महत्वपूर्ण गुणवत्ता मानकों जैसे मृदा पी–एच, ई.सी., कार्बनिक कार्बन, लेबाइल कार्बन, लेबाइल कार्बन के अवयव, सुलभ पोटैशियम, उपलब्ध गन्धक और विनिमय सोडियम की मात्रा का विश्लेषण किया गया। आंकड़े आवृत्ति विश्लेषण (हिस्टोग्राम) के अधीन है और उत्तर प्रदेश राज्य के 15 जिलों में मिट्टी की गुणवत्ता मानकों के लिए विषयगत जी.आई.एस मानचित्र विकसित किए गए।

- जुताई की स्थिति (पडल्ड, अनपडल्ड, किसान विधि) के बावजूद 0–5 सेमी. मिट्टी की गहराई में मृदा कार्बन की मात्रा जीरो टिल सीड ड्रिल एवं हैपी टर्बोसीडर में सर्वाधिक पाई गई। अनपडल्ड (धान) की स्थिति के तहत जीरो टिल और हैपी टर्बोसीडर ने सर्वोच्च मिट्टी के कार्बन की मात्रा (0.72 प्रतिशत) बनाए रखी जबकि पडल्ड स्थिति के कारण कार्बन के समान स्तर को प्राप्त नहीं किया जा सका। यह स्पष्ट रूप से इंगित करता है कि धान–गेहूँ फसल चक्र प्रणाली में नो टिल पद्धति के अन्तर्गत मृदा कार्बन का निर्माण हो सकता है बशर्ते धान की सीधी बुआई की जाए।

- लोहा का इष्टतम अनुशंसित मात्रा को नैनो रूप (54 μm) में प्रयोग से सोयाबीन पौधों की तना वृद्धि दानों की उपज और जैव रासायनिक गुण जैसे कुल घुलनशील प्रोटीन, झिल्ली स्थिरता, पौधों में प्रोलीन संचय हुआ। हालांकि, एनपीस की उप इष्टतम मात्रा ने जड़ विकास और गैस विनियम मापदंडों जैसे प्रकाश संस्लेषण दर, पौधों की प्रत्यावर्तन दर और प्रवाहकीय प्रवाहकत्व को सकारात्मक रूप से प्रभावित किया।

Healthy soils for a healthy life

International Decade of Soils
2015-2024

- मक्का फसल के दानों की उपज 4363 किग्रा./है. 120 किग्रा./है नाइट्रोजन +10 टन/है. बायोचार प्रयोग के साथ उच्चतम पाई गई। उर्वरक अनुप्रयोग ने बीज और बायोमास उपज पर महत्वपूर्ण प्रभाव दिखाया। 120 किग्रा./है. नाइट्रोजन के साथ 5 या 10 टन/है. बायोचार प्रयोग का प्रभाव लगभग एक समान ही पाया गया। 5 अथवा 10 टन/है. बायोचार का प्रयोग मक्का की उपज बढ़ सकते हैं। और सांख्यिकीय रूप से एक–दूसरे के बराबर पाए गए।

- 150 किग्रा./है. नाइट्रोजन के प्रयोग से मक्का की उच्चतम उपज प्राप्त की गई लेकिन यह दानेदार यूरिया, लायमस यूरिया और नीम लेपित यूरिया द्वारा 120 किग्रा./है. नाइट्रोजन के प्रयोग के बराबर पाई गई। लाइमस यूरिया के माध्यम से एकल खुराक के नाइट्रोजन के प्रयोग से प्राप्त उपज 120 किग्रा./है. नाइट्रोजन को तीन भागों में प्रयोग के बराबर ही पाई गई। नीम लेपित यूरिया का 120 किग्रा./है. नाइट्रोजन का एकल खुराक में प्रयोग से प्राप्त उपज सांख्यिकीय रूप से दानेदार यूरिया के 150 किग्रा./है. प्रयोग से प्राप्त उपज के बराबर ही पाई गई।

- उच्च कार्बन–डाई–आक्साइड और उच्च तापक्रम के साथ ओ.टी.सी. अध्ययन दर्शाता है कि नाइट्रोजन, फास्फोरस एवं पोटेशियम का अवशोषण नाइट्रोजन एवं पर्यावरणीय कारकों से अर्थपूर्ण रूप से प्रभावित है। लेकिन, केवल नाइट्रोजन अवशोषण के मामले में अन्योन्य क्रिया प्रभाव अर्थपूर्ण पाया गया। उच्च अनाज उपज, पत्ती बायोमास और पत्ती में नाइट्रोजन की मात्रा के कारण 100 किग्रा./है. नाइट्रोजन एवं उच्च कार्बन उपचार में अर्थपूर्ण रूप से उच्च नाइट्रोजन अवशोषण पाया गया।

- मृदा एवं पौधों में सूक्ष्म एवं द्वितीयक पोषक तत्व तथा प्रदूषक तत्वों पर आधारित अखिल भारतीय समन्वित अनुसंधान परियोजना के अन्तर्गत 1.97 लाख मिट्टी के भूसंदर्भित नमूनों का मान एवं आर्क जी.आई.एस.सॉफ्टवेयर का प्रयोग करते हुए भारत के 58 कृषि जलवायु उप क्षेत्रों के लिए गन्धक, जस्ता, ताँबा, लोहा, मैंग्नीज और बोरान की कमी के नक्शे बनाए गए। यह नक्शे विभिन्न कृषि जलवायु उप क्षेत्रों में स्थान विशिष्ट सूक्ष्म एवं द्वितीयक पोषक तत्वों के प्रबन्ध के लिए प्रयोग में लाए जायेंगे।

विषयवस्तु II : संरक्षण कृषि, कार्बन सीक्यूस्ट्रेशन और जलवायु परिवर्तन

- वर्टीसोल के लिए विकसित संरक्षण कृषि तकनीकों को लोकप्रिय बनाने के लिए भोपाल जिले के नजदीक 4 गाँवों में दो प्रमुख फसल चक्र प्रणालियों जैसे सोयाबीन–गेंहूँ और सोयाबीन–चना में भागीदारी प्रक्षेत्र परीक्षण के माध्यम से सर्वश्रेष्ठ संरक्षण कृषि पद्धतियों का प्रदर्शन किया गया। किसान पद्धति के मुकाबले संरक्षण कृषि में फसल की पैदावार अपेक्षाकृत अधिक पाई गई।

- फसल अवशेषों के जमीन में धारण के साथ संरक्षण जुताई प्रथाओं के छः वर्ष बाद के आंकड़े दर्शाते हैं कि पुंज स्थिरता, पुंज से सम्बधित कार्बन की मात्रा और विभिन्न कार्बन पूल पर इसका सकारात्मक प्रभाव पड़ा। सी.टी. की तुलना से एन. टी और आर.टी में 0–5 सेमी. मिट्टी परत में बड़े मैक्रो समुच्चय में प्रतिशत जल स्थिर पुंजीकरण और पुंज सम्बधित कार्बन की मात्रा अधिक पाई गई।

- चार फसल चक्रों के बाद जमीन में फसल अवशेषों के धारण के साथ कम जुताई का मुख्य एवं सूक्ष्म पोषक तत्वों का वितरण एवं मृदा में उनकी उपलब्धता पर सकारात्मक प्रभाव देखा गया। जुताई और फसल प्रणालियों को मद्देनजर न रखते हुए उप सतह परतों की तुलना से सतह की मिट्टी की परत (0–5 सेमी.) में मुख्य एवं सूक्ष्म पोषक तत्वों की मात्रा अधिक पाई गई। 0–5, 5–15 और 15–30 सेमी. मृदा परत में सी.टी. के मुकाबले उपलब्ध नाइट्रोजन की मात्रा अधिक पाई गई। लेकिन उपलब्ध फास्फोरस एवं पोटैशियम की मात्रा सी.टी की तुलना में आर.टी में मृदा की ऊपरी 5 सेमी. की गहराई में अर्थपूर्ण रूप से अधिक पाई गई।

- संरक्षण कृषि के तहत सोयाबीन में विभिन्न शाकनाशी खरपतवार प्रबंधन उपचारों के परीक्षण में पेन्डीमेथालीन@1000 ग्राम सक्रिय तत्व/है. का पूर्व उद्भव प्रयोग और उसके बाद बुआई के 30 दिन बाद इमाजेथापर @100 ग्रा. सक्रिय तत्व/है. के पद उद्भव प्रयोग से न्यूनतम खरपतवार बायोमास और अधिकतम दानों की उपज प्राप्त हुई यह उपज दो

बार हाथ निराई और पेन्डीमेथालीन@1000 ग्रा. सक्रिय तत्व / है. का पूर्व उद्भव प्रयोग उसके बाद 30 दिन की बुआई के बाद प्रोपाक्यूजाकोप 100 ग्रा. सक्रिय तत्व / है. + क्लोरीमुरोन इथाइल 9 ग्रा. सक्रिय तत्व / है. के बराबर ही थी। बगैर जुताई की दशा में सोयाबीन में पूर्व एवं पद उद्भव शाकनाशियों के संयोजन से खरपतवारों का प्रभावी ढंग से नियंत्रण किया जा सकता है।

- संरक्षण कृषि के अन्तर्गत मक्का आधारित फसल चक्र प्रणालियों में पूर्व उद्भव पेन्डीमेथालिन @750 ग्रा. सक्रिय तत्व / है. के प्रयोग और उसके बाद 30 दिन की बुआई उपरान्त पद उद्भव अट्राजीन @1000 सक्रिय तत्व / है. के प्रयोग से खरपतवारों का प्रभावी ढंग से नियंत्रण किया जा सकता है। यह देखा गया है कि तीन वर्ष के प्रक्षेत्र परीक्षण के बाद कुछ उपचारों में शाकनाशी प्रयोग के बाद कुछ खरपतवार जैसे इचिनोक्लोएक्रसगली, आल्टरनेन्थर एसेसेलिस और डायचेन्थियम एनुअलअट्मेयर बचने अथवा पुनः उत्पन्न होने में सफल रहे।

- यादृच्छिक वन कार्यप्रणाली का प्रयोग करते हुए अल्फीसोल मृदा में मृदा पी–एच, मृदा कार्बनिक कार्बन, सुलभ नाइट्रोजन, फास्फोरस एवं पोटेशियम के आकलन के लिए कीमोमेट्रिक मॉडल का विकास किया गया है। विकसित मॉडल में मिट्टी के विभिन्न गुणों के आधार पर निर्धारण गुणांक (R^2) 0.91 से 0.96 पाया गया। जबकि एक स्वतंत्र डेटा सेट के साथ मॉडल की मान्यता से पता चला है कि R^2 के माध्यम से व्यक्त की जाने वाली अनुमानित क्षमता मिट्टी के अलग–अलग गुणों में स्पष्ट रूप से भिन्न–भिन्न है। विकसित मॉडल से मृदा में काफी अच्छी तरह से मृदा कार्बनिक कार्बन ($R^2= 0.88$) और पी–एच ($R^2= 0.72$) का अनुमान लगा सकते हैं। उपलब्ध नाइट्रोजन और फास्फोरस के लिए सत्यापन डाटासेट के R^2 मूल्य क्रमशः 0.56 और 0.53 थे जबकि यह ई.सी. के लिए कम से कम 0.19 और उपलब्ध पोटैशियम के लिए 0.23 पाए गए।

- एक अच्छी तरह से कैलिब्रेटेड और मान्य ए.पी.एस.आई.एम. फसल मॉडल का इस्तेमाल मध्य भारतीय वर्टिसोल में भविष्य में जलवायु परिदृश्यों के तहत मृदा कार्बनिक कार्बन और सोयाबीन–गेंहूँ उत्पादकता की गतिशीलता का अध्ययन करने के लिए किया। 0–15 सेमी. और 15–30 सेमी. की गहराई में मृदा कार्बनिक कार्बन में परिवर्तन अध्ययन के तहत सभी आर.सी.पी. और समय के स्लाइस में महत्वपूर्ण नहीं था। इसके अलावा 2050 में, सोयाबीन की पैदावार में आर.सी.पी. 2.6, 4.5, 6.0 और 8.5 में क्रमशः 12,17,15 और 22 प्रतिशत की वृद्धि होगी जबकि विभिन्न आर.सी.पी. में 2050 में गेहूँ की उपज में वृद्धि आधार के ऊपर 2 से 4 प्रतिशत तक होगी।

- तीन सूचकांक अर्थात् नाइट्रोजन दक्षता सूचकांक (डी.ए.एन.) और केनोपी थ्रेसहोल्ड (डी.ए.सी.टी.) का प्रयोग गेंहूँ की फसलों में पानी और पोषक तत्वों के मूल्यांकन के लिए किया गया। उपचार संयोजन 11×N4 में एन एस आई का उच्चतम मान प्राप्त किया गया जबकि उपचार संयोजन 13×N1में डी.ए.एन.एस. और डी.ए.सी.टी. का उच्चतम मान देखा गया।

विषयवस्तु III : सूक्ष्मजैविक जैव विविधता एवं जैव प्रौद्योगिकी

- लिग्नोसेलुलोलिटिक कवक, एक्टीनोमायसीट्स और बैक्टीरिया के कन्सोर्टियम के साथ काउडंग स्लरी, आरम्भिक नाइट्रोजन, गुण और दही का प्रयोग स्व स्थाने अपघटन की प्रक्रिया को तेज कर देते हैं जिसके फलस्वरूप धान और गेंहूँ फसल अवशेषों का अपघटन 30 दिन के भीतर और गन्ना फसल अवशेष का अपघटन 45 दिन के भीतर हो जाता है।

- ना.फा.पो. के साथ संस्थान ने फसल अवशेषों के मिलाने से धान और गेंहूँ की उपज में काफी सुधार हुआ। मृदा कार्बनिक कार्बन, एन्जाइम की सक्रियता, उपलब्ध नाइट्रोजन, फास्फोरस की मात्रा केवल ना.फा.पो. अनुप्रयोग की तुलना से अधिक पाई गई।

- वन मिट्टी में सबसे अधिक कार्बनिक कार्बन था उसके बाद चारे वाली फसल की मिट्टी में। मृदा कार्बनिक कार्बन की मात्रा 5.5 ग्रा./कि.ग्रा. से 12.2 ग्रा./कि.ग्रा. पाई गई। सर्वाधिक रूबिस्को एन्जाइम्स को चारा वाली फसलों और

Healthy soils for a healthy life

International
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2015-2024

प्राकृतिक खरपतवार में सर्वाधिक पादप फाइटोलिथ कार्बन देखा गया। पर्टिकुलेट कार्बनिक कार्बन वन भूमि में सर्वाधिक उसके बाद चारा वाली जमीन और सबसे कम जुताई वाली भूमि में देखा गया।

- 100 प्रतिशत अकार्बनिक उपचार की तुलना में 100 प्रतिशत जैविक उपचार के तहत सोयाबीन के बीज की उपज में सुधार हुआ। इसी तरह, एन्जाइम जैसे फ्लोरीसीन डाइएसीटेट (एफ.डी.ए.), डिहाइड्रोजिनेज, एल्केलाइन फास्फेट फास्फेटेज एवं बीटा ग्लूकोसाइडेज की सक्रियता 100 प्रतिशत कार्बनिक उपचार में सर्वाधिक देखी गई जो यह दर्शाती है कि मिट्टी में कार्बनिक पदार्थों के मिलाने से सूक्ष्मजीवों की सक्रियता पर लाभकारी प्रभाव पड़ता है।

- मध्य भारत में जैविक खेती के लिए उपयुक्तता के लिए विभिन्न परीक्षणों में समान जैविक पोषक प्रबन्धन प्रथा के तहत सोयाबीन और मक्का की 12–12 प्रजातियां उगाई गई। सोयाबीन की उपज के मामले में इसकी प्रजाति आर.वी. एस–2002–4 (1290 कि.ग्रा./है.) ने अच्छा प्रदर्शन किया उसके बाद जे.एस. 93–05 (680 कि.ग्रा./है.) ने मक्का की जिन प्रजातियों का मूल्यांकन किया गया उनमें से मक्का की कंचन प्रजाति की उपज सर्वाधिक (290.7 कि.ग्रा./है.) पाई गई जबकि सबसे कम उपज प्रोएग्रो 4212 प्रजाति में पाई गई।

- पोषक तत्वों के गुणवत्ता घटक जैसे प्रोटीन और तेल सामग्री के रूप में सोयाबीन की 12 प्रजातियों के परिणाम दर्शाते हैं कि प्रोटीन की मात्रा के सन्दर्भ में उनमें सांख्यिकीय रूप से अर्थपूर्ण अन्तर नहीं पाया गया। हालांकि संख्यानुसार आर.वी. एस. 2002–7 में तेल की सर्वाधिक मात्रा एवं उसके बाद आर.वी.एस. 2002–6 में पाई गई। मक्का में सर्वाधिक प्रोटीन और ट्रप्टोफेन की मात्रा प्रोएग्रा 4212 प्रजाति में पाई गई।

विषयवस्तु IV : मृदा प्रदूषण और उपचार

- भोजन संदूषण के लिए शून्य सहिष्णुता के दृष्टिकोण के आधार पर मिट्टी के विभिन्न प्रकारों में क्रोमियम और लैड की क्रांतिक सीमा निर्धारित की गई। यह क्रमशः इन्दौर की काली मृदाओं के लिए 52 और 143 मिग्रा./किग्रा., रांची की लाल और लेटराइट मृदा के लिए 332 और 78 मि.ग्रा./कि.ग्रा. और कानपुर की जलोढ़ मृदा के लिए 87 और 84 मि.ग्रा./कि. ग्रा. थी।

- मध्य प्रदेश के आदिवासी बहुल अलीराजपुर, झाबुआ और धार जिलों की मिट्टी की गुणवत्ता की स्थिति का आकलन करने के लिए नई पद्धति विकसित की गई है। चयनित मिट्टी के मापदंडों/संकेतकों के लिए फसल उपज के साथ उनके सम्बन्ध, कमी अथवा कम श्रेणी के वर्गों के प्रतिशत नमूने और भिन्नता के सह–कुशलता के आधार पर स्कोरिंग और वेटेज दिया गया। मृदा गुणवत्ता सूचकांक (एस.क्यू.आई.) की गणना सभी संकेतकों के अंकों के आधार पर की गई है। सापेक्ष एस.क्यू.आई. के आधार पर यह पाया गया है कि अध्ययनित जिलों की मिट्टी की मिट्टी गुणवत्ता खराब है।

- मृदा एंजाइम की गतिविधियों जैसे कि यूरियेज, डिहाइड्रोजिनेज, अल्केलाइन और अम्लीय फास्फेट को मापा गया और प्रयोगात्मक परिणामों से पता चला है कि TiO_2 नैनो कणों की कम मात्रा 40 पी.पी.एम. ने एंजाइम की गतिविधि को बढ़ाया (प्ररण) लेकिन 100 पी.पी.एम. TiO_2 नैनो कणों की उच्च खुराक ने एंजाइम गतिविधियों को कम किया (निषेध)।

- तांबा आक्साइड नैनो कणों ने ग्राम–पॉजिटिव (बी. सबटिलिस) और ग्राम–निगेटिव (ई. कोलाई) बैक्टीरिया दोनों के खिलाफ उल्लेखनीय एंटीबायोटिक गतिविधि दिखायी है।

EXECUTIVE SUMMARY

Theme I: Soil Health and Input Use Efficiency

Soil Fertility Evaluation

- Evaluation-cum demonstration of three nutrient management technologies developed by ICAR-IISS *viz.,* Integrated Plant Nutrient Supply System (IPNS-I), IPNS-II, and Soil Test based Fertilizer Recommendation for Targeted Crop Yields (STCR) were carried out in farmers' fields of Mengra Kalan village of Bhopal for a period of three years (2013-2016) in soybean-wheat cropping system. From the three crop seasons it was observed that all the IISS technologies performed better in resource rich large farm fields and moderately good in resource poor small farm fields.

- Among the different INM modules, grain and stover yield of maize significantly increased with application of 75% NPK of STCR based dose with 5t ha^{-1} farmyard manure (FYM). Maize productivity also increased with application of 75% NPK dose of STCR based fertilizer module with integration of different organic sources of nutrients *viz.*, poultry manure and urban compost.

- Maize yield and nitrogen use efficiency (NUE) significantly varied with the application of different modified urea materials. Among different modified urea materials, neem coated urea (NCU) recorded higher grain, stover and total dry matter yield of maize crop and NUE followed by biochar coated urea (BCU) and pine oleoresin coated urea (POR). Agronomic use efficiency (AEn) and partial factor productivity (PFPn) also significantly differed with the application of different modified urea materials.

- The balanced and integrated nutrient management improved the biological condition across the cropping systems and soil types. Application of FYM over and above NPK further improved soil biological properties.

- For soil quality monitoring in the Indo-Gangetic Plains of India, geo-referenced soil samples were collected from 15 districts of Uttar Pradesh state covering AESR 4.3 and 9.2, and analyzed for key soil quality parameters *viz.*, soil pH, EC, organic carbon, labile carbon, labile carbon fractions, available potassium, available sulphur and exchangeable sodium content. The data were subjected to frequency analysis (Histogram) and thematic GIS maps were developed for the soil quality parameters for 15 districts of U.P. state.

- Soybean plants fertilized with optimal recommended dose of Fe_3O_4 (54 μM) in nano form (size 100 nm) had high shoot growth, grain yield and biochemical traits *viz.*, total soluble protein, membrane stability, proline accumulation in plants under sand culture. However, sub-optimal concentration of nano particles (NPs) had positively influenced root growth and gas exchange parameters *viz.*, photosynthesis rate, transpiration rate and stomatal conductance of plants.

- The grain yield of the maize crop was highest (4363 kg ha^{-1}) with the application of 120 kg N + 10 t biochar ha^{-1}. Fertilizer application showed significant effect on seed and biomass yield. Application of 5 or 10 t ha^{-1} biochar along with 120 kg N ha^{-1} were statistically at par. Biochar additions could enhance the maize yield at 5 or 10 t ha^{-1} and were statistically at par with each other.

- The highest maize grain yield was obtained with the application of N@150 kg N ha^{-1} but it was found to be statistically at par with 120 kg N ha^{-1} as prilled urea, limus urea as well as neem coated urea (NCU). Application of N in single dose through LIMUS urea resulted in statistically similar yield to that of 120 kg N through prilled urea

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in 3 splits. Application of NCU @120 kg N ha^{-1} in single dose was statistically at par with 150 kg N ha^{-1} as prilled urea.

- Open top chamber (OTC) studies with elevated CO_2 and higher temperature revealed that the uptake of N, P and K were significantly affected by N and environment factors. However, the interaction effect was significant only in case of N uptake. Significantly higher N uptake was observed under elevated CO_2 treatment due to higher grain yield, leaf biomass and no change in leaf N concentration.

- Under the AICRP on Micro- and Secondary Nutrients and Pollutant Elements in Soils and Plants, deficiency maps for S, Zn, Cu, Fe, Mn and B were prepared for 58 agro-eco sub regions (AESRs) of India using 1.97 lakh georeferenced soil samples on Arc GIS software. These maps will be of used for site-specific micro- and secondary nutrient management in different AESRs.

Theme II : Conservation Agriculture, Carbon Sequestration and Climate Change

- Best bet conservation agricultural practices for two predominant cropping systems, namely, soybean-wheat and soybean-chickpea were demonstrated through participatory field trials in four villages of nearby Bhopal district to popularize the conservation agricultural technologies developed for Vertisols. Crop yield recorded were relatively higher in conservation tillage as compared to the farmers' practice.

- Conservation tillage practices in combination with crop residue retention followed for six years showed positive impact on aggregate stability, aggregate associate–C concentration, and different carbon pools. Per cent water stable aggregates and aggregate associated-C concentrations in large macro-aggregates at 0-5 cm soil layer were higher in the no-tillage (NT) and reduced tillage (RT) than that in conventional tillage (CT).

- Reduced tillage with residue retention showed a positive effect on macro- and micronutrient distribution and availability in soils after four crop cycles. In the surface soil layer (0-5 cm), the major- and micro-nutrients concentrations were higher compared to sub-surface layers, regardless of tillage and cropping systems. Available N concentration in RT was significantly higher than CT in 0-5, 5-15 and 15-30 cm soil layers. However, available P and K concentrations were significantly higher in RT than CT only in the top 5 cm soil depth.

- Among various herbicidal weed management treatments tested in soybean under conservation agriculture, pre-emergence application of Pendimethalin @ 1000 g ai/ha followed by (*fb*) post emergence application of Imazethapyr @ 100 g ai/ha at 30 DAS recorded lowest weed biomass and maximum seed yield which was at par with two hand weeding and pre-emergence application of Pendimethalin @1000 g ai/ha *fb* post emergence Propaquizafop @100 g ai/ha + Chlorimuron ethyl @9 g ai/ha at 30 DAS. Weeds in soybean can effectively be managed using a combination of pre- and post-emergence herbicides under no till condition.

- Weeds in maize based cropping system under CA could be effectively managed with pre-emergence application of Pendimethalin @ 750 g ai/ha followed by post-emergence Atrazine @ 1000 g ai/ha at 30 DAS. It has been observed after three years of experimentation that some of the weeds like *Echinocloa crusgalii, Alternenthera sessalis* and *Dichanthium annulatum* are able to escape or regenerate after herbicide application in some treatments.

- The chemometric models for estimation of soil pH, EC, SOC, Av-N, Av-P, and Av-K in Alfisols were developed following the random-forest methodology. The coefficient of determination (R^2) of the developed model for different soil properties ranged from 0.91 to 0.96. Validation of the model with an independent data set showed

that the predictability as expressed through R^2 varied markedly among the different soil properties tested. The models developed could predict the SOC (R^2=0.88) and pH (R^2=0.72) of the soil reasonably well. The R^2 values of the validation dataset for the available N and P were 0.56 and 0.53, respectively, while they were as low as 0.19 and 0.23 for the EC and available K, respectively.

- A calibrated and validated APSIM crop model was used to study the dynamics of soil organic carbon and soybean-wheat productivity under future climatic scenarios in central Indian Vertisols. The change in soil organic carbon in the soil depth of 0-15 cm and 15-30 cm was non-significant in all the RCPs and time slices under study. Further, in the year 2050, the soybean yield will increase by 12, 17, 15 and 22% in RCPs 2.6, 4.5, 6.0 and 8.5, respectively, however, the wheat yield will increase by 2 to 4% over the base in the year 2050 under the different RCPs.

- Three indices, namely Nitrogen Sufficiency Index (NSI), Degrees Above Non-Stressed (DANS) and Degrees Above Canopy Threshold (DACT) were used to evaluate water and nutrient stresses in wheat crops. Higher value of NSI was observed in treatment combination $I_1 * N_4$, whereas the highest value of DANS and DACT were observed in treatment combination $I_3 * N_1$.

Theme III: Microbial Diversity and Biotechnology

- Application of consortia of ligno-cellulolytic fungi, actinomycetes and bacteria along with cow dung slurry, starter nitrogen, molasses and curd accelerated *in-situ* decomposition process resulting in rice and wheat residue decomposition within 30 days and sugarcane residues within 45 days.

- The crop yield of rice and wheat were substantially improved by the application of NPK along with *in situ* residue incorporation. Soil organic carbon, activity of enzymes, available N, P and K were relatively greater than application of NPK fertilizer alone.

- The total organic carbon was maximum in forest soil followed by forage crops. The SOC varied from 5.5 g/kg to 12.2 g/kg. The glomalin content varied from 112 to 255 g/kg. The maximum Rubisco-enzymes were observed in forage crops and natural weed fields. The maximum plant phytolith carbon was observed in grassland and natural weeds. The particulate organic carbon was maximum in forest land followed by forage land and the least was observed in cultivated lands.

- An improvement in seed yield of soybean under 100% organic treatments in comparison to 100% inorganic treatment was observed. Similarly, enzyme activity such as fluorescein diacetate (FDA), dehydrogenase, alkaline phosphatase and β -Glucosidase were found the highest in100% organic treatment.

- In varietal testing for suitability for organic farming in central India, out of the 12 varieties of soybean and maize grown under similar organic nutrient management practices, the soybean cultivar, RVS-2002-4 (1290 kg ha^{-1}) out performed in terms of seed yield followed by JS- 20-41. The lowest soybean seed yield was found under JS-93-05 (680 kg/ha). Amongst the maize varieties evaluated, Kanchan variety recorded the highest yield (2907 kg ha^{-1}) followed by Proagro 4212 and the lowest in Sweet Corn variety.

- Nutritional quality constituents such as protein and oil content of the 12 varieties of soybean indicated there was no significant difference in protein content of soybean cultivars. However, relatively higher protein content was recorded in cv JS-9305 followed by JS-20-29. The higher oil content was recorded in RVS-2002-7 followed by RVS-2002-6. In maize, higher values of protein and tryptophan were recorded in Pro-agro-4212 variety.

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2015-2024

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Theme IV: Soil Pollution and Remediation

- Based on approach of zero tolerance to food contamination, critical limits of total chromium (Cr) and lead (Pb) in different soil types were determined as 52 and 143 mg/kg for black soil of Indore, 332 and 78 mg/kg for red and laterite soil of Ranchi, and 87 and 84 mg/kg for alluvial soil of Kanpur, respectively.

- New methodology has been developed to assess the soil quality status of tribal Alirajpur, Jhabua and Dhar districts of Madhya Pradesh. Weightage to selected soil parameters/indicators were given based on their correlation with crop yield, percent samples under deficiency or lower category classes and co-efficient of variation. Soil quality index (SQI) was calculated by addition of products of weight and scores of all the indicators. Based on relative SQI, it was found that most soils in the studied districts have poor soil quality.

- Soil enzyme activities like urease, dehydrogenase, alkaline and acidic phosphatase, were determined and results revealed that at lower doses up to 40 ppm of TiO_2 nano particles (size 100 nm) enhanced the activity of the enzyme (induction), but the enzyme activities were reduced (inhibition) at higher doses of 100 ppm TiO_2 NP.

- The copper oxide nano particles (size 50 nm) showed remarkable antibacterial activity against both Gram-positive (*B. subtilis*) and Gram-negative (*E. coli*) bacteria.

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1. INTRODUCTION

The two major global challenges of the 21st century *viz*. food and nutritional security depend primarily upon the soil resources for successful eradication of hunger and malnutrition. Interventions in agriculture in the past have resulted in unprecedented exploitation of these scarce soil resources worldwide. In spite of India's achievement in self-sufficiency in food grain production, there is a need to produce 'more food from limited resources' for more people. However, since last 4-5 decades, soil health is declining at faster rate with higher rates of erosion, declining factor productivity and reduced nutrient use efficiency (NUE), loss of soil biota and degradation of land due to environmental pollution. Under such scenario, increasing food-grain production from shrinking land resources requires reorientation of research pursuits, addressing the emerging issues like enhancing nutrient and water use efficiency, sustaining soil and produce quality, soil biodiversity and genomics, climate change and carbon sequestration, minimizing soil pollution etc. To address these issues, ICAR-Indian institute of Soil Science was established on 16th April, 1988 with the mission of "Providing scientific basis for enhancing and sustaining productivity of soil resources with minimal environmental degradation". Since its inception, the institute has made earnest effort to attain its mission and received national and international recognitions. The institute activity has been strengthened further by the scientific and managerial activities of All India Coordinated Research Projects/All India Network Project. The four AICRPs/AINP act as a part of the "Network-Support Programmes" of the Institute with their centers located in various State Agricultural Universities, providing access to the diverse soils, agro-ecosystems across the agro-ecological zones of the country for effective implementation of the various programs of the Institute at national level. During the year under report the institute has made significant scientific contributions in the frontier areas of soil science such as input use efficiency including nanotechnology, carbon sequestration and climate change, integrated nutrient supply system (IPNS), biofortification, nutrient transformation and dynamics in soil-plant systems, environmental impact on agricultural production, utilization of solid wastes and waste water, bio and phyto-remediation etc. The salient research findings, infrastructural development, technology transfer, human resource development, awards and recognitions and linkages and collaborations etc. are briefly highlighted in the present report.

1.1 Mission and Mandate

The Institute has the mission of "Providing scientific basis for enhancing and sustaining productivity of soil resources with minimal environmental degradation" with following mandates:

a) Basic and strategic research on physical, chemical and biological processes in soils related to management of nutrients, water and energy
b) Advanced technologies for sustainable soil health and quality
c) Coordinate the network research with State Agricultural Universities, National, International and other Research Organizations

1.2 Priorities and Thrust Areas

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

Programme 1: Soil Health and Input Use Efficiency

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

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2015-2024

- Crop simulation modeling and remote sensing
- Fertilizer fortification
- Resilience of degraded soil.
- Soil quality assessment

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

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

Programme 3: Microbial Diversity and Genomics

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

Programme 4: Soil Pollution, Remediation and Environmental Security

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

1.3 Organization Set-Up

Divisions

(i)   Soil Physics
(ii)   Soil Chemistry & Fertility
(iii)   Soil Biology
(iv)   Environmental Soil Science

Sections

(i)   Farm Section
(ii)   Administration Section
(iii)   Remote Sensing & GIS

Technical Units/Cells

(i)   Prioritization, Monitoring and Evaluation Cell (PME)
(ii)   Agriculture Knowledge Management Unit (AKMU)
(iii)   Institute Technology Management Unit (ITMU)
(iv)   Library, Information and Documentation Unit
(v)   Right to Information (RTI)

(vi)   Results, Framework & Documentation (RFD)

(vii)   Consultancy Processing Cell (CPC)

(viii) Official Language Cell (Hindi Cell)

All India Co-ordinated Research Projects (AICRPs) / Network project (AINP)

(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 (MSPE)

(iv)   All India Network Project on Soil Biodiversity and Biofertilizers (SBB)

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ORGANIZATIONAL SETUP OF ICAR - INDIAN INSTITUTE OF SOIL SCIENCE

Administration

Finance

Audit & Accounts

MANAGEMENT UNITS

IMC

DIRECTOR

QRT

RAC

IRC

CENTRAL UNITS/ SECTIONS

- Farm Section
- AKMU
- ITMU
- Library
- Central Laboratory
- Training-cum Referral Laboratory
- Remote Sensing & GIS
- Vehicle

CELLS

- PME
- CPC
- RFD
- RTI
- Hindi Cell
- Women Cell
- Grievance Cell
- Academic Cell

RESEARCH WING

AICRPs/AINP

- LTFE
- MSN
- STCR
- Soil Biodiversity & Biofertilizers

DIVISIONS

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

1.4   Manpower

a)   Scientific

S. No.	Discipline	Sanctioned				In Position			
		PS	SS	S	Total	PS	SS	S	Total
1	RMP	1	0	0	1	1	0	0	1
2	Agricultural Economics	0	1	1	2	0	0	0	0
3	Agricultural Extension	0	0	1	1	0	0	1	1
4	Agricultural Microbiology	1	1	2	4	0	1	1	2
5	Agricultural Statistics	0	1	2	3	0	0	2	2
6	Agronomy	1	2	4	7	0	2	3	5
7	Computer Application	0	1	0	1	0	0	0	0
8	Plant Biochemistry	0	1	1	2	0	1	0	1
9	Plant Physiology	1	1	1	3	1	1	1	3
10	Soil Science	9	8	16	33	9	7	16	32
	Total	**13**	**16**	**28**	**57**	**11**	**12**	**24**	**47**

a)   Technical

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

a)   Administrative

S. No.	Designation	Sanctioned	In Position
1	Senior Administrative Officer	1	0
2	Finance & Accounts Officer	1	1
3	Assistant Finance & Accounts Officer	1	1
4	Assistant Administrative Officer	1	1
5	Private Secretary	2	2
6	Assistant	6	4
7	Personal Assistant	5	3
8	Stenographer Gr-III	2	2
9	Security Supervisor	1	1
10	Upper Division Clerk	2	2
11	Lower Division Clerk	6	2
12	Skilled Supporting Staff	25	20
	Total	**53**	**39**

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Decade of Soils
2015-2024

1.5 Finance: Budget statement (Lakhs) for the financial year 2016-17 is as follows

Institute/AICRPs	Budget		Total	Expenditure		Total
	Non-Plan	Plan		Non -Plan	Plan	
Main IISS Institute	1201.45	324.13	1525.58	1199.87	264.59	1464.46
AICRP- LTFE	0	361.00	361.00	0	360.99	360.99
AICRP- STCR	0	445.00	445.00	0	511.51	511.51
AICRP- MSN	0	470.00	470.00	0	554.37	554.37
AINP on SBB	0	199.30	199.30	0	228.33	228.33
CRP on CA Platform	0	230.00	230.00	0	229.99	229.99
Total	**1201.45**	**2029.43**	**3230.88**	**1199.87**	**2149.78**	**3349.65**

1.6 Resource Generation

S. No.	Head of Account	Amount (Rs)
1.	Sale of Farms Produce	727538.00
2.	Sale of Fish	1375.00
3.	Income from Royalty, Sale of Publication and Advertisement	37479.00
4.	Analytical and Testing Fee	22910.00
5.	Application fee from candidates	128100.00
6.	Diploma Charges	100.00
7.	Interest earned on Short Term Deposits	6048197.00
8.	Income generated from Internal Resource Generation	164390.00
	Total	**7130089.00**

2. Research Achievements

Theme - I: Soil Health and Input Use Efficiency

2.1 Improving Input Use Efficiency

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

Maize yield was significantly influenced with application of various integrated nutrient management (INM) modules in a long term fertilizer experiment at ICAR-IISS research farm (Table 2.1.1). Among the different INM modules, grain and stover yield of maize significantly increased with application of 75% NPK of STCR based dose with 5t ha^{-1} farmyard manure (FYM) and followed by general recommended dose (GRD) and other FYM based INM modules (Fig.2.1.1a). Maize productivity also increased with application of 75% NPK dose of STCR based fertilizer module with integration of different organic sources of nutrients *viz*., poultry manure and urban compost. All INM modules were statistically at par with GRD in terms of maize yield, whereas under organic sources of nutrients alone, grain yield was significantly lower. The highest agronomic efficiency and partial factor productivity was highest in FYM based INM module followed by GRD (Fig. 2.1.1b). The application of 5 t FYM ha^{-1} in every season also enhanced the grain and straw yield of chickpea as compared to residue management (mulching by maize residues) treatment. The increase in grain and straw yield of chickpea, was due to residual fertility of organic manures in maize (Fig.2.1.1c). Total organic carbon (TOC) and carbon stock (Mg/ha) significantly differed among the INM modules (Fig.2.1.1d&2.1.1e). Among the different INM modules, application of FYM @ 20 t ha^{-1} in every season (T11) in the maize–chickpea cropping system resulted significant increase in TOC and carbon stock (Mg/ha) followed by other organic based INM modules (T9, T12, T10 and T5).

Table 2.1.1 Treatment details

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

Note: Nutrient application is based on soil test crop response equation, **MR**-Maize residue, **UC**- Urban compost, **PM**-Poultry manure, **FYM**- Farmyard manure, and **Gly-**_Glyricidia_ loppings
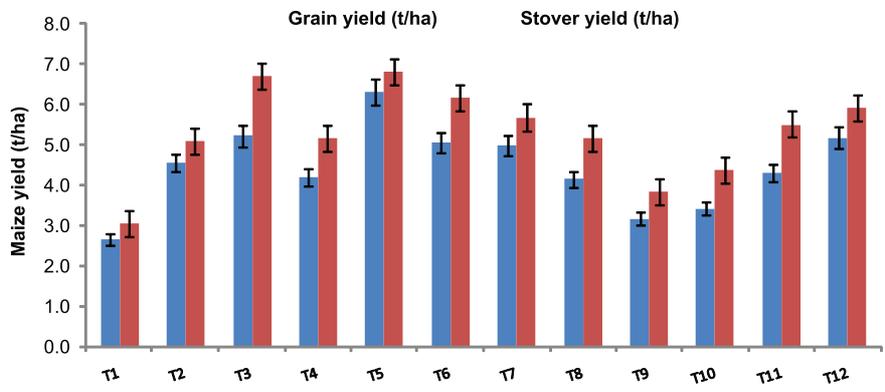
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Decade of Soils
2015-2024

Fig. 2.1.1a Performance of maize yields under different INM modules
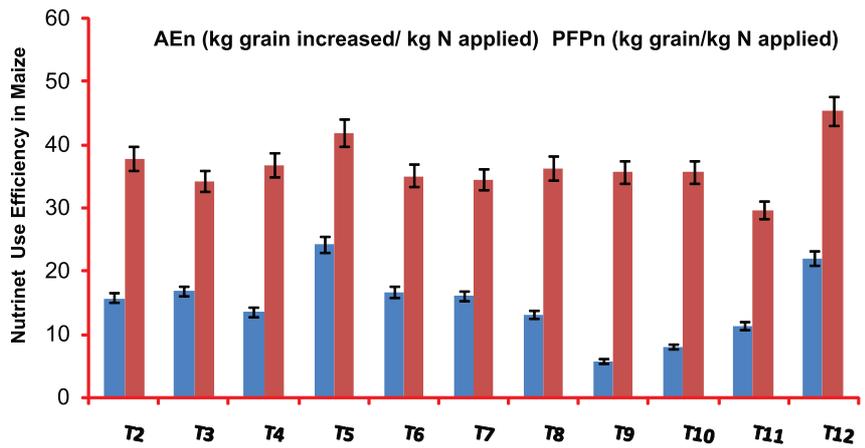

Fig. 2.1.1b Agronomic N use efficiency (AEn) and partial factor productivity (PFPn) in maize under different INM modules
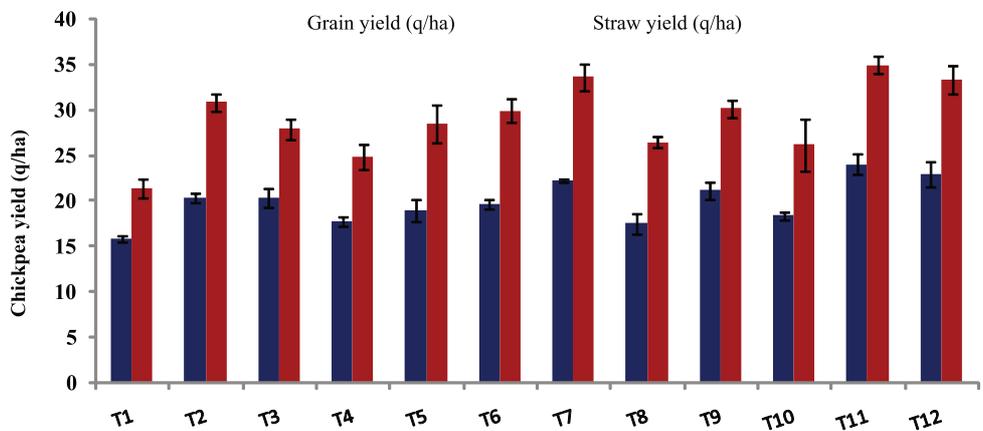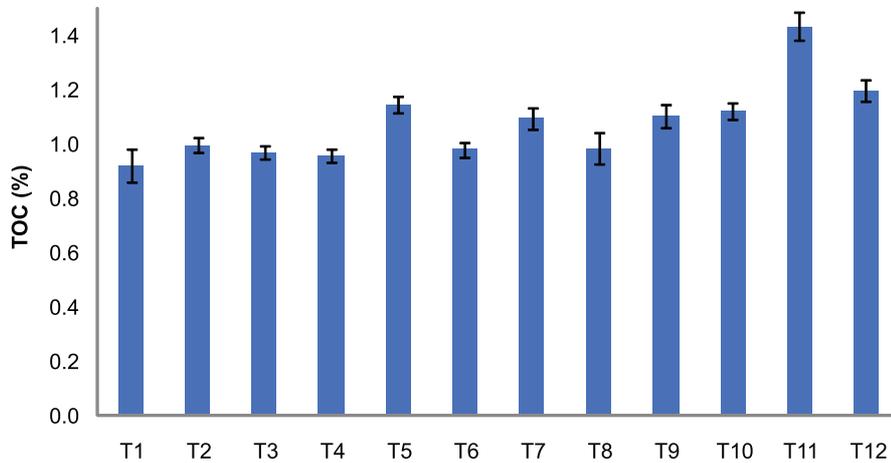

Fig. 2.1.1c Effects of residual fertility of INM modules on chickpea yields

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Fig. 2.1.1d Effects of different INM modules on total organic carbon in soil
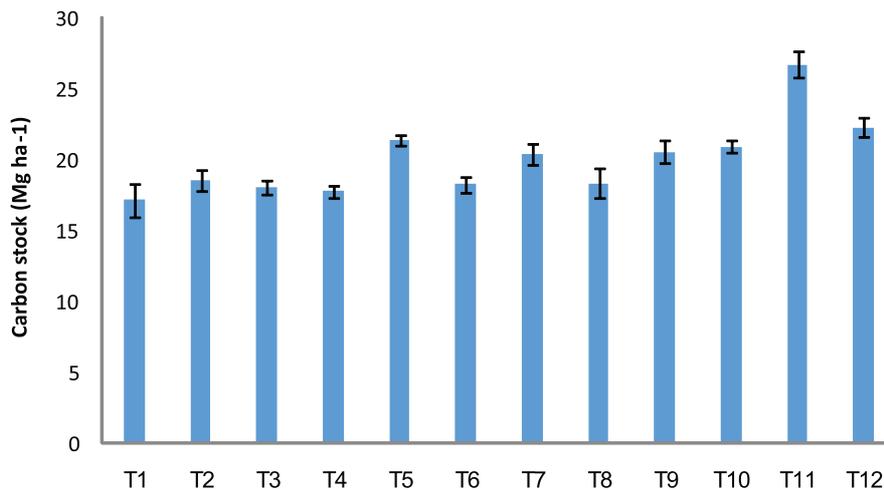
Fig 2.1.1e Effect of different integrated nutrient management modules on carbon stock

2.1.2 Evaluation of modified urea materials and agronomic interventions for enhancing nitrogen use efficiency and sustaining crop productivity

A field experiment was conducted during 2016-17 to evaluate different modified urea materials for enhancing nitrogen use efficiency and sustaining crop productivity. The results showed that maize yield and nitrogen use efficiency (NUE) were significantly variable with the application of different modified urea materials. Amongst the different modified urea materials, neem coated urea (NCU) recorded higher grain, stover and total dry matter yield of maize crop and NUE followed by biochar coated urea (BCU) and pine oleoresin coated urea (POR) (Fig.2.1.2a). The increase in total dry matter yield might be due to slow release of N for crop growth and development. The increase in total dry matter yield might be due slow release of N for longer period during crop growth. The N use efficiencies (Fig. 2.1.2b) i.e. agronomic use efficiency (AEn) and partial factor productivity (PFPn) also significantly differed under different modified urea materials.
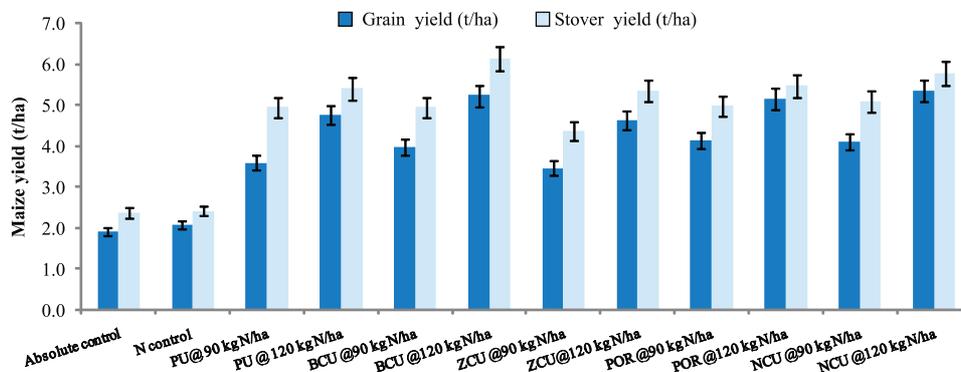
Fig. 2.1.2a Effect of different modified urea materials on maize yields
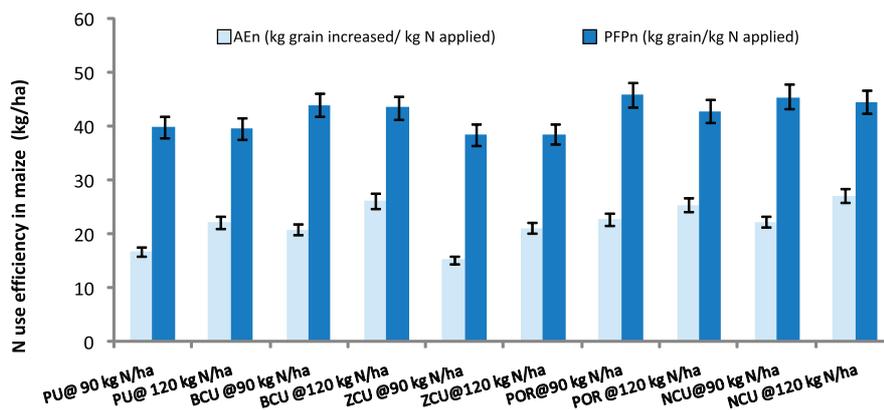
Fig. 2.1.2b Nitrogen use efficiencies of maize as influenced by modified urea materials

2.1.3 Fertilizer scheduling in Vertisols

A field experiment was conducted during 2016-17 to evaluate the best agronomic interventions for enhancing crop yield and nitrogen use efficiency. The agronomic interventions tested were (i) N application in split doses and at varying levels and (ii) time of application in maize crop. Results showed that total dry matter yield of maize crop was higher under soil test crop response equation based (STCR) fertilizer application; probably due to higher amount of nutrient addition. While, among the varying nitrogen (N) rate and time of application, grain and stover yield of maize crop were significantly higher in the treatments where basal dose of N was skipped and total N was applied in two equal splits (60 kg N/ha) at 20 and 40 days after sowing (DAS), respectively (Fig.2.1.3a). The total dry matter yield of maize crop was also improved in the treatments where addition of low cost biochar used as soil amendment. The biochar which was used in the experiment was produced from pyrolysis of subabul (*Leucaena leucocephala*) biomass includes stem and twigs. Agronomic N use efficiency and partial factor productivity significantly differed with varying N rate and time of application (Fig. 2.1.3b). The nutrient efficiencies were higher in the treatment where basal dose of nitrogen was skipped and total nitrogen was applied into two equal split dose at knee high (20 days after sowing) and tasseling stage (40 days after sowing), respectively followed by biochar treatments.
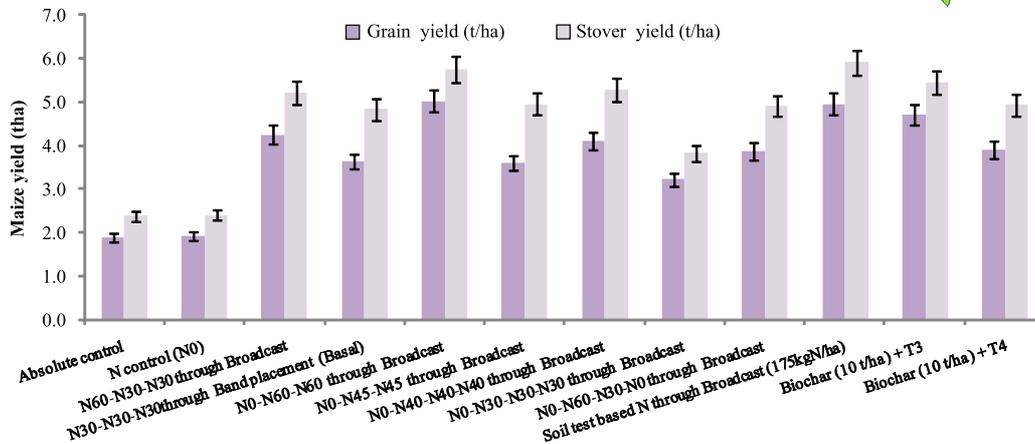
Fig. 2.1.3a Effect of time and application of nitrogen on maize yields
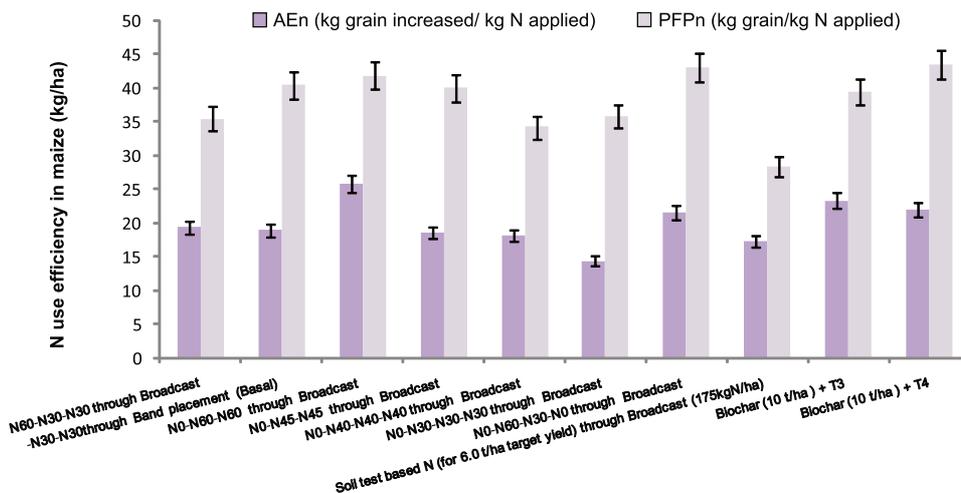
Fig. 2.1.3b Effect of time and application of nitrogen on N use efficiencies in maize crop

2.1.4 Nanoparticles influence growth and metabolism of plants for improving nutrient use efficiency

The impact of nano-micronutrient fertilization on growth and metabolism of plants *viz*. soybean (Plate 2.1.4), wheat and maize were studied under hydroponic as well as sand culture system using ZnO, CuO and Fe_3O_4 nanoparticles (NPs). In soybean, the nano-micronutrient fertilization of plants with normal concentration of Fe NPs/ Cu NPs / Zn NPs positively influenced the shoot growth, grain yield and biochemical traits *viz*. total soluble protein, membrane stability, proline accumulation in plants. However, sub-optimal concentration of NPs positively influenced root growth and gas exchange parameters *viz.,* photosynthesis rate, transpiration rate and stomatal conductance of plants. Plant height of soybean was enhanced by nano-micronutrient fertilization of Cu NP (0.5 μM). However, Zn NP (2μM) also promoted plant height in soybean crop. Leaf growth characteristics of soybean *viz*. leaf area and LAR were found to be promoted by Zn NP (2μM) and Fe NP (27μM). In wheat, the nano-micronutrient fertilization of plants with NPs had positively influenced most of the morphological parameters while the sub-optimal concentration of NPs had positively influenced biochemical traits *viz.,* proline accumulation and chlorophyll content of plants. Gas exchange parameters

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were also positively influenced by NPs in wheat. Grain yield was positively affected by increased concentration of Zn NP (2µM) and Fe NP (54µM) in soybean. However, in wheat, maximum grain yield was found with reduced concentration of NPs viz. Zn NP (1µM), Fe NP (27µM) and Cu NP (0.25 µM). Photosynthesis rate was enhanced by Fe NP (54µM) and Cu NP (0.25µM) in soybean. But in wheat photosynthesis rate was enhanced in Zn NP (2µM) treatments. The above findings indicated that the effect of nanoparticles and its dose was crop specific. Moreover, it is also observed that nanoparticles at reduced concentration may act as catalyst for growth and metabolism which can be utilized for higher yield of plants. Experimental results indicated that there is a possibility of reducing the dose of elemental nutrient for plants in nano form to increase the nutrient use efficiency of a major cereal crops like maize and wheat and pulses like soybean.

Plate 2.1.4 Sand cultured soybean grown with Fe (T1 to T4), Cu (T1, T5 to T7) and Zn (T1, T8 to T10) NPs

2.1.5 Effect of biochar application on yield of maize and chickpea

A field experiment was conducted to assess the effect of biochar addition to soil on maize-chickpea cropping system. The residual effect of biochar for N supply in *rabi* season was assessed in chickpea crop. Biochar was applied to soil and mixed in top layer and the maize crop was sown with usual fertilizer application method. The grain yield of the maize crop varied between 1336 and 4363 kg ha^{-1} with the highest under the treatment of 120 kg N + 10 t biochar ha^{-1}. Fertilizer application showed significant effect on seed and biomass yield. At 120 kg N ha^{-1}, biochar addition increased the yield but significant increase could be noticed at 5 and 10 t ha^{-1} over 120 kg N ha^{1}. Application of 5 or 10 t ha^{-1} biochar along with 120 kg N ha^{-1} were statistically at par. While lowering the N levels to 80 kg ha^{-1} there was significant decrease in grain yield of maize. Biochar additions enhanced the maize yield at 5 or 10 t ha^{-1} and were statistically at par with each other (Table 2.1.5: Fig. 2.1.5a and 2.1.5b). The chickpea seed yield ranged between 1247 and 1574 kg ha^{-1} and both grain and straw yields were not significantly affected by fertilizer and /or biochar treatments.

Table 2.1.5 Effect of biochar additions on maize grain yield (kg ha^{-1})

Treatment	Chickpea (2015-16)		Maize (2016)	
	Grain	Straw	Grain	Straw
Absolute control	1247	2346	1336	1425
N omission	1349	2744	1443	1577
120 kg N	1468	2997	3694	3529
120 kg N + 2 t biochar h^{-1}	1386	2764	3762	3728
120 kg N + 5 t biochar h^{-1}	1574	2933	4029	3720
120 kg N + 10 t biochar h^{-1}	1543	2983	4363	3951
80 kg N h^{-1}	1416	2934	3090	2899
80 kg N + 2 t biochar h^{-1}	1541	3109	3389	3087
80 kg N + 5 t biochar h^{-1}	1353	2767	3519	3324
80 kg N + 10 t biochar h^{-1}	1403	3003	3898	3648
CD	NS	NS	385	472
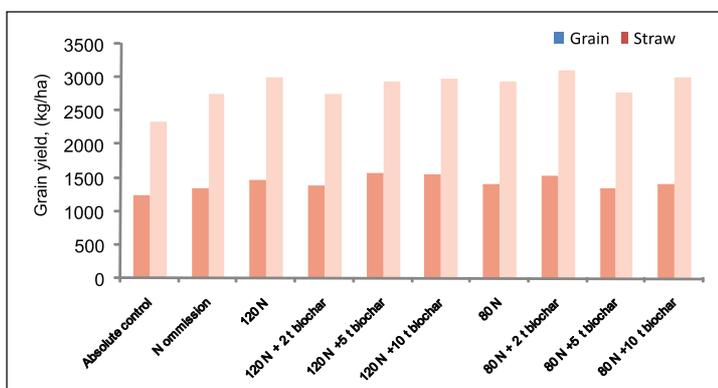
Fig. 2.1.5a Residual effect of biochar and N application to maize on chickpea crop
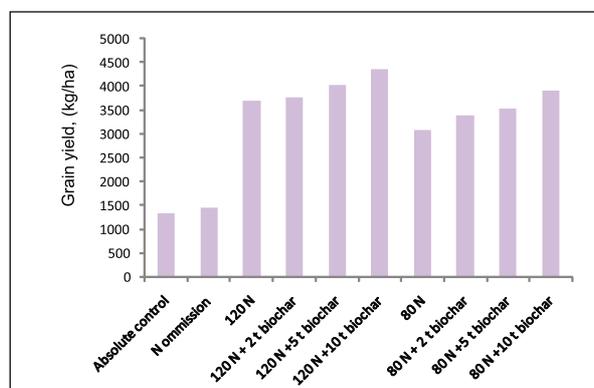
Fig. 2.1.5b Effect of biochar and N application on performance of maize crop

2.1.6 Evaluation of urease inhibitor product for nutrient use efficiency in wheat

A study on use of slow release N sources was carried out for two years on wheat crop. Nitrogen was supplied in one, two or three splits as normal urea, LIMUS urea or neem coated urea (NCU). The mean grain yield of wheat varied between 2427 and 5068 kg ha^{-1}. The highest grain yield was obtained with the application of N@150 kg N ha^{-1} but it was found at par with 120 kg N ha^{-1} as prilled urea, limus urea as well as NCU. Application of N in single dose through LIMUS urea resulted in statistically similar yield to that of 120 kg N through prilled urea in 3 splits.
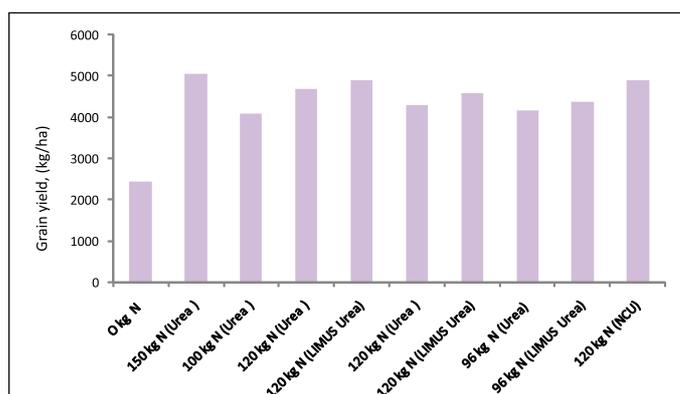
Fig. 2.1.6 Effect of different N sources and application timings on wheat grain yield

Table 2.1.6 N recovery by wheat during two years of experimentation with different N sources

Treatment	N source	N dose kg ha^{-1}	Time of N application			Apparent N recovery %
			Basal application: Just broadcast urea on surface and not incorporate in soil	1st top dressing at CRI (BBCH 21-25)	2nd Top dressing at heading (BBCH 51-59)	
T1	No nitrogen	0	0	0	0	-
T2	Prilled urea	150	75	37.5	37.5	48.8
T3	Prilled urea	100	50	25	25	51.2
T4	Prilled urea	120	60	30	30	49.1
T5	Limus urea	120	60	30	30	52.8
T6	Prilled urea	120	0	120	0	54.0
T7	Limus urea	120	0	120	0	56.5
T8	Prilled urea	96	0	96	0	58.2
T9	Limus urea	96	0	96	0	58.4
T10	Neem Coated Urea	120	0	120	0	54.2

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Application of NCU @120 kg N ha^{-1} in single dose was statistically at par with 150 kg N ha^{-1} as prilled urea. There was slight improvement in the apparent recovery by the wheat crop with LIMUS urea. At equal level of N application even NCU has shown better results (Table 2.1.6: Fig. 2.1.6 and Plate 2.1.6).

Plate 2.1.6 Wheat crop stand under different nitrogen applications

2.1.7 Enhancing resource use efficiency in pulse based cropping system in central India

Physiological analysis of resource use efficiency under soybean based inter-cropping system was carried out under flat bed and broad bed system of land configuration (Plate 2.1.7). Morpho-physiological parameters were recorded in soybean based inter cropping system involving crops *viz.*, pigeon pea, maize, sesamum, sorgum and black gram in *kharif* 2016 and lentil in *rabi* 2016-17 under rainfed and supplemental irrigation. The soil parameters were recorded and presented in Fig. 2.1.7.

Plate 2.1.7 Flat bed and broad bed land configuration under soybean based inter-cropping system
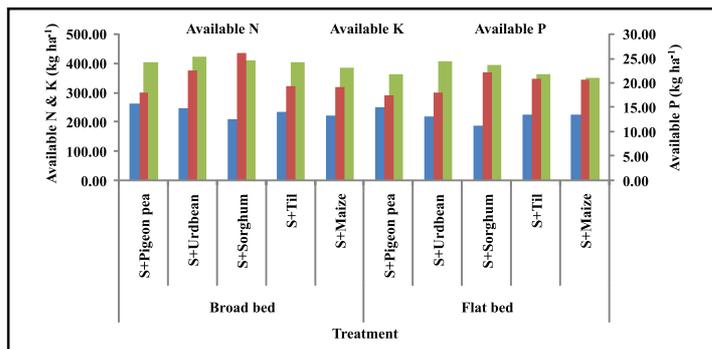
Fig. 2.1.7 Effect of land configuration and soybean based inter-cropping system on soil fertility

2.1.8 Simulating the effect of elevated CO_2 and temperature on water productivity and nutrient use in soybean-wheat cropping system

To study the effect of climate treatments (CO_2 and temperature as the key variables) and nitrogen application levels on nutrient and water use of soybean-wheat system, a crop experiment with soybean (var. JS 20-29) was taken up in the open top chambers (OTCs), in the *kharif* season of 2016 with two levels of CO_2 (ambient, 550 ppmv), two levels of temperature (ambient, + 2.5°C) and four nitrogen levels (0, 50, 100 and 150%). An absolute control treatment (N0P0K0) was also taken. In total, there were five climate conditions *viz.,* open field, ambient chamber, elevated CO_2, elevated temperature, and elevated CO_2 and temperature. At time of sowing, vermicompost @ 2.0 tonnes ha^{-1} was
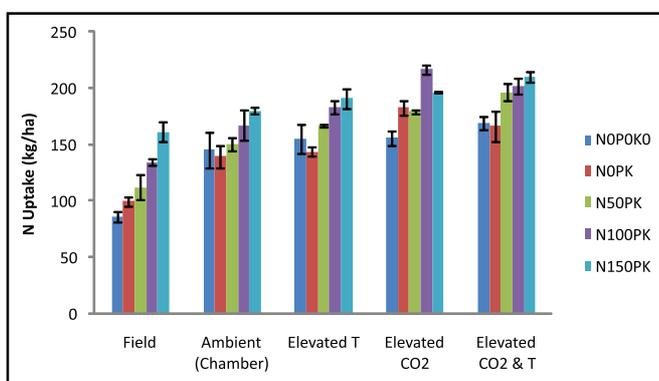
Fig. 2.1.8a Nitrogen uptake by soybean under different climate and N application treatments

Fig. 2.1.8b Phosphorous uptake by soybean under different climate and N application treatments

applied along with 30 kg N ha^{-1} (in the form of urea), 60 kg P$_2$O$_5$ ha^{-1} (through SSP) and 40 kg K$_2$O ha^{-1} (through MOP) to the soybean crop. The key growth parameters *viz.*, plant height, leaf area, above ground plant biomass and grain yield were recorded. The plant nutrient concentration in respect of N, P, K was determined for seed, leaf and straw. The plant N concentration in the seeds was not significantly affected by the climate, but elevated CO$_2$ resulted a significant reduction in N concentration in straw under all N application levels.

The uptake of N, P and K in soybean crop was significantly affected by N and environment factors. However, the interaction effect was significant only in

Fig. 2.1.8c Potassium uptake by soybean under different climate and N application treatments

case of N uptake. In general, with increase in N application, uptake of N, P and K increased under all the climate treatments. Significantly higher N uptake was observed under elevated CO$_2$ treatment at N$_{100}$ due to higher grain yield, leaf biomass and leaf N concentration at N$_{100}$ level (Fig. 2.1.8a). Chamber effect in terms of N uptake was significant under all N levels where as it was significant in case of P and K uptake only under limited N levels (Fig. 2.1.8b and 2.1.8c).

2.1.9 Soil quality assessment and developing indices for major soil and production regions of India

The investigation was undertaken by ICAR-IISS, Bhopal with participation from three other ICAR Institutes, *viz.* CRIDA, Hyderabad; NBSS & LUP, Nagpur and IIFSR, Modipuram. Under this project, sampling protocol was developed in which the selected agro-ecological sub-regions AESRs were divided into 20 km grids. A total of 1368 grids were obtained using ArcGIS 9.3 platform. From each grid point, geo-referenced soil samples from the surface layer (0-15 cm) collected covering two different types of farm families, *viz.* (1) small and marginal, (2) medium to large. Grid samples were collected from 61 districts and 670 grid points covering AESR 4.1, 4.3, 6.1, 6.2, 9.2 and 18.4. In-situ sampling was done for measuring soil bulk density for 2-7 cm and 7-12 cm soil depths. A questionnaire was also prepared and was used for collection of information from the farmers regarding nutrient application, crop production and past cropping history. Samples were analyzed for pH, EC, organic carbon, KMnO$_4$ oxidizable labile carbon (Weil et al., 2003), labile carbon fractions (Chan et al., 2001), available P, available K, available S, exchangeable sodium, and dehydrogenase activity. The analyzed soil sample data in respect of AESR 4.3, 9.2 and 6.1 were subjected to frequency

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analysis (Histogram). Thematic GIS maps were developed for soil pH, EC, organic carbon, labile carbon, labile carbon fractions, available potassium, available sulphur and exchangeable sodium content for AESR 4.3 and 9.2 covering 15 districts of Uttar Pradesh state. Spatial distribution maps were developed using ordinary kriging for the analyzed soil quality parameters (Fig. 2.1.9a and 2.1.9e).
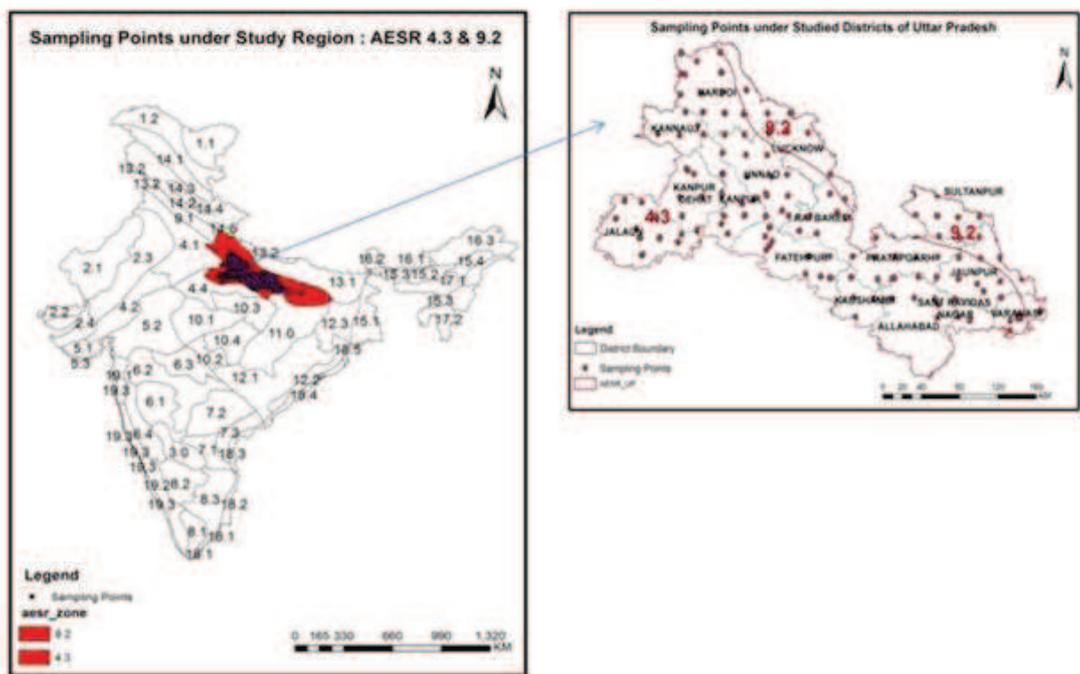
Fig. 2.1.9a Sampling points under study region: AESR 4.3 & 9.2
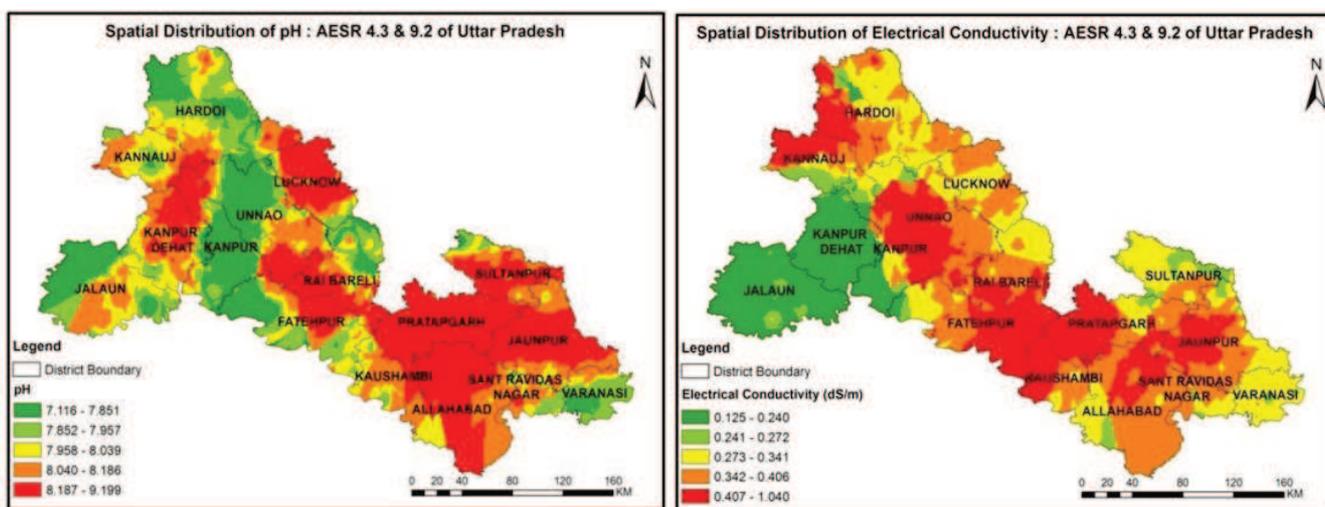
Fig. 2.1.9b Spatial distribution map using ordinary kriging for pH in soils of AESR 4.3& 9.2.

Fig. 2.1.9c Spatial distribution map using ordinary kriging for electrical conductivity in soils of AESR 4.3 & 9.2.
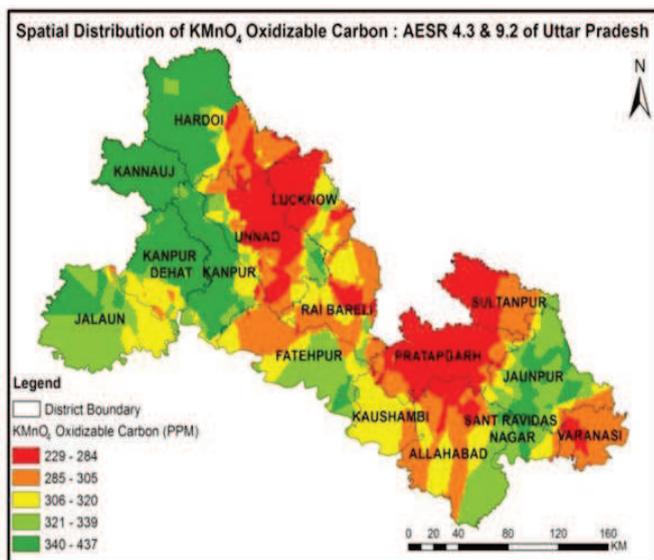
Fig. 2.1.9d Spatial distribution map using ordinary kriging for labile carbon in soils of AESR 4.3 & 9.2.
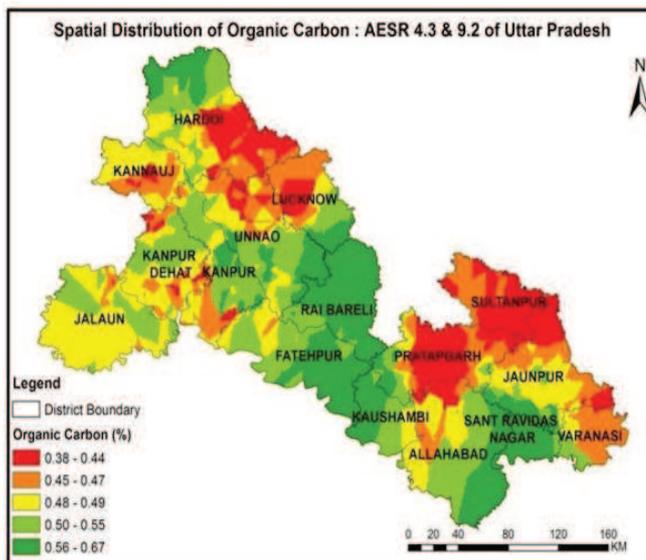
Fig. 2.1.9e Spatial distribution map using ordinary kriging for organic carbon in soils of AESR 4.3 & 9.2.

2.1.10 Impact of conservation agricultural practices on soil health

In order to quantify the effect of long-term conservation agriculture practices on soil health, samples were collected from the ongoing experiment on 'long-term effect of resource conservation technologies on crop productivity, water requirement and soil health in rice-wheat cropping sequence' at ICAR-IIFSR, Modipuram. The experiment was established in the year 2004 at IIFSR, Modipuram. The treatments of main plot (Rice) consist of P1-Unpuddled, P2-Puddled, P3-Manual transplanter. The sub-plots (Wheat) consist of T1- Zero till drill, T2-Happy turbo-seeder, T3-Roto till drill, T4-Bed planting and T5-Conventional sowing. The soil samples collected from the experiments were analyzed for soil chemical, biological and physical parameters. Also core samples were collected for estimation of soil bulk density.

The perusal of data indicated that irrespective of soil conditions in main plots (Puddled, Unpuddled and Farmer's practice), soil carbon concentration in 0-5cm depth was found maximum under zero till seed drill and happy turbo seeder plot. Among the planting methods, highest soil organic carbon (SOC) was recorded under P1-unpuddled condition. Invariably, SOC concentration was found maximum in 0-5 cm of soil depth and decreased with soil depth. Among the different sowing methods, the highest SOC concentration was recorded in zero seed drill and happy turbo seeder (0.72%) in 0-5 cm of soil depth (Table 2.1.10a). In 5-15 and 15-30 cm of soil depths, SOC concentration was found maximum in P3 (Farmers practice) under the treatments of T1 (zero till drill) and T2 (Turbo happy seeder) under unpuddled condition. Soil organic carbon stratification ratio under unpuddled condition in 0-5cm soil depth ranged from 1.09 (puddled condition) to 1.59 (unpuddled condition). Lowest SOC concentration was recorded under bed planting method. Under unpuddled (rice) condition, zero till and happy turbo seeder maintained highest (0.72%) soil carbon content whereas same level of carbon could not be attained under puddled condition. This clearly indicated that soil carbon could be built up under no till system in rice-wheat cropping system provided rice crop is direct seeded.

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2015-2024

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Table 2.1.10a. Soil organic carbon content (%) as affected by sowing methods in rice-wheat cropping system

0-5 cm depth						
	T1	**T2**	**T3**	**T4**	**T5**	**Mean P**
P1	0.72	0.72	0.62	0.55	0.61	0.65
P2	0.58	0.69	0.65	0.51	0.59	0.60
P3	0.71	0.62	0.60	0.62	0.66	0.64
Mean T	0.67	0.68	0.62	0.56	0.62	
Factors	Factor (P)	Factor (T)	Factor(T) at same level of P		Factor (P) at same level of T	
C.D.	0.028	0.083	NS		NS	

5-15 cm depth						
	T1	**T2**	**T3**	**T4**	**T5**	**Mean P**
P1	0.455	0.403	0.506	0.517	0.548	0.486
P2	0.455	0.517	0.475	0.444	0.424	0.463
P3	0.548	0.568	0.465	0.527	0.475	0.517
Mean T	0.486	0.496	0.482	0.496	0.482	
Factors	Factor (P)	Factor (T)	Factor(T) at same level of P		Factor (P) at same level of T	
C.D.	N/A	N/A	0.111		0.12	

15-30 cm depth						
	T1	**T2**	**T3**	**T4**	**T5**	**Mean P**
P1	0.31	0.351	0.372	0.444	0.475	0.391
P2	0.434	0.372	0.424	0.331	0.393	0.391
P3	0.496	0.475	0.331	0.403	0.413	0.424
Mean T	0.413	0.4	0.375	0.393	0.427	
Factors	Factor (P)	Factor (T)	Factor (T) at same level of P		Factor (P) at same level of T	
C.D.	N/A	N/A	0.135		0.133	

In terms of labile carbon content, unpuddled condition (P_1) maintained the highest concentration of $KMnO_4$ oxidisable C and the lowest was recorded under (P_2) condition. Among different sowing methods, zero till drill recorded the highest concentration of labile carbon (456 mg/kg) in zero till drill under unpuddled condition. Roto till drill maintained the lowest labile carbon concentration under puddle condition (Table 2.1.10b). Labile carbon concentration drastically decreased with increasing soil depth. It was observed that zero till drill maintained high concentration of labile carbon (405 mg/kg) even under the farmers practice (manual transplant).

Table 2.1.10b   Soil labile carbon concentration (ppm) as affected by sowing methods in rice-wheat cropping system

0- 5cm depth	T1	T2	T3	T4	T5	Mean P
P1	456.3	372.4	373.5	334.4	375.4	382.4
P2	326.0	366.5	342.6	384.2	368.5	357.6
P3	405.8	382.0	336.2	374.0	406.8	381.0
Mean T	396.0	373.6	350.8	364.2	383.6	
Factors	Factor (P)	Factor (T)	Factor (T) at same level of P		Factor (P) at same level of T	
C.D.	10.43	9.53	17.795		17.899	

5-15 cm depth	T1	T2	T3	T4	T5	Mean P
P1	275.8	207.6	333.5	291.2	292.9	280.2
P2	294.5	325.9	332.8	284.7	303.6	308.3
P3	299.2	316.7	279.8	319.3	300.5	303.1
Mean T	289.8	283.4	315.4	298.4	299.0	
Factors	Factor (P)	Factor (T)	Factor (T) at same level of P		Factor (P) at same level of T	
C.D.	4.13	10.51	18.42		16.76	

15-30 cm depth	T1	T2	T3	T4	T5	Mean P
P1	179.7	190.1	280.9	237.0	168.8	211.3
P2	242.8	236.2	245.1	243.5	262.9	246.1
P3	214.0	200.7	211.7	279.1	239.0	228.9
Mean T	212.2	209.0	245.9	253.2	223.6	
Factors	Factor (P)	Factor (T)	Factor (T) at same level of P		Factor (P) at same level of T	
C.D.	6.63	9.05	16.3		15.42	

No significant difference in soil pH was recorded under different puddling conditions. However, the treatment of bed planting maintained higher soil pH (8.30) in comparison to all other treatments (8.1). The effect of bed planting of wheat on changes in soil pH was similar under all the three puddling conditions (Table 2.1.10c). No significant difference in soil pH was recorded in different depths of sampling. However, a general trend of increase in soil pH (0.2 units) was recorded in 15-30 cm of soil depth in comparison to 0-15cm of soil depth. The trend was similar for soil electrical conductivity.

Table 2.1.10c Soil pH as affected by sowing methods in rice-wheat cropping system

0-5 cm

	T1	T2	T3	T4	T5	Mean P
P1	8.06	8.11	8.04	8.23	8.16	8.12
P2	8.02	8.09	8.05	8.29	8.25	8.14
P3	8.14	8.18	8.30	8.33	8.12	8.21
Mean T	8.07	8.13	8.13	8.28	8.18	
Factors	Factor (P)	Factor (T)	Factor (T) at same level of P		Factor (P) at same level of T	
C.D.	N/A	0.097	N/A		N/A	

5-15 cm

	T1	T2	T3	T4	T5	Mean P
P1	8.35	8.35	8.24	8.40	8.36	8.34
P2	8.22	8.29	8.17	8.25	8.27	8.24
P3	8.37	8.25	8.32	8.34	8.27	8.31
Mean T	8.31	8.29	8.24	8.33	8.30	
Factors	Factor (P)	Factor (T)	Factor (T) at same level of P		Factor (P) at same level of T	
C.D.	N/A	NA	N/A		N/A	

2.1.11 Conversion of naturally occurring plant nutrient containing minerals into nano form to enhance the availability of plant nutrients in soil

Vast deposits of minerals, which are not suitable for industrial use, can be made useful as sources of plant nutrients for the crop production. Currently most of the chemicals, which are used as fertilizers, are made water soluble so as to provide easy supply of nutrient to the growing plants. In contrast, non-soluble minerals can be converted to nano-size through top-down approach as a source of plant nutrients. Preparation of nano-particles by top-down method means starting from micron scale and go down in size using different techniques. Mechanical grinding using high energy ball mills is one of the methods to attain particles in the nano-scale (<100 nm). The release of plant nutrient from nano-sized mineral particles in soil is made through chemical and biological weathering, the rate of which can be regulated by properly managed practices. Similarly, vast deposits of gluconite/waste mica can be potentially utilized as source of K to plants by converting them to nano-size level. Almost all the minerals (Plate 2.1.11) were collected for the preparation of the nano-particles by top-down approach. In a similar manner other natural mineral deposits like Spheralite / Smisthonite (as a source of Zn) can be made useful for agriculture purpose with a reduced cost and without adverse impact to environment.

Plate 2.1.11 Different minerals collected for the preparation of nano particles of the respective elements

The Sphalerite zinc mineral was collected and after grinding into micro level, it was converted to nano level (< 30.73 nm) by High Energy Ball Mill (SPEX, 8000D Mixer/Mill) through top down approach. It took near about 6-9 hours grinding. The particle size was estimated by Particle Size Analyzer (Dynamic Light Scattering Techniques) (Fig.2.1.11).
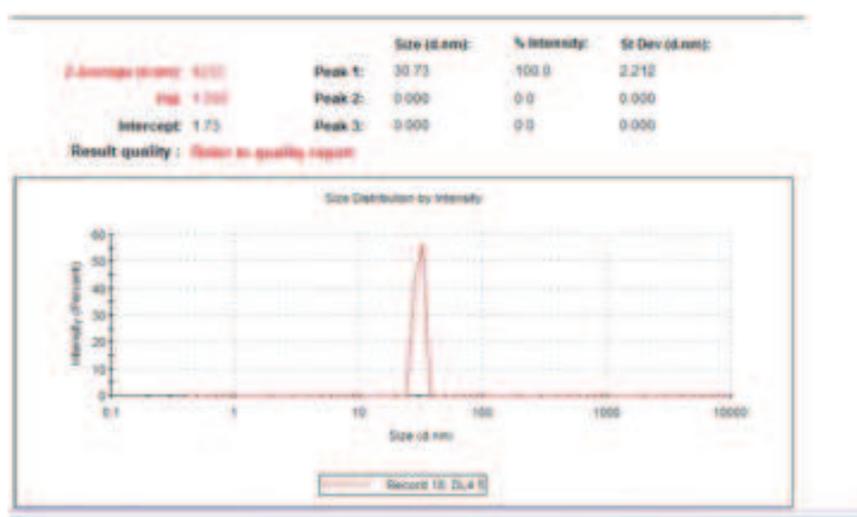
Fig. 2.1.11 Intensity distribution of Sphalerite nano particles through Photon Collision Spectroscopy

2.1.12 *In-situ* decomposition of rice-wheat residues using ligno-cellulolytic microbes for improving crop productivity and soil health

Although, crop residues are having tremendous value to farmers, a large portion of the residues, approximately 90-140 Mt, is burnt in field mainly to clear the field from straw and stubble after harvest of the preceding crop. It could be ascribed to unavailability of labour, high cost in removing the residues, lack of requisite machinery to incorporate in soil and use of combine harvesters in rice-wheat cropping system. Thus, field experiments were carried out at farmers' fields of Haryana and Madhya Pradesh to decompose rice and wheat residues using *in-situ* decomposition technique. In this process, consortia of ligno-cellulolytic microorganisms have been identified, cultured by ICAR-IISS used to decompose crop residue. For one hectare of rice or wheat about 34 to 38 quintals of post-harvest crop residues is left over in the field after operation of combine harvester. These residues can be decomposed systematically with following steps. For *in-situ* decomposition, fresh cow dung about 4 tons (on dry weight basis) was mixed thoroughly with water. To this slurry about 37 kg urea, 50 kg molasses, 25 kg curd, 1.7 kg mycelial mat (cellulolytic fungi) and 34L of microbial inoculum (lignocellulolytic bacteria and actinomycetes) were added and spread over the residue. All these residues and ingredients were incorporated into soil by a tractor drawn rotavator. One light irrigation was given immediately after mixing these consortia of microbes and other materials. Then, second irrigation was given after 15 days of treatment application. Rice was grown after one month of treatment application. Similar technology was followed for wheat crop after harvest of rice. The crop performance was compared with residue burning plots, indicated that the crop yield was better in *in-situ* decomposition treated plot than burning of crop residues. Such experiments were conducted in farmers' fields of Haryana. It was observed that grain yield of rice was 3-7% greater in the treatment receiving *in-situ* decomposition of crop residue as compared to burning treated plot. Similarly, in wheat crop burning of crop residue resulted 2-6% lower yield that *in-situ* decomposition treated plot (Table 2.1.12a; Plate 2.1.12). The soil organic carbon was greater in *in-situ* decomposition treated plot as compared to burning of crop residues. The soil available nutrient

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(NPK) status was varied little but soil biological activities improved relatively greater (dehydrogenase activity and soil respiration) than burning of crop residue treated plots (Table 2.1.12b).

Table: 2.1.12a Effect of burning and *in-situ* decomposition of rice – wheat residue on grain yields

Village	Rice Yield (q ha^{-1})		Wheat Yield (q ha^{-1})	
	Residue burning	*In-situ* decomposition	Residue burning	*In-situ* decomposition
Gyong (Kaithal) (10 farmers)	33.57	35.85	49.34	50.06
Bahupur (Panipat) (7farmers)	41.97	43.27	50.55	52.72
CSSRI Karnal (3 plots)	33.53	34.82	47.90	50.60

Note : Basmati rice cultivar was grown in Gyong and CSSRI farm. Whereas in Bahupur pusa rice 1121 cultivar was grown.

Table 2.1.12b Effect of *In-situ* decomposition of rice and wheat residue on soil chemical and biological activities in Inceptisols of Haryana

Locations	SOC (%)		pH		EC d Sm^1		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})		DHA (ugTPFg^{-1} 24h^{-1})		Soil Res. (mg kg^{1}d^{-1})	
	A*	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Gyong	0.48	0.46	8.77	8.55	0.41	0.70	229	240	12	10	351	344	16	18	20	22
Bahupur	0.56	0.68	8.26	7.81	0.88	0.63	268	315	21	24	204	289	15	17	8	11
CSSRI, Karnal	0.54	0.56	8.05	7.90	0.23	0.24	216	264	13	19	202	206	17	19	8	10

*A= Initial; B= After In-situ decomposition; Gyong = Average mean of 10 farmers field, Bahupur =Average mean of 7 farmers field; CSSRI, Karnal = average mean of 3 research farm plots

(A) Haryana Field

(B) Madhya Pradesh Field

Plate 2.1.12 Crop performance in farmers field under *in-situ* decomposition of crop residue

2.1.13 Recycling of domestic kitchen waste using family net compost vessel (FNCV)

To recycle the domestic kitchen waste, a family net compost vessel (FNCV) was developed. In this technique, about 2.5 feet length and 1.5 feet diameter of nylon net was inserted with plastic container to hold the kitchen waste inside the vessel (Plate 2.1.13). The decomposed cow dung along with epigeic earthworms was kept inside the vessel about 2-3 days prior to addition of kitchen waste. About 150 g of kitchen waste was collected daily followed by partial drying outside the vessel. The material was then chopped to 4-6 cm length and kept inside the vessel. To maintain proper moisture, water was added regularly and jute gunny bag

Plate 2.1.14 Demonstration of family net compost vessel

was kept on the surface of the waste to avoid drying. After one month of decomposition, the compost was analyzed for total C and total N. It was observed that the TOC reduced from 42.3% to 23.8% and total N was increased from 0.63 to 1.12 % and thus, C/N ratio of compost is about 21:1.

2.1.14 Evaluation of organic, inorganic and integrated crop management practices on soybean yield

During *kharif* season of 2016, the seed yield of soybean was recorded highest in 100% organic treatment followed by 75% organic + 25% inorganic and 75% organic + innovative treatment which were significantly higher than 100% inorganic and State recommendation treatments (Table 2.1.15 and Plate 2.1.15).

Plate 2.1.15 Soybean crop in organic farming *(kharif 2016)*

Table 2.1.15 Yield of soybean (kg ha^{-1}) under different nutrient management practices (*Kharif 2016*)

Practice/ Cropping System (CS)	Organic Management (As per NPOF standard)		Inorganic Management		Integrated Management	
	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5	Practice 6
CS1	1139	1009	956	1094	944	927
CS2	1090	1037	935	1093	858	901
CS3	1167	975	1036	1079	849	891
CS4	1089	1048	951	1029	991	976
LSD (p=0.05)	Manure		107			
	Cropping System		NS			
	Manure X Cropping system		122			

Cropping systems: (CS1) Soybean-Wheat, (CS2) Soybean-Mustard, (CS3) Soybean-Chickpea and (CS4) Soybean-Linseed
Practice-1-100% Organic (Organic manure equivalent to 100 % N requirement of the system); Practice-2- 75 % organic (Organic manure equivalent to 75 % N requirement of the system) +innovative practices (spray of cow urine and vermi-wash 10% each twice); Practice-3- 50 % Organic + 50 % inorganic ; Practice-4-75% Organic + 25 % inorganic; Practice-5- 100% inorganic package ; Practice-6- Sate recommendations

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2.1.15 Soil enzyme activities under organic farming

Soil enzyme activity is an indirect indication of the activities of microbes which is directly correlated with soil microbial dynamics. Enzyme activity in the soil environment is considered to be a major contributor of overall soil microbial activity. Enzyme activity in terms of fluorescein diacetate (FDA), dehydrogenase, alkaline phosphatase and β glucosidase were determined in soil as influenced by different nutrient management practices. Fluorescein diacetate hydrolysis activity was found to be highest under 100% organic plot which was closely similar to 75% organic+ innovative/25% inorganic as compared to 100% inorganic in wheat. For other crops also FDA hydrolysis was recorded highest in 100% organic followed by 75% organic + innovative/25% inorganic treatment indicating beneficial effect of addition of organics on soil microorganisms (Fig. 2.1.16a). Amongst the cropping systems, soybean-wheat recorded higher FDA followed by soybean-linseed, soybean-chickpea and soybean-mustard crop. Higher dehydrogenase activity was recorded in organic management compared to inorganic and integrated management (Fig. 2.1.16b). Similarly, alkaline phosphatase and β glucosidase enzymes activities were recorded highest in 100 % organic followed by 75 % organic + 25 % inorganic and 75 % organic + innovative treatment indicating beneficial effect of addition of organics on soil microorganisms (Fig. 2.16.16c and 2.1.16d).
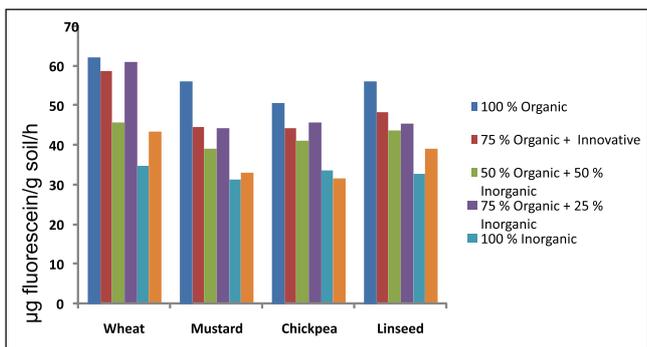
Fig. 2.1.16a Fluorescein diacetate hydrolysis activity as affected by different nutrient sources in different crops
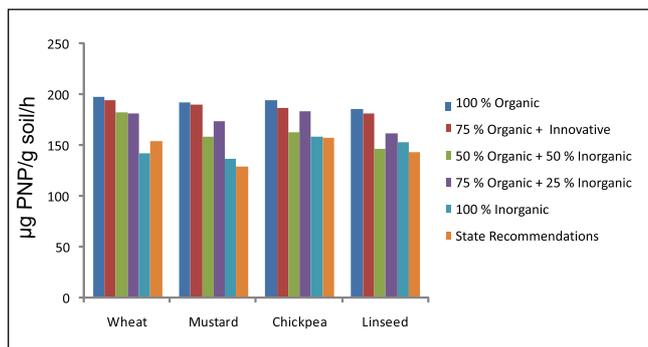
Fig. 2.1.16b Soil dehydrogenase activity as affected by different nutrient sources under different crops
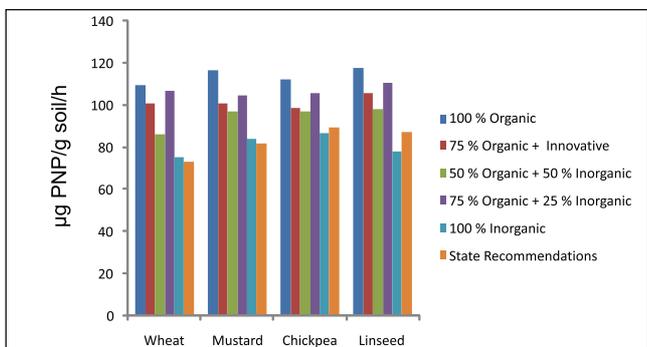
Fig. 2.1.16c Alkaline phosphatase activity as affected by different nutrient sources under different crops
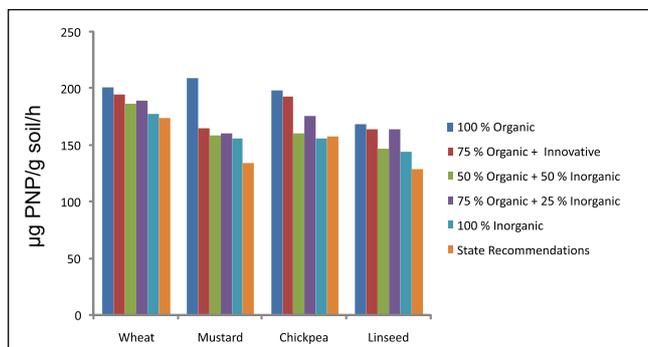
Fig. 2.1.16d β glucosidase activity as affected by different nutrient sources under different crops

2.1.16 Evaluation of response of different varieties of major crops for organic farming

Performance of different varieties of soybean and maize were evaluated for their yield response to screen out promising varieties for organic management practices for central India (Plate 2.1.17). Among the varieties of soybean grown under similar nutrient source and doses, the cultivar RVS-2002-4 (1290 kg ha^{-1}) out performed in terms of seed yield followed by JS- 20-41, JS-97-52, RVS-2002-6, JS-335, NRC-7, JS-20-29, RVS-2002-7, NRC-37, JS-95-60, JS-20-34 and JS-93-05. Among the maize varieties, yield of Kanchan variety recorded the highest yield (2907 kg ha^{-1}) followed by Proagro 4212, Pratap 6, JM 216, CPBG 4202, Sona 222, Arawali, JM 8, JM 12, Pratap 5 and Popcorn 1. Analysis of nutritional quality constituents such as protein and oil content of the said varieties of soybean indicated higher protein content   was recorded in cv JS-20-29   followed by JS-9305, NRC-37 and JS-335. However, higher oil content was observed in RVS-2002-7 followed by RVS-2002-6, JS 20-29. In maize, the higher values of protein, ash and tryptophan were recorded in Pro-agro-4212 variety (Table 2.1.17).

Table 2.1.17 Performance evaluation of different varieties of soybean under organic farming practices

Variety	Seed yield (kg/ha)	Protein (%)	Oil (%)	Variety	Seed yield (kg/ha)	Protein (%)	Ash (%)	Tryptophan (g/16 g N)
JS-335	1080	36.78	19.44	Kanchan	2907	9.74	1.62	0.89
JS-93-05	680	37.43	19.27	Pratap 5	1730	9.64	1.49	0.84
JS-95-60	940	36.75	19.01	Arawali	2047	9.88	1.45	0.77
JS-20-41	1147	36.62	19.51	Sona 222	2140	9.66	1.56	0.84
NRC-7	1057	36.52	18.81	Pratap 6	2670	9.6	1.53	0.79
NRC-37	977	37.08	18.79	JM 216	2343	9.84	1.48	0.75
JS-20-29	1057	37.36	19.75	Popcorn 1	1173	9.24	1.48	0.69
RVS-2002-4	1290	36.29	19.73	JM 8	1950	9.74	1.51	0.88
RVS-2002-6	1097	36.21	19.91	JM 12	1767	9.44	1.5	0.81
RVS-2002-7	1043	36.49	20.09	Proagro 4412	2847	10.04	1.6	0.91
JS-97-52	1110	36.37	18.67	Sweet Corn	983	9.37	1.39	0.71
JS-20-34	875	36.24	18.23	CPBG 4202	2327	9.98	1.54	0.87
CD (0.05)	142	NS	0.6		495	0.3	0.11	0.03

Plate 2.1.17 A view of maize and soybean experiment (*Kharif* 2016)

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2015-2024

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2.1.17 Geo-referenced organic clusters survey

Geo-referenced organic cluster survey was carried out at Chandpur village, Bhopal. Most of the organic farmers have their own irrigation facilities and integrated animal component in farming and organic manures are prepared on-farm. Among the respondents, the highest total land holding was found to be 25 hectares while, minimum was 2 hectares. Out of which, the maximum area under organic farming was 8 hectares and minimum was 1 hectare. Among the on-farm resources, farm yard manure is still the most predominant source of organic manure being used by the farmers followed by vermicompost. Crop residue availability with the farmers ranged from 1 to10 t/ha. Neem based pesticides are the major organic pesticides for the management of pest and diseases in organic crops. Farmers make their own organic pesticides to make organic farming profitable. Most of the farmers under organic farming employed manual weeding whereas, summer ploughing and crop rotation were the other practices employed for the management of weeds. Only 10-20 % of organic produces are reserved for house hold consumption and the rest are sold out in local market (*krishi mandi*). Minimum requirement of off-farm market inputs and maintenance of soil health and healthy products are the major reasons behind the adoption of organic farming. However, slow response to organic inputs, non-availability of premium price, improper market mode was opined as the constraints of organic farming. Farmers also cultivate typical local variety of wheat *cv*. vanci, for success in organic farming

2.2 AICRP on LTFE

2.2.1 Impact of Nutrient Management on Soil Biological Properties under LTFE

Biological condition of soil is one of the indicators for assessing soil health. The biological properties are always being excluded from the soil testing programmes because they are highly dynamic in nature, have no reproducibility and estimation methods are time consuming. Impact of nutrient management on biological properties of soil under long term fertilizer experiments was studied and reproduced hereunder.

Microbial Population

Population of microorganism like bacteria, fungi, *Azotobacter* and *Actinomycetes* gives a better picture about soil biological health. Study carried out on microbial population at different LTFE sites namely, Pantnagar, Coimbatore, Bhubaneshwar, Parbhani and Pattambi revealed that fertilizer application resulted increase in number of cells of all types of soil organisms compared to control (Table 2.2.1a). It is interesting to note that increase in dose of fertilizer from 100% to 150% NPK did not have any adverse effect on microbial count; rather a positive effect was noted at these places. Data further indicated that addition of farm yard manure (FYM) or green manuring (GM) had additional effect on their population. Moreover, soil microorganism also need nutrients for their growth and development and body synthesis. Increase in number of cells of soil organisms is due to availability of fresh residual biomass in larger quantity as a result of better crop growth.

Table 2.2.1a Long term effect of fertilizer and manure on microbial population in soil

Treatment	Bacteria ($\times 10^6$)	Fungi ($\times 10^4$)	Actinomycetes ($\times 10^5$)	Azotobacter ($\times 10^3$ cfu g^{-1})
Pantnagar (Mollisols)				
Control	0.55	0.60	0.78	152
100% N+Zn	1.46	1.27	1.89	410
100% NP+Zn	1.68	1.66	1.00	476
100% NPK	1.80	1.48	1.71	286
150% NPK	1.87	1.48	1.76	256
100% NPK+Zn	2.19	1.91	1.84	336
100% NPK+FYM	2.32	1.99	2.16	630
LSD (P=0.05)	0.17	0.11	0.31	43.8
Pattambi (Alfisols)				
Control	24.00	15.25	0.08	9.50
100% N	29.50	18.50	0.10	10.75
100% NP	32.00	21.25	0.12	12.25
100% NPK	39.75	26.00	0.17	17.50
150% NPK	40.75	26.75	0.17	18.25
100% NPK+ lime	37.50	24.50	0.15	16.75
50% NPK+ GM	43.75	34.50	0.19	20.25
100% NPK+ GM	52.25	36.75	0.27	24.75
50% NPK+ FYM	48.50	41.50	0.21	20.75
100% NPK+ FYM	61.50	48.50	0.33	28.25
LSD (P=0.05)	9.652	9.175	0.09	7.653
Coimbatore (Inceptisols)				
Control	45.0	1.10	0.70	-
100% N	72.0	1.20	0.80	-
100% NP	72.0	1.20	0.80	-
100% NPK	90.0	1.40	1.00	-
150% NPK	83.0	1.30	0.90	-
100% NPK + ZnSO$_4$	87.0	1.30	0.90	-
100% NPK + FYM	131.0	1.60	1.20	-

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Treatment	Bacteria ($\times 10^6$)	Fungi ($\times 10^4$)	Actinomycetes ($\times 10^5$)	Azotobacter ($\times 10^3$ cfu g^{-1})
Bhubaneshwar (Inceptisols)				
Control	31.8	40.3	0.48	-
100% N	39.5	62.0	1.48	-
100% NPK	61.3	75.3	1.50	-
100% NPK +Lime	81.3	50.8	0.53	-
100% NPK +FYM	90.3	90.5	3.10	-
LSD (P=0.05)	27.4	38.8	1.02	-
Parbhani (Vertisols)				
Control	3.10	15.00	2.60	-
100% N	3.60	19.50	2.85	-
100% NP	3.40	21.00	3.10	-
100% NPK	3.40	20.00	3.20	-
150% NPK	3.70	22.00	4.00	-
100% NPK + FYM	5.30	23.00	4.60	-
LSD (P=0.05)	0.26	1.57	0.30	-

Enzyme Activities

Enzyme activity in soil indirectly estimates microbial activity in soil. Perusal of data on soil enzymes such as Dehydrogenase, phosphatase, fluorescein diacetate and urease at different LTFE location (Table 2.2.1b, 2.2.1c and 2.2.1d) indicated that irrespective of soil and cropping systems application of fertilizer nutrient resulted increase in activities of all the soil enzymes. Increase in enzymatic activities depends on activities of soil microorganism. Soil respiration is an indirect indicator of evolution of CO_2 from soil to express the microbial population. As more will be the microbial population and activity hence. Data (Table 2.2.1c & 2.2.1d) generated on soil CO_2 efflux at Akola, Bhubaneshwar, Pattambi and Raipur revealed that application of fertilizer nutrients resulted increase in CO_2 efflux suggesting application of fertilizer to have positive effect on soil microorganisms.

Table 2.2.1b   Long-term effect of manure and fertilizer use on enzymatic activities

Treatments	DHA (µg TPF g^{-1} 24 h^{-1})	Acid phosphatase (µg PNPg^{-1} hr^{-1})	Alkaline phosphatase (µg PNPg^{-1} h^{-1})	FDA (µg fluorescein g^{-1} hr^{-1})
Barrackpore (Inceptisols)				
Control	2.8	139	479	10.9
100% N	4.0	146	519	11.3
100% NP	4.4	147	532	11.6
100% NPK	6.0	170	579	13.9
150% NPK	5.7	186	603	16.1
100% NPK + FYM	7.1	275	616	19.0
Parbhani (Vertisols)				
Control	34.1	56.8	132.6	-
100% N	36.2	57.9	133.3	-
100% NP	40.1	64.7	142.2	-
100% NPK	40.0	64.9	140.7	-
150% NPK	46.7	72.4	151.1	-
100% NPK + FYM	51.6	76.7	161.7	-
LSD (P=0.05)	2.48	2.43	2.84	-

Table 2.2.1c Long-term effect of manure and fertilizer use on enzymatic activities and soil CO_2 efflux

Treatments	DHA (μg TPF g^{-1} 24 hr^{-1})	Urease activity (μg NH$_4$-N g^{-1} 24 hr^{-1})	Acid phosphatase (μg PNPg^{-1} hr^{-1})	CO_2 Efflux (mg 100 g^{-1} soil)
Pattambi (Alfisols)				
Control	188.2	141.5	17.63	3.63
100% N	164.7	214.2	19.68	5.86
100% NP	121.2	180.7	27.96	6.05
100 % NPK	106.8	192.5	19.11	5.91
150% NPK	106.9	202.7	19.22	5.74
100% NPK+ lime	207.4	180.2	21.49	6.07
50% NPK+ GM	257.3	205.0	27.89	6.67
100% NPK+ GM	368.2	223.5	29.90	6.62
50% NPK+ FYM	313.6	216.5	28.13	6.85
100% NPK+ FYM	394.4	239.0	38.54	7.03
LSD (P=0.05)	7.37	9.09	2.866	0.624
Akola (Vertisols)				
Control	36.34	38.88	-	20.08
100% N	41.02	50.50	-	24.75
100% NP	44.89	51.77	-	28.05
100% NPK	45.89	55.40	-	31.63
150% NPK	51.02	61.02	-	38.23
100% NPK + FYM	57.92	65.19	-	41.80
LSD (P=0.05)	6.09	8.47	-	4.18
Raipur (Vertisols)				
Control	21.69	18.35	-	37.13
100% N	30.14	18.04	-	37.73
100% NP	29.79	22.56	-	39.83
100% NPK	37.28	31.77	-	43.13
150% NPK	44.67	34.82	-	45.75
50% NPK + BGA	31.04	28.52	-	40.20
50% NPK + GM	43.32	30.42	-	45.08
100% NPK + Zn	36.87	26.75	-	42.38
100% NPK+ FYM	46.62	36.41	-	46.65
LSD (P=0.05)	5.16	4.58	-	4.75
Jagtial (Inceptisols)				
Control	3.22	-	94.5	
100% N	2.77	-	86.5	
100% NP	5.08	-	95.8	
100% NPK	4.03	-	120.7	
150% NPK	5.13	-	139.3	
100% NPK + FYM	5.70	-	153.8	
LSD (P=0.05)	0.38	-	15.4	

Table 2.2.1d Long-term effect of manure and fertilizer use on enzymatic activities and CO_2 evolution

Treatment	DHA (μg TPF g^{-1} 24 h^{-1})	CO_2 Efflux (mg 100 g^{-1} soil)
Pantnagar (Mollisols)		-
Control	0.24	-
100% N+Zn	5.78	-

Treatment	DHA (μg TPF g^{-1} 24 h^{-1})	CO$_2$ Efflux (mg 100 g^{-1} soil)
100% NP+Zn	5.45	-
100% NPK	4.27	-
150% NPK	5.40	-
100% NPK+FYM	6.82	-
LSD (P=0.05)	0.08	-
Ranchi (Alfisols)		
Control		36.8
100% N		31.8
100% NP		44.8
100% NPK		39.8
150% NPK		50.0
100% NPK + lime		55.0
100% NPK + FYM		65.3
LSD (P=0.05)		6.5
Bhubaneshwar (Inceptisols)		
Control		0.049
100% NPK		0.060
150% NPK		0.063
100% NPK + Zn		0.062
100% NPK + FYM		0.072
LSD (P=0.05)		0.007

Carbon Dynamics

Palampur (Alfisols)

The data on microbial biomass C, N, P and S determined and given in (Table 2.2.1e) clearly indicated that increased application of nutrients have increased the microbial biomass, C, N, P and S. Incorporation of FYM over and above NPK further increased the values of these estimates. Application of lime also had positive effect on microbial activities in soil. It means application of fertilizer nutrient had favoured microbial activities in soil. It is noteworthy that imbalanced use of nutrients (100% N and NP) had an adverse effect on activities of microorganisms.

Table 2.2.1e Effect of long-term use of chemical fertilizers and amendments on microbial biomass (mg kg^{-1})

Treatment	Microbial biomass C	Microbial biomass N	Microbial biomass P	Microbial biomass S
Control	279	10.5	1.87	4.41
100% N	182	12.3	0.81	5.80
100% NP	295	13.9	1.89	6.62
100% NPK	464	18.4	3.09	7.29
150% NPK	441	21.3	3.37	7.66
100% NPK + lime	620	22.0	3.44	10.93
100% NPK + FYM	676	23.4	3.49	11.67
LSD (P=0.05)	11.9	3.07	0.19	0.89

Bangalore (Alfisols)

The data on different fractions of carbon (Table 2.2.1f) revealed that application of fertilizer nutrients resulted in increase in all the fractions of carbon *viz*. total organic carbon (TOC), particulate soil organic carbon

(PSOC), soil microbial biomass carbon (SMBC), water soluble organic carbon (WSOC), soil carbohydrate carbon (SCC) and soil mineralizable carbon (SMC). Data further indicated that increasing amount of fertilizer as well as addition of FYM plus lime further made improvement in these fractions of carbon. Increase in carbon and its fractions is due to addition of carbon in larger quantity through residual biomass of root, due to higher crop yield under fertilizer treatments. Synthesis of glomalin is one of the indicators to assess carbon sequestration. Increase in glomalin content under higher levels of fertilizer nutrients confirms that it helps in soil aggregation and thereby in C-sequestration (Table 2.2.1f). Incorporation of FYM had more pronounced effect on synthesis of glomalin.

Table 2.2.1f Effect of long term manure and fertilizers application on fractions of carbon in soil under finger millet–maize cropping system (mg kg^{-1})

Treatments	TOC (mg kg^{-1})	PSOC (mg kg^{-1})	SMBC (mg kg^{-1})	WSOC (mg kg^{-1})	SCC (mg kg^{-1})	SMC (mg kg^{-1})	Glomalin content (mg kg^{-1})
Control	4792.0	325.0	180.0	14.5	244.8	288.0	1.49
100% N	4896.0	344.0	198.0	18.6	265.6	311.0	1.58
100% NP	5123.0	373.0	204.0	20.0	286.8	319.0	1.79
100% NPK	6243.0	551.0	229.0	26.7	350.5	339.0	2.24
150% NPK	6632.0	679.0	239.0	28.8	398.6	364.0	3.02
100% NPK +lime	6423.0	657.0	235.0	27.4	377.6	350.0	2.69
100% NPK +FYM	7418.0	839.0	293.0	32.1	439.2	424.0	4.23
LSD (*P*=0.05)	335.5	32.8	17.7	2.3	23.3	35.1	0.35

TOC= total soil carbon; PSOC= particulate soil organic carbon; SMBC= soil microbial biomass carbon; WSOC= water soluble organic carbon; SCC= soil carbohydrate carbon in soil; SMC= soil mineralizable carbon

Barrackpore (Inceptisols)

Data generated (Table 2.2.1g) on microbial biomass C (MBC) showed that imbalanced nutrient resulted in decline in MBC. The data further indicated that increase in dose of nutrient from 100 to 150% NPK resulted in increase in biological properties. It means use of chemical fertilizer had positive effect on microbial activity in soil. However, use of FYM showed additional effect on these properties.

Table 2.2.1g Long-term effect of manure and fertilizer use on microbial biomass carbon, and microbial quotient

Treatments	Microbial biomass carbon (mg kg^{-1})	MBC/ SOC Ratio
Control	221	3.95
100% N	287	4.16
100% NP	298	4.20
100% NPK	328	4.62
150% NPK	331	4.53
100% NPK + FYM	435	4.89

Pantnagar (Mollisols)

Application of fertilizer nutrient resulted increase in different fractions of carbon (Table 2.2.1h) *viz*. SMBC, SMBN, SMBP, WSC and WSCH. Addition of FYM has further improved these fractions.

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Table 2.2.1h Long term effect of fertilizer and manure on carbon pools and dehydrogenase activity (Pantnagar)

Treatment	SMBC (mg kg^{-1})	SMBN (mg kg^{-1})	SMBP (mg kg^{-1})	WSC (mg kg^{-1})	WSCH (mg kg^{-1})
Control	7.85	6.94	0.24	2.96	2.30
100% N+Zn	245.20	34.20	3.70	60.80	41.30
100% NP+Zn	199.20	36.20	4.10	59.60	40.60
100% NPK	177.20	29.00	3.20	51.80	31.10
150% NPK	186.70	27.50	4.20	53.70	33.20
100% NPK+FYM	260.00	35.20	6.20	74.70	42.50
LSD (P=0.05)	2.73	2.41	0.08	1.03	0.74

SMBC= soil microbial biomass carbon; SMBN= soil microbial biomass nitrogen; SMBP= soil microbial biomass phosphorus; WSC= water soluble carbon; WSCH= water soluble carbohydrate; DHA= dehydrogenase activity

Ranchi (Alfisols)

Fertilizer application resulted (Table 2.2.1i) in increase in water soluble carbon, water soluble carbohydrates, respiration rate, microbial biomass carbon, microbial biomass nitrogen and soil respiration (CO_2 efflux). The results indicated that application of fertilizers had positive effect on microbial activities in soil. Increase in amount of water soluble carbon and carbohydrate on application of fertilizer is due to larger root activity as a result of better crop growth.

Table 2.2.1i Long term effect of continuous cropping, fertilization, manuring and liming on active and slow pool of SOC under soybean-wheat cropping system

Treatments	Humic acid (g kg^{-1})	Fulvic acid (g kg^{-1})	E_4/E_6 ratio of HA	E_4/E_6 ratio of FA
Control	1.10	1.10	1.10	3.77
100% N	1.12	1.13	1.72	4.12
100% NP	1.13	1.14	1.59	4.12
100% NPK	1.26	1.22	2.12	5.1
150% NPK	1.33	1.28	2.24	5.42
100% NPK + lime	1.28	1.26	2.19	5.37
100% NPK + FYM	1.42	1.39	2.38	6.2
LSD (P=0.05)	0.1	0.09	0.194	0.46

Raipur (Vertisols)

There was increased soil respiration (CO_2 evolution) and microbial biomass N with long-term application of fertilizer indicating higher activity of organisms (Table 2.2.1k). under the fertilized treatment. Addition of FYM and green manuring further improved the measured parameters.

Table 2.2.1k Effect of inorganic fertilization and integrated nutrient management practices on microbial biomass

Treatments	SMB Carbon (μg g^{-1} soil)	SMB Nitrogen (mg 100 g^{-1} soil)	Potential mineralizable N (μg)
Control	158.05	62.91	175.00
100% N	187.30	74.56	182.00
100% NP	208.85	75.16	196.00
100% NPK	223.34	82.48	238.00
150% NPK	250.59	92.50	252.00
50% NPK + BGA	225.10	77.09	196.00
50% NPK + GM	247.58	82.91	245.00
100% NPK + Zn	232.14	75.27	245.00
100% NPK+ FYM	253.22	96.85	273.00
LSD (0.05)	17.06	8.70	62.73

Pattambi (Alfisols)

The data on soil MBC, C and N mineralization and hot water soil carbohydrates indicated positive effect of fertilizer addition on long term basis (Table 2.2.1l). Addition of FYM and green manuring further improved the parameters.

Table 2.2.1l Effect of treatment on MBC, C mineralization potential, N mineralization potential and hot water extractable soil carbohydrates (HWC)

Treatments	MBC (μg g^{-1} soil)	C- Mineralization (%)	N-Mineralization (kg ha^{-1})	HWC (mg kg^{-1})
Control	205.45	1.32	177.27	2132.43
100% N	244.06	1.51	208.74	3081.21
100% NP	338.58	1.66	201.20	3644.80
100 % NPK	332.40	1.70	205.71	3051.75
150% NPK	223.36	1.79	214.21	3877.01
100% NPK+ lime	353.23	1.69	216.71	3071.67
50% NPK+GM	420.45	1.74	234.71	4888.59
100% NPK+ GM	468.65	1.89	250.21	5014.13
50 % NPK+ FYM	515.43	1.83	222.25	5583.59
100% NPK+ FYM	552.75	1.90	228.83	5917.08
LSD (P=0.05)	33.307	0.048	12.213	315.042

MBC= microbial biomass C; HWC= hot water extractable soil carbohydrates

Bhubaneshwar *(Inceptisols)*

Application of fertilizer nutrients either alone or in combination and also with organic manure increased the microbial biomass C and N. Increase in respiration (CO_2 evolution) confirms the findings (Table 2.2.1m).

Table 2.2.1m Effect of long term (nine years) manuring on microbial properties of surface soil

Treatments	MBC (mg kg^{-1})	MBN (mg kg^{-1})	Microbial quotient x 100	Respiration quotient
Control	151	26.76	4.52	0.329
100% NPK	251	61.07	5.39	0.238
150% NPK	338	76.97	6.50	0.189

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2015-2024

Treatments	MBC (mg kg^{-1})	MBN (mg kg^{-1})	Microbial quotient x 100	Respiration quotient
100% NPK + Zn	313	71.69	6.31	0.197
100% NPK + FYM	420	143.07	6.72	0.171
LSD (P=0.05)	50.70	14.60	1.46	0.027

2.3 AICRP-Micronutrients

2.3.1 Influence of Manganese stress on growth, yield and nutrient balance in okra

Okra (*Abelmoschus esculentus* L.) grown in refined sand with variable Mn levels (0.1 to 200 µM) exhibited characteristic symptoms of Mn deficiency at 20 DAS at 0.1µM Mn (Plate 2.3.1a). In addition to retarded growth, young leaf lamina of plants developed interveinal chlorosis which later intensified with the development of irregular brown spots (Plate 2.3.1b). At 35 DAS (5 days after Mn supply), plants grown at excess Mn (>10 µM Mn) supply showed depression in growth. After 7-8 days, plants grown at 100 and 200 µM Mn supply exhibited interveinal chlorosis on old leaves followed by inward curling of leaf margins. With increase in age these chlorotic spots turned brown and necrotic and caused eventual death of leaf lamina.

Plate 2.3.1a Response of variable Mn (0.1, 1, 10, 100 and 200 µM) supply in okra (L—R)

Plate 2.3.1b Interveinal scattered chlorosis of okra leaves at 0.1 µM Mn

Levels of manganese below or above 10 µM detrimentally affected biochemical (enzymes activities), uptake of essential nutrients and visible (lesions) responses in okra and are inhibitory to plant growth and development.

Table 2.3.1 Variable manganese and concentration of manganese, iron, phosphorus and sulphur in different plant parts of okra

Plant part	Levels of Mn (µM)				
	0.1	1.0	10	100	200
Mn concentration (µg g^{-1} dry matter)					
Leaves	4.65	15.54	88.6	176.2	226.0
Stem	5.36	12.67	56.7	104.6	198.2
Root	9.85	23.56	98.8	199.0	243.8
Fruit	4.69	16.24	65.4	112.8	188.4
Fe concentration (µg g^{-1} dry matter)					
Leaves	85.5	67.4	58.5	48.7	42.5
Stem	63.8	58.2	43.6	39.7	32.8
Root	92.5	88.8	75.3	55.3	43.8
Fruit	69.4	62.5	44.5	36.4	29.8

| Plant part	Levels of Mn (µM)				
	0.1	1.0	10	100	200
Cu concentration (µg g⁻¹ dry matter)					
Leaves	9.9	7.6	6.0	5.3	4.7
Stem	44.6	37.5	25.8	22.4	19.8
Root	52.3	43.4	35.7	33.5	25.5
Fruit	12.4	10.5	8.7	8.1	7.6
Zn concentration (µg g⁻¹ dry matter)					
Leaves	50.5	48.3	45.5	41.2	39.5
Stem	43.4	39.8	36.5	30.5	29.7
Root	59.6	57.5	50.5	42.5	37.5
Fruit	49.3	46.7	40.2	33.5	30.6
P concentration (% dry matter)					
Leaves	0.90	0.87	0.86	0.92	0.91
Stem	0.70	0.69	0.66	0.65	0.68
Root	0.82	0.78	0.78	0.79	0.79
Fruit	0.48	0.46	0.43	0.44	0.65
S concentration (% dry matter)					
Leaves	1.04	1.21	1.82	1.57	1.23
Stem	1.09	1.11	1.76	1.34	0.98
Root	0.98	1.12	1.32	1.04	0.87
Fruit	0.66	0.58	0.78	0.71	0.56

Excess Mn supply has been associated with an increased activity of indoleacetic acid, oxidase, peroxidase and polyphenol oxidase; lower activities of catalase and ascorbic acid oxidase, and malate dehydrogenase. The increase in peroxidase activity could be associated with the mechanism of the necrotic browning with the accumulation and deposition of oxidized Mn. The accumulation of P in different plant parts of okra suggested that P may reduce the toxicity of excess Mn by rendering it inactive within the plant. P may detoxify excess Mn in the plant roots through precipitation. However, P does not seem to detoxify excess Mn in the stems and the leaves since no precipitation was found in those parts of the plant (Table 2.3.1).

2.3.2 AESR-wise mapping of micro- and secondary nutrients deficiency in soils

Mapping micronutrients deficiency is essential for understanding spatial variability of nutrients in soils and also for devising site-specific nutrient management strategies for better farm economy and increased sustainability in crop production. Delineation of micronutrients deficiency is an uninterrupted activity of project. Mapping of micronutrients deficiency was performed using 1.97 lakh georeferenced soil samples, collected across the country and also taken from other studies. We have grouped the status of S, Zn, Cu, Fe, Mn and B in to agro-ecological sub-regions (AESR) of India. Depending upon the soil, bioclimatic type and physiographic situations, the country has been grouped into 20 agro-eco regions (AER) and 60 agro-eco sub regions (AESR). We have covered 58 AESRs for mapping micronutrients deficiency. Based on the analytical results, the deficiency maps of micro- and secondary nutrients were prepared using GIS. The deficiency level of S, Zn, Cu, Fe, Mn and B were grouped on the basis of agro-ecological sub regions (AESR) of India and digitized maps were prepared (Refer maps 2.3.2a-2.3.2f).
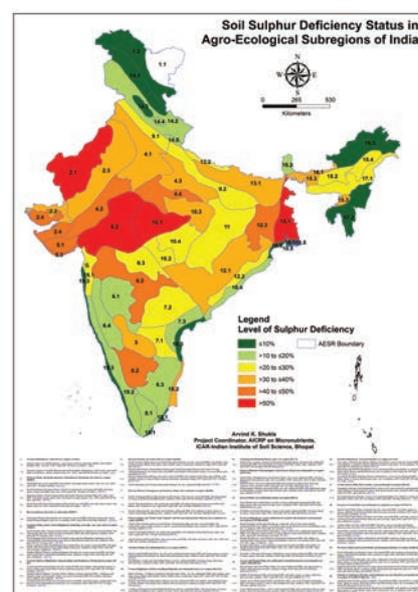
Map 2.3.2a Sulphur deficiency status in soils of AESR of India

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2015-2024

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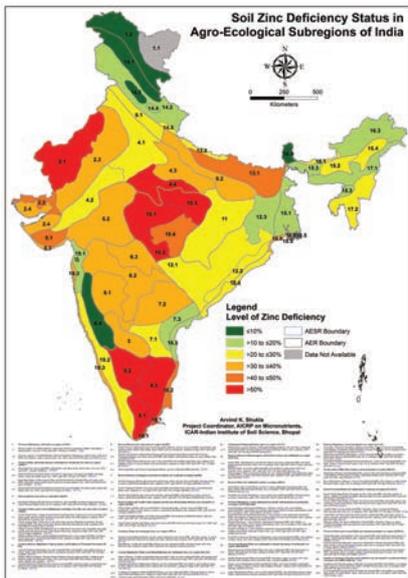
Map 2.3.2b Zinc deficiency status in soils of AESR of India
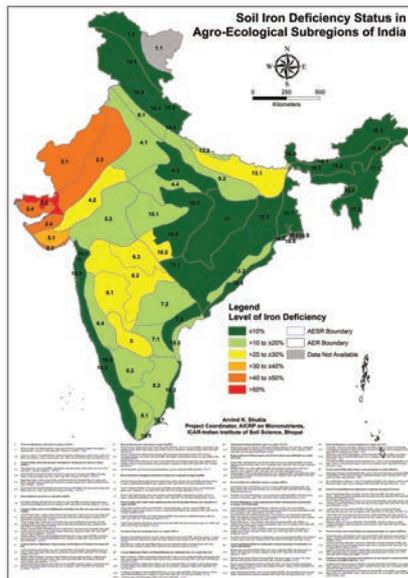
Map 2.3.2c Iron deficiency status in soils of AESR of India
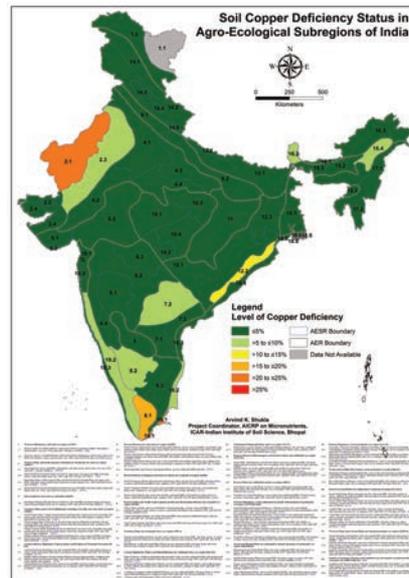
Map 2.3.2d Copper deficiency status in soils of AESR of India
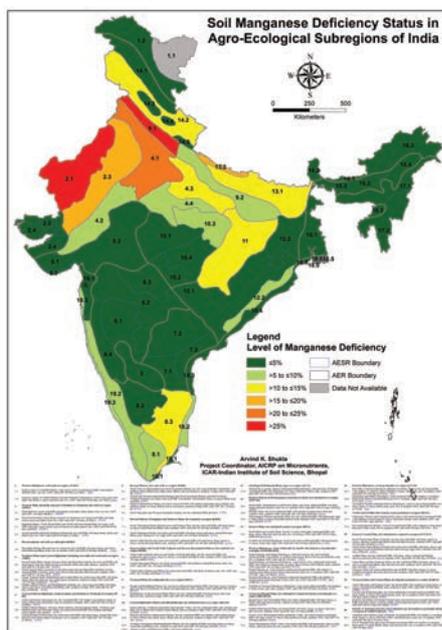
Map 2.3.2e Manganese deficiency status in soils of AESR of India
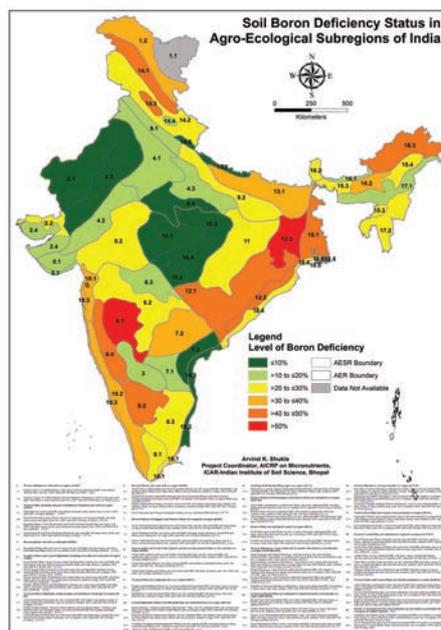
Map 2.3.2f Boron deficiency status in soils of AESR of India

These digitized maps of micronutrients status will be highly useful in understanding the nature and extent of micronutrient problems besides formulating strategies to alleviate their deficiency and help policy makers and industries to produce and distribute the right kind of micronutrient fertilizers in different agro ecological regions of India. These maps would also be helpful in mitigating the constrains of micronutrients deficiency to sustainable agricultural productivity through site specific variable rate application of micronutrients controlled by prescription

maps. Further the map would provide quantitative support for decision and policy making to improve agricultural approaches to balanced and prudent micronutrient management and precision agriculture.

2.3.3 Establishment of transition zones for micro- and secondary nutrients

Based on large number of field experiments and crop response to micronutrients and sulphur, a generalized transition zones were worked out for different nutrients across the soil types. The first 3 categories indicate level of deficiency (acute deficient, deficient, marginal deficient) and next 3 levels specify adequacy (marginally sufficient, adequate and high) (Table 2.3.3).

Table 2.3.3 Generalized transition zone of critical limit for available sulphur and micronutrients in soil

| Transition zone of critical limit | Available nutrients (mg kg^{-1}) | | | | | |
	CaCl$_2$-S	DTPA-Zn	DTPA-Fe	DTPA-Cu	DTPA-Mn	HWS-B
Acute deficient	≤ 7.5	≤ 0.3	≤2.5	≤ 0.2	≤ 1.0	≤ 0.2
Deficient	>7.5 to ≤15	>0.3 to ≤0.6	>2.5 to ≤4.5	>0.2 to ≤0.4	>1.0 to ≤3.0	>0.2 to ≤0.5
Marginally deficient	>15 to ≤ 22.5	>0.6 to ≤0.9	>4.5 to ≤6.5	>0.4 to ≤0.6	>3.0 to ≤5.0	>0.5 to ≤0.7
Marginally sufficient	>22.5 to ≤ 30	>0.9 to ≤1.2	>6.5 to ≤8.5	>0.6 to ≤0.8	>5.0 to ≤7.0	>0.7 to ≤0.9
Adequate	>30 to≤ 40	>1.2 to ≤1.8	>8.5 to ≤10.5	>0.8 to ≤1.0	>7.0 to ≤9.0	>0.9 to ≤1.10
High	> 40	> 1.8	> 10.5	> 1.0	> 9.0	> 1.10

2.3.4 Chemical speciation and suitability of extractants for Mn

Chemical speciation and suitability of soil extractants for assessing Mn availability to maize (*Zea mays* L.) in acidic soils of Uttarakhand was performed with twenty surface (0-15 cm) soil samples collected in bulk from the districts of Udham Singh Nagar, Nainital, Champawat of Uttarakhand Province and Moradabad district of Uttarakhand. These soils showed a wide variation in general properties. Soil texture varied from sandy clay loam to clay. Soil pH ranged from 4.57 to 6.83 while soil EC varied from 0.022 to 0.927 dSm^{-1}. Soil organic C content varied from 3.63 to 49.03 g kg^{-1} soil.

The results showed that in acid soils, the residual Mn fraction was the most dominant chemical fraction followed by amorphous Fe oxide- occluded; Mn oxide occluded; acid soluble; organically bound; crystalline Fe oxide-occluded; exchangeable; lead-displaceable and water-soluble fractions (Table 2.3.4). Water soluble- and exchangeable- Mn fractions showed a significant and positive correlation with the tissue Mn concentration and uptake by maize. However, the step-wise multiple regression analysis revealed that different chemical fraction of Mn in acidic soils influenced Mn availability in an intricate manner and water soluble-; exchangeable-; Pb displaceable-; acid soluble-; amorphous Fe oxide occluded-; crystalline Fe oxide occluded-; and residual fractions of Mn together accounted only 50.8% variation in Mn uptake by maize. The DTPA (pH 7.3), the most commonly used soil extractant for assessing the availability of

Table 2.3.4 Chemical fraction of Mn in acidic soil

| Range | Chemical fractions of Mn (mg kg^{-1} soil) | | | | | | | | |
	Water Soluble	Exchangeable	Lead displaceable	Acid Soluble	Mn-oxide occluded	Organically bound	Amorphous Fe-oxide	Crystalline Fe-oxide	Residual
Min.	0.01	<0.001	0.26	3.26	7.11	0.56	6.42	1.80	8.25
Max.	7.48	58.77	47.44	56.69	99.88	66.65	98.1	37.04	498.0
Mean	0.94	14.57	13.1	21.59	35.47	19.41	39.87	15.28	209.7

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micronutrient cations in soils, was not suitable to assess the availability of Mn in the acidic soils. Amongst the soil extractants, AB-DTPA (pH 7.6) and DTPA (pH 5.3) appeared to be the most promising soil extractants to assess the availability of Mn in the acidic soils as these solutions extracted Mn mainly from water soluble Mn fraction of soil which strongly influenced the tissue concentration and uptake of Mn by maize plants.

Amongst the different extractants used for assessing the Mn availability in soil, the DTPA and AB-DTPA extractants showed 1:1 relationship while Mehlich 3 and Ion exchangeable resin extractable Mn were poorly related with the DTPA extractable Mn. The 89% contribution of Mn extractable through $MgCl_2$ matched with DTPA-extractable Mn, while Modified Olsen's and 0.005M $CaCl_2$ extractable Mn had also shown 63 and 56% similarity with DTPA-extractable Mn (Fig. 2.3.4a).
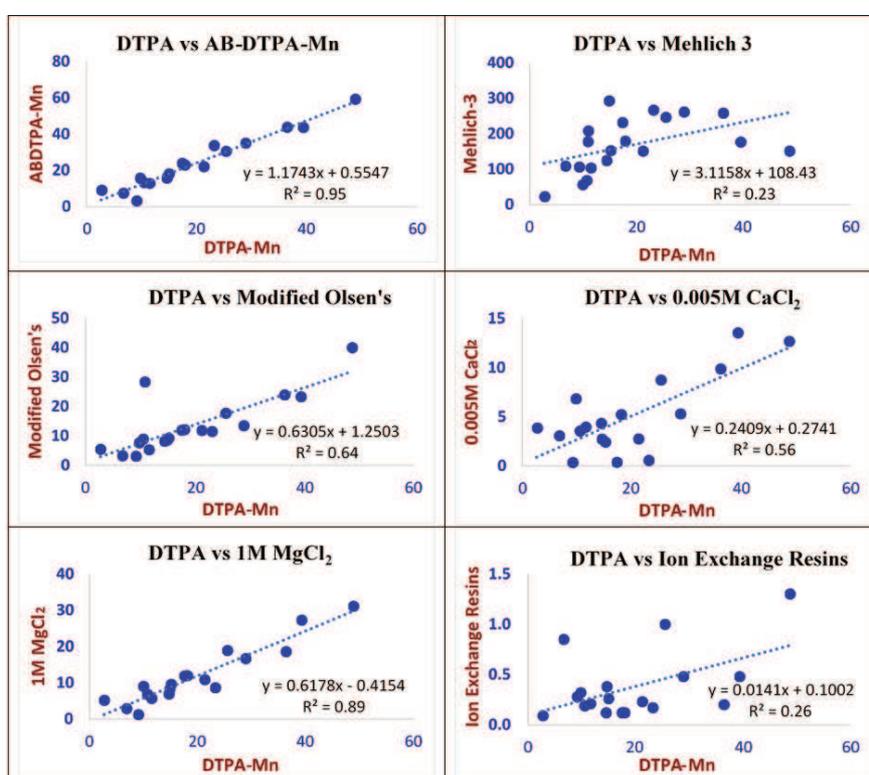
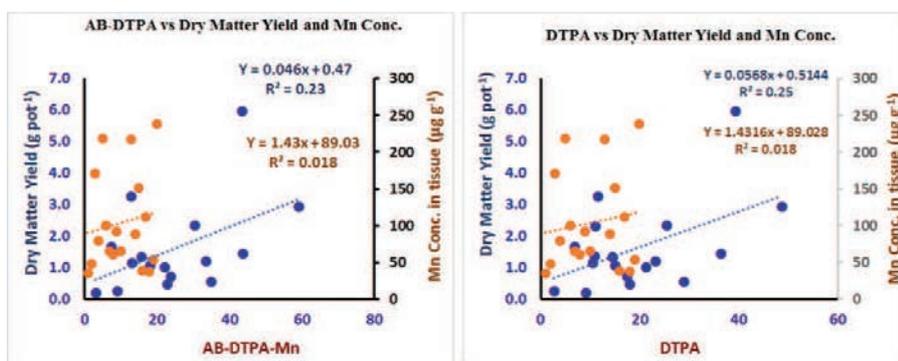**Fig. 2.3.4a Relationship of DTPA extractable Mn with various extractants**

Fig. 2.3.4b Relationship of DTPA and AB-DTPA extractable- Mn with dry matter yield and Mn concentration in maize grain grown in soils of Uttarakhand

Interestingly, the extractant which are highly correlated with each other did not show a relationship with dry matter yield and Mn conc. The other extractant except 0.005 M $CaCl_2(R^2=0.05)$ also not shown any relationship with dry matter and Mn Concentration in maize plants (Fig. 2.3.4b).

2.3.5 Foliar supplementation of Zn and Fe in apple

In order to standardise the dose of foliar supplementation of Zn and Fe in apple, an experiment was conducted on farmer's apple orchard (*cv*. Royal Delicious) at Garsa valley of Kullu (Himachal Pradesh). Foliar application of Zn and Fe at four levels (0.0, 0.5, 1.0 and 2.0% $ZnSO_4$/ $FeSO_4$) were applied at three stages such as petal fall, fruit development and one month prior to harvest of the apple. Results presented in Table 2.3.5a indicated that increase in spray concentration of Zn from 0.5 to 2.0% significantly increased the apple fruit yield in comparison to control and the maximum yield (173.0 kg tree^{-1}) was recorded at 2.0% foliar application. Similarly, significantly highest fruit yield of apple (201.5 kg tree^{-1}) was observed with 2.0% foliar application of $FeSO_4$.

Table 2.3.5a Effect of Zn and Fe on apple fruit yield (kg tree^{-1})

Treatment	Apple Fruit Yield	Treatment	Apple Fruit Yield
No Zn	102.0	No Fe	106.2
0.5% $ZnSO_4$	130.5	0.5% $FeSO_4$	154.3
1.0% $ZnSO_4$	161.8	1.0% $FeSO_4$	172.8
2.0% $ZnSO_4$	173.0	2.0% $FeSO_4$	201.5
CD (P=0.05)	**12.6**	**CD (P=0.05)**	**12.5**

The Zn concentration of apple leaves and fruits significantly increased following external application of Zn with advancement of crop stage and maximum leaf and fruit Zn content was recorded at 2.0% foliar spray of Zn from its initial Zn content of 19.7 mg kg^{-1} (Table 2.3.5b). However, no Zn supplementation showed marked decrease in leaf and fruit Zn content over the time. Similar results were also observed in case of foliar application of Fe at different growth stages of apple as Fe concentration of apple leaf and fruit significantly increased with advancement of crop stage and maximum Fe content in leaf and fruit was recorded at 2.0% foliar application of Fe.

Table 2.3.5b Effect of different levels of foliar spray of Zn and Fe on their concentration fruit and leaf (mg kg^{-1})

Treatment	Petal fall Leaf	Fruit Development Fruit	Leaf	One month prior to Harvest Fruit	Leaf
Zn content (mg kg^{-1})					
No Zn	19.7	37.9	16.4	47.4	14.3
0.5% $ZnSO_4$	27.0	42.2	30.8	93.8	75.8
1.0% $ZnSO_4$	28.8	44.0	33.2	139.9	121.9
2.0% $ZnSO_4$	31.6	47.0	36.4	170.0	151.9
CD 5% (P=0.05)	**6.2**	**6.6**	**5.6**	**9.8**	**8.9**
Fe content (mg kg^{-1})					
No Fe	163.1	196.7	154.2	245.8	152.2
0.5% $FeSO_4$	194.2	219.1	203.8	487.0	393.5
1.0% $FeSO_4$	206.9	228.2	217.0	726.2	632.6
2.0% $FeSO_4$	227.1	242.9	240.4	882.3	788.7
CD (P=0.05)	**47.1**	**34.2**	**27.2**	**50.9**	**48.7**

2.3.6 Amelioration of boron deficiency in groundnut

In an experiment in groundnut Anantapur district of the Telangana state, pod and kernel yield as influenced by different B treatments ranged from 635 to 841 kg ha^{-1} and 445 to 606 kg ha^{-1} with a mean of 759 and 547 kg ha^{-1}, respectively was observed. Soil application of 0.5 kg B + 1 foliar spray of B gave maximum response of 10.79% percent in kernel yield. Boron content in the kernels ranged from 26.58 to 42.24 mg kg^{-1} with a mean of 35.63 mg kg^{-1}. Highest boron content of 42.24 mg kg^{-1} was recorded in the treatment that received 1.00 kg B ha^{-1} through soil application of borax (Table 2.3.6).

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2015-2024

Table 2.3.6 Effect of boron application on groundnut yield and its content in kernel

Treatments	Yield (kg ha^{-1})			B content in kernel
	Pod	kernel	Haulm	
Control	635	445	750	26.58
0.25 kg B through Borax	822	608	928	33.74
0.25 kg B+1 FS* of B	655	465	759	34.12
0.50 kg B through Borax	749	554	837	35.46
0.50 kg B+1 FS* of B	841	606	921	36.93
0.75 kg B through Borax	743	535	852	41.33
0.75 kg B+1 FS* of B	780	562	902	42.13
1.00 kg B through Borax	781	570	913	42.24
Only one FS* of B	814	594	934	30.56
Two FS of B at 30 and 60 DAS	774	534	894	33.23
Mean	**759**	**547**	**869**	**35.63**

* foliar spray before flowering

2.3.7 Delineation and mapping of heavy metals in soil series of Haryana

In a pursuit to delineate the background levels of heavy metals, the soil samples collected from the selected benchmark sites of the Haryana were analyzed for soluble heavy metals concentration. Overall, the soils of the state are neutral to alkaline, mostly non-saline, low to high organic carbon status, low to high calcareousness. The analysis results revealed that the content of major heavy metals *viz.*, Pb, Cd, Ni, Co and Cr varied from 0.02-6.00, 0.01-1.92, 0.01-1.66, 0.02-2.00, 0.07-0.28 mg kg^{-1} in soils of different states of Haryana. However, these potentially toxic metals were found below their respective phytotoxicity levels (Pb: 10.0, Cd/Ni/Co/Cr: 2.0 mg kg^{-1}). The district level maps showing the spatial distribution of these heavy metals in soil series of Haryana have been prepared (Map 2.3.7).
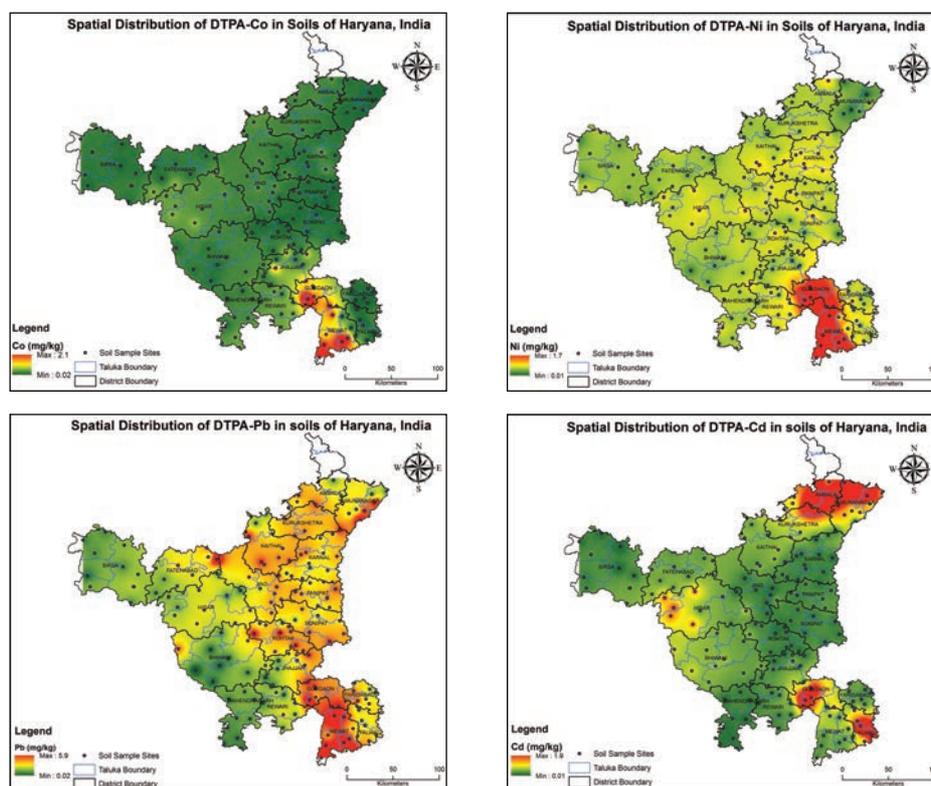
Map 2.3.7 Background levels of heavy metals (a. Pb, b. Cd, c. Co, and d. Ni) in selected soil series of Haryana

Theme II. Conservation Agriculture, Carbon Sequestration and Climate Change

2.4. Conservation Agriculture and Climate Change

2.4.1 Development and refinement of component technologies of conservation agriculture (CA) and quantifying impact of CA practices on soil and environment.

Conservation agricultural (CA) systems are gaining increased attention worldwide as a way to reduce the water footprint of crops by improving soil water infiltration, increasing soil water retention and reducing runoff and contamination of surface and ground water. It permits management of soils for sustainable agricultural production without excessively disturbing the soils, while protecting it from the processes of soil degradation like erosion, compaction, aggregate breakdown, loss of organic matter, leaching of nutrients. In CA the organic materials added were decomposed slowly, and larger portion of it is incorporated into the surface layer, thus reduces the liberation rate of carbon into the atmosphere. This could have profound consequences in our fight against the emission of greenhouse gas into the atmosphere from agricultural operations and thus would help to forestall the calamitous impacts of global warming. The CA system constitutes a major departure from the past ways of doing things. A whole range of agricultural practices, right from sowing to harvest, management of crop residues, weed, nutrient and water, need to be fine-tuned and evaluated for different agro eco-regions. Adoption of CA is very low in the rainfed central Indian plateau regions. Suitable conservation agricultural practices, tillage, cropping system/crop rotation, water, nutrient and weed management practices needs to be evaluated and fine-tuned for this region. It is also required to evaluate the long- and short-term impact of CA on soil properties, greenhouse gas emission to atmosphere and their potential implications for crop productivity and sustainability. The platform project in this institute was undertaken to accomplish the following objectives:

- To identify best tillage, water and nutrient management practice under CA
- To quantify changes in soil quality parameters, nutrient dynamics, carbon sequestration and greenhouse gas (GHG) emissions under conservation agriculture
- Budgeting nutrient, water and energy use under CA

2.4.1.1 Demonstration of Best-Bet Conservation Agriculture Practices on Farmers' Fields

To popularize the conservation agricultural technologies for Vertisols, already developed CA practices were demonstrated through participatory field trials during the year (2016-17) in four villages situated nearby Bhopal namely Khamkheda, Rasla Khedi, Kanera and Momanpur (Plate 2.4.1.1). Demonstrations were carried out in 18 farmers field with two predominant cropping systems being practiced in this region *viz*., soybean-wheat and soybean-chickpea. In each farmer's field four modules of tillage systems namely, Farmer's Practice, Improved conventional practice, reduced tillage and no tillage were demonstrated on a plot area minimum of 1000 m^2 each for a tillage module. All the technical expertise and inputs were provided to the farmers and crops were grown under the supervision of the project team. Crop performance, growth parameters and yield attributes were recorded for all the crops. In no tillage and reduced tillage treatments chemical weed were control was followed and crops were sown through *Kamboj* happy seeder. Among the four tillage modules tested performance crops in no tillage was found to be relatively better compared to the other tillage practices. Crop growth, yield and yield attributes recorded for soybean, wheat and chickpea crops averaged over 18 farmer's field trails are presented in tables below (Table 2.4.1.1a).

Table 2.4.1.1a Crop growth and yield parameters of soybean under different tillage practices (2016)

Treatment	Plant height at harvest (cm)	Branches /plant	Pods /plant	Grains/pod	Seed yield (q/ha)	Straw yield (q/ha)
No tillage	30.06	5.43	15.9	2.7	15.95	26.90
Reduced tillage	29.66	5.27	15.0	2.6	15.23	26.58
Improved conventional tillage	29.26	5.06	14.8	2.6	14.63	26.08
Farmer's practice	28.33	4.83	14.4	2.6	13.06	25.99
CD	NS	NS	NS	NS	1.02	NS

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Seed yield of soybean *cv*. JS 9560 in no- and reduced tillage was significantly higher compared to that of farmers practice. The seed yield was the highest in no tillage system. Plant height, no. of branches per plant, pods/plant, grains/pod and straw in no tillage was relatively higher than the other tillage treatments though the difference was not significant.

During *rabi* season wheat *cv*. GW-322 and chickpea *cv*. JG-130 were grown under four tillage systems following standard package of practices. Crop growth and yield parameters of wheat and chickpea are presented in Table 2.4.1.1b and 2.4.1.1c. Grain yield of wheat varied between 48.34 and 44.97 q ha^{-1} and in chickpea it varied between 17.37 and 16.14 q ha^{-1}. Both the conservation tillage treatments i.e. no tillage and reduced tillage maintained yield level on par with the yield level of the conventional tillage practices for both the *rabi* season crops. Crop performance as evident from plant height and yield parameters were slightly better in conservation tillage compared to the farmers' practice. Farmer perception about this new package of practices are quite positive and they are ready to continue the CA practices in their field.

Table 2.4.1.1b Crop growth and yield parameters of wheat under different tillage practices (2016-17)

Treatment	Plant height at harvest (cm)	Ear length (cm)	No. of tillers/ m row length	Grain yield (q/ha)	Straw yield (q/ha)
No tillage	79.3	10.15	77.2	48.34	71.07
Reduced tillage	79.4	10.15	77.0	47.44	71.37
Improved conventional tillage	78.1	9.92	75.5	47.30	71.30
Farmer's practice	76.4	9.82	74.5	44.97	70.95
CD	NS	NS	NS	NS	NS

Table 2.4.1.1c. Crop growth and yield parameters of chickpea under different tillage practices (2016-17)

Treatment	Plant Height at harvest (cm)	No. of Branches /plant	Seed/ Pod	Seed yield (q/ha)	Straw yield (q/ha)
No tillage	46.0	8.5	1.13	17.37	24.42
Reduced tillage	45.8	8.5	1.11	17.35	24.43
Improved conventional tillage	45.7	8.5	1.11	17.28	24.56
Farmer's practice	43.6	8.3	1.06	16.14	24.37
CD	NS	NS	NS	NS	NS

Plate 2.4.1.1 Soybean grown under conservation agricultural practice in the farmer's field (2016)

2.4.1.2 Fine-tuning of conservation agricultural practices for Vertisols of central India

Two on-station field experiments with five tillage treatments, namely, T1: Conventional tillage (No residues and manual weed control), T2: Reduced tillage (RT)-1 (sowing with residues + 1 duck foot, weed control (WC) with herbicides), T3: RT-2 (Strip tillage - sowing with strip till- drill with residues, WC with herbicides), T4: RT-3 (Strip tillage - sowing with strip till- drill with residues, Hand weeding) and T5: No-tillage with three nutrient doses namely N1:75% of the recommended dose of fertilizer (RDF), N2:100% RDF, N3: Soil test based recommendation on soybean-wheat and maize-chickpea cropping systems following split plot design with three replications were initiated during *kharif* 2015 at the experimental farm of ICAR-IISS, Bhopal to identify and evaluate potential cropping systems and conservation tillage practices best suited for the Vertisols of central India. The field experiments were conducted for two crop cycles during 2015-16 and 2016-17. Periodic observation on soil moisture, temperature and penetration resistance and biometric observation were recorded during the crop seasons. Soil organic carbon content and available nutrients in the surface soil were also determined after two crop cycles.

2.4.1.3 Soil penetration resistance

Soil penetration resistance (SPR) was recorded 7 days after sowing of *rabi* crops when the field was near field capacity moisture content. The SPR at 0-10 cm soil depth was lower in conventional tillage treatment compared to conservation tillage practices (reduced tillage, strip tillage and no-tillage). However, beyond 10 cm soil depth differences in SPR between the tillage treatments was not conspicuous (Fig. 2.4.1.3). This was due to the loosening of the surface soil through more intensive primary tillage operations in conventional tillage compared to the other tillage treatments.
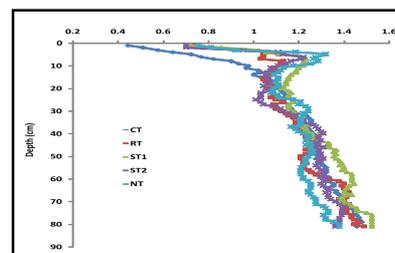
Fig. 2.4.1.3 Soil penetration resistance one week after sowing of maize

2.4.1.4 Soil organic carbon and available major nutrients

Soil samples from the surface 0-15cm depth were collected after the first crop cycle, to estimate soil organic carbon and available major nutrients (N, P, K). During the short period (one year) of experimentation, SOC content was not influenced by tillage practices or nutrient levels. Similar results were also observed for available phosphorus and potassium. However, tillage system effect on available nitrogen was significant (Table 2.4.1.4). Available nitrogen content was the highest in CT compared to the other tillage treatments and it was the lowest in Strip tillage with hand weeding treatment. Among the nutrient management treatments, the available nitrogen, phosphorus and potassium concentration was significantly higher in 100% N and STCR treatments as compared to that of 75% N treatment. However, definite results about the treatment effect on soil nutrient concentration are expected after 4-6 years of continuous implementation of tillage and nutrient application coupled with sufficient residue retention in soil.

Table 2.4.1.4 SOC and available nutrient after harvest of *kharif* crop

Treatment details	OC (%)	Avail. N (kg/ha)	Avail. P (kg/ha)	Avail. K (kg/ha)
Tillage				
T1 (CT)	0.52	200.3	19.9	441.0
T2 (RT)	0.51	190.6	20.6	450.0
T3 (ST+chemical weeding.)	0.54	196.8	19.1	444.5
T4 (ST+hand weeding)	0.54	180.5	19.9	440.3
T5 (NT)	0.55	188.1	18.5	446.1
SEM	0.006	1.6	1.03	5.15
CD(5)%	NS	5.36	NS	NS
Nutrient Levels				
N1(75%)	0.53	184.8	17.0	439.3
N2(100%)	0.52	191.0	20.1	446.3
N3(STCR)	0.54	198.0	21.7	447.3
SEM	0.005	1.3	0.64	2.3
CD(5)%	NS	4.04	1.89	6.91
Interaction (Tillage x Nutrient levels)	0.53			
SEM	0.011	3.06	1.43	5.24
CD(5)%	NS	NS	NS	NS

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2015-2024

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2.4.1.5 Crop yield and system productivity

Crop yield as influenced by different tillage and nutrient management systems under soybean-wheat and maize-chickpea cropping system are given in Fig.2.4.1.5a to 2.4.1.5g. In the *kharif* season soybean yield ranged between 14-18 q ha^{-1} (Fig. 2.4.1.5c) while maize yield ranged between 27-39 q ha^{-1} (Fig. 2.4.1.5d). Relatively lower yield of maize across different treatments was mainly due continual rainfall throughout crop growing period. Yield of wheat varied between 36-46 q ha^{-1} among different treatments (Fig.2.4.1.5e) while chickpea yield varied between 20-25 q/ha (Fig.2.4.1.5f). Tillage treatments did not show any significant effect on yields of both the *kharif* and *rabi* season crops in 2016-17. Higher nitrogen application such as N100 and N application based on STCR recorded higher grain yield under soybean-wheat and maize-chickpea systems, regardless of tillage practices.
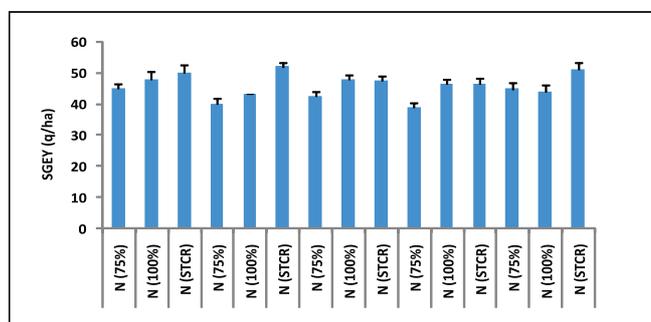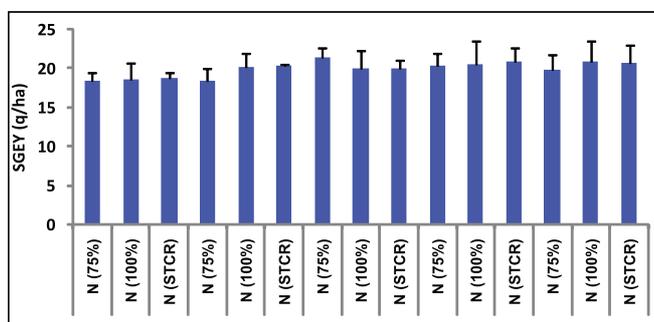
Fig.2.4.1.5a   Total system productivity expressed as SGEY (q ha^{-1}) under soybean-wheat cropping system

Fig.2.4.1.5b   Total system productivity expressed as SGEY, (q ha^{-1}) under maize-chickpea cropping system
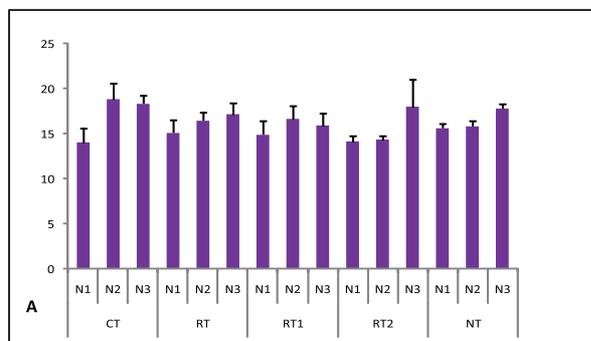
Fig.2.4.1.5c Effect of different tillage and nutrient doses on soybean yield (A) soybean yield under different tillage and nutrient levels (B) soybean yield under different tillage averaged over nutrient doses
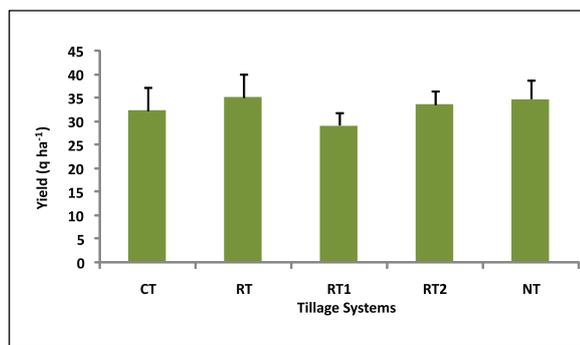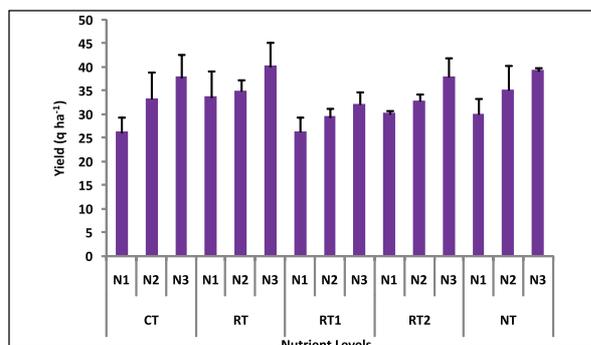
Fig.2.4.1.5d Effect of different tillage and nutrient doses on maize yield (A) maize yield under different tillage and nutrient levels (B) maize yield under different tillage systems averaged over nutrient doses

Annual Report
2016-17
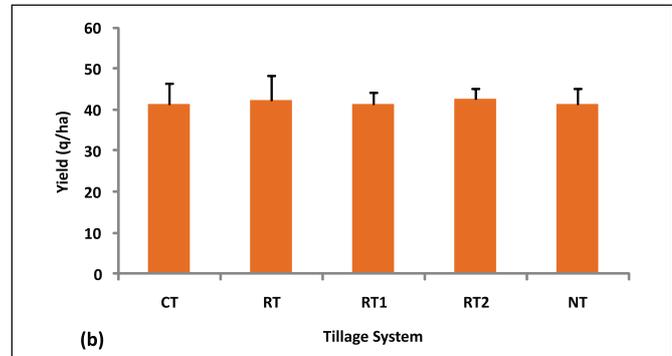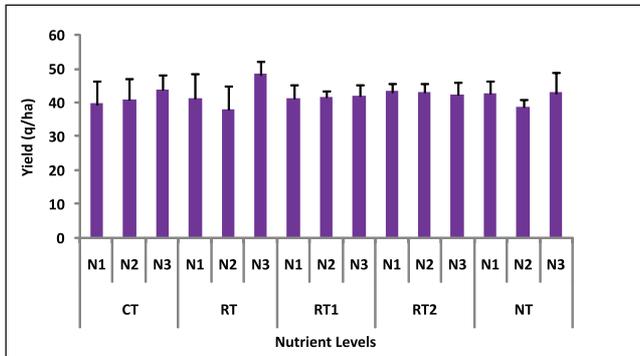
Fig.2.4.1.5e Effect of different tillage and nutrient doses on wheat yield (A) wheat yield under different tillage and nutrient levels (B) wheat yield under different tillage averaged over nutrient doses
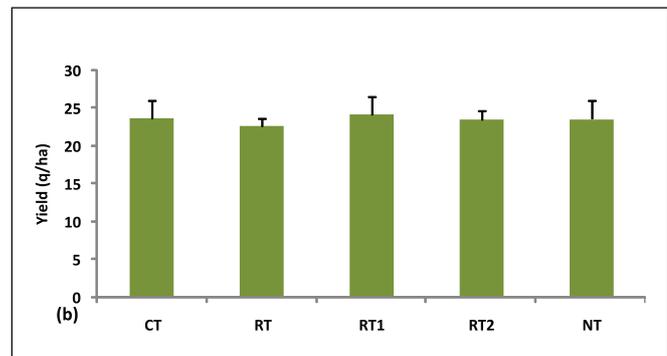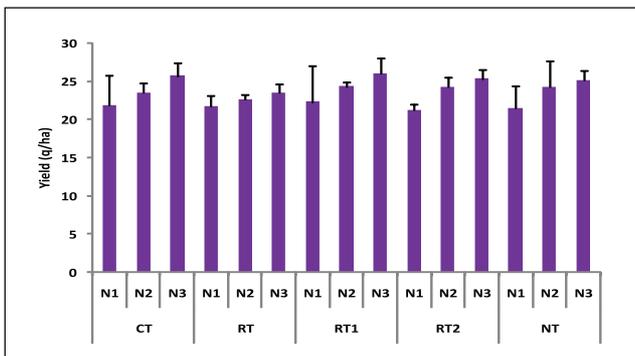
Fig. 2.4.1.5f Effect of different tillage and nutrient doses on chickpea yield (a) chickpea yield under different tillage and nutrient levels, (b) chickpea yield under different tillage system averaged over nutrient doses

2.4.1.6 Long-term effect of conservation tillage and residue retention on crop productivity

A long-term experiment was initiated during *kharif* 2010 at the experimental farm of the ICAR-IISS, Bhopal with two tillage treatments namely conventional tillage (CT) with residue removed and reduced tillage (RT) with residue retained as main plot and six cropping systems namely i) Soybean- Fallow, ii) Maize- Chickpea, iii) Soybean- Fallow R (R: rotated with maize-chickpea), iv) Soybean + Pigeon pea (2:1), v) Soybean+ Cotton (2:1) and vi) Soybean– Wheat as sub-plots. The crop yields during 2016-17 were recorded and presented in terms of soybean grain equivalent yield (SGEY, q ha^{-1}) (Fig. 2.4.1.6). Yield data indicated that tillage did not have significant effect on soybean grain equivalent yield after completion of seven crop cycles. However, irrespective of tillage, maize-chickpea cropping system recorded significantly higher yield followed by soybean +pigeon pea (2:1) and soybean+ cotton (2:1) cropping systems. The interactive effect of tillage x cropping system on SGEY was non- significant. Lower SGEY under soybean based cropping system was due to lower yield of soybean during the *kharif* season.
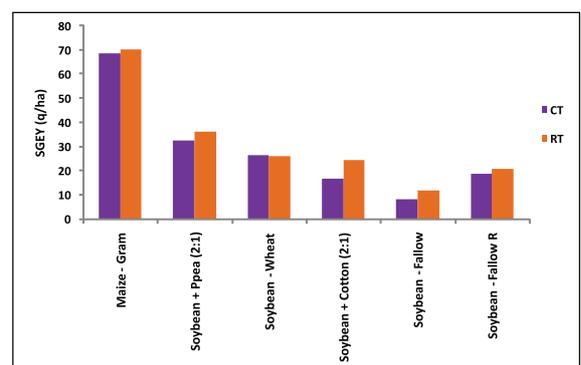
Fig.2.4.1.6 Total system productivity under different tillage and cropping systems

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2.4.1.7 Effect of conservation tillage and cropping systems on soil aggregation, aggregate associated carbon and carbon pools in Vertisol

To evaluate the effect of tillage practices and cropping systems on soil aggregation, mean weight diameter (MWD) and % water stable aggregate (WSA) of soil samples collected from 0-5, 5-15, 15-30 and 30-45 cm depths were determined. The MWD decreased with increasing soil depth with little variations across different tillage practices. At the top layer (0-5 cm), both the tillage and cropping system had a significant effect (P <0.05) on MWD, whereas at lower depths, only tillage had a significant effect (P <0.05) on MWD. Similarly, at 0-5 cm soil layer NT (70.74%) and RT (70.09%) registered significantly higher % water stable aggregates (WSA) (P <0.05) than CT (59.50%). Tillage practices had a significant effect (P <0.05) on the concentration of aggregate associated-C in large macro-aggregate (LM) at 0-5cm and 5-15cm soil layers. Higher concentration of aggregate associated-C was recorded in the NT and RT at a depth of 0-5 cm than in CT. Similar to tillage effect, cropping systems had a significant effect (P <0.05) on aggregate associated-C only in the surface layer (0-5cm). It was observed that after completion of 4th crop cycle, the organic carbon (%) fractions followed the order Non labile >Very labile >Less labile >Labile for 0-5cm and 5-15cm depth. Carbon pool data followed a similar trend in lower depths (15-30 and 30-45cm). It is concluded that conservation tillage practices in combination with crop residue retention and cropping system has positive impact on the aggregate stability, aggregate associate–C, and different carbon pools in Vertisols of Central India.

2.4.1.8 Conservation tillage and retention of crop residue on nutrient status in Vertisols

Short-term effect (< 5 year) of conservation agriculture (CA) practices on the nutrient status especially major nutrients namely N, P and K and micro-nutrients namely Fe, Mn, Zn, and Cu in a Vertisol of Central India was evaluated through a field experiment consisting of two main tillage treatments namely, conventional tillage (CT) and reduced tillage (RT) and six different cropping systems. It was observed that soil pH was not affected (p > 0.05) either by tillage or cropping system or their interactions. RT coupled with crop residue retention increased soil organic carbon (SOC) compared to CT only of the surface 0-5 cm soil depth. In surface soil layer (0-5 cm), the major- and micro-nutrients concentrations were higher compared to sub-surface layers, regardless of tillage and cropping systems (Fig. 2.4.1.8). Available N concentration in RT was significantly higher than that in CT in 0-5, 5-15 and 15-30 cm soil layers. However, available P and K concentrations were significantly higher in RT than CT only in the top 5 cm soil depth. At lower soil depth the
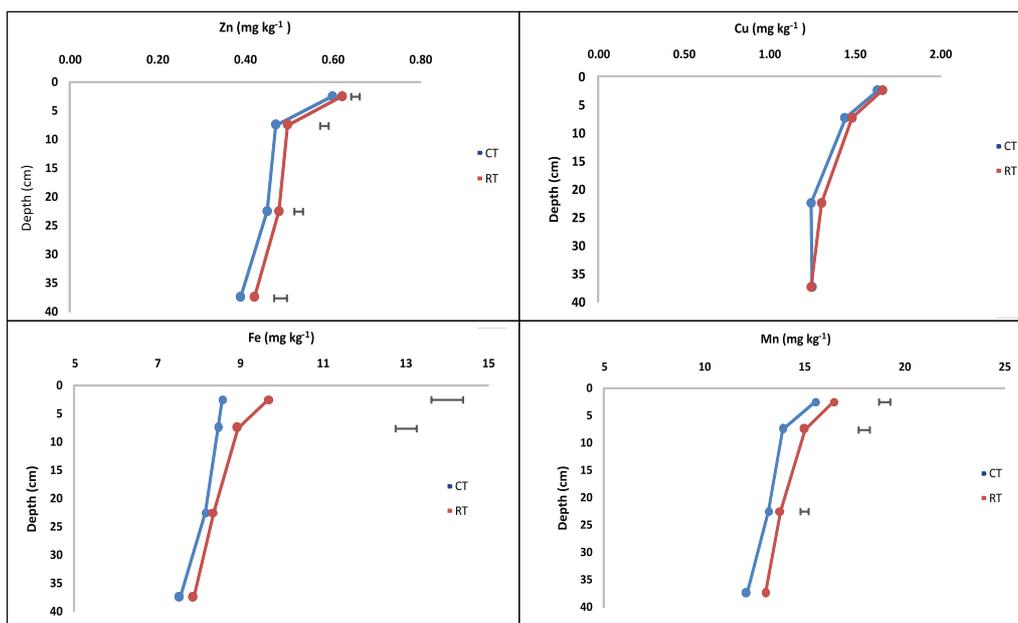
Fig. 2.4.1.8 Effect of tillage on (a) DTPA extractable Fe, (b) Mn, (c) Zn and (d) Cu after four crop cycles; Horizontal bar indicate significantly different at LSD at p≤ 0.05.

difference was not significant. The DTPA extractable - Cu, Fe, Mn and Zn showed decreasing trends with increasing depth (Fig. 2.4.1.8). Except Cu, other micronutrients concentration was significantly affected ($p< 0.05$) by tillage after four crop cycles, whereas cropping system had significant effect on DTPA-Cu and -Fe only. DTPA extractable Zn concentration was significantly higher in RT compared to CT up to 45 cm soil depth while for DTPA extractable Mn and Fe, the differences were significant only up to a soil depth of 30 cm and 15 cm, respectively. The SOC showed a significantly positive ($p < 0.001$) relationship while soil pH showed a significantly negative relationship with N, P, K, and DTPA extractable Fe, Mn, Zn and Cu. Conservation tillage practices and cropping system showed a positive effect on macro-and micronutrient distribution and availability in soils after four crop cycles.

2.4.1.9 Evaluation of different weed management options under conservation tillage

On-station field experiments were conducted during the year (2016-17) to study the weed flora population and identify suitable weed management options in soybean-wheat, soybean-chickpea, maize-chickpea and maize-mustard cropping systems under no tillage system in Vertisols. The major weed flora recorded in the experimental field during *kharif* season of 2016 were *Echinocloa crusgalii, Dichanthium annulatum, Panicum javanicum and Brecharia recemosa* among grassy weeds and *Digera arvensis, Alternenthera sessalis, Celosia argentea, Euphorbia hirta, Euphorbia microphylla,* and *Acalypha indica* among broad leaved weeds. Among various herbicidal weed management treatments tested in soybean, pre-emergence application of Pendimethalin @ 1000 g ai/ha followed by post emergence application of Imazethapyr @ 100 g ai/ha at 30 DAS recorded lowest weed biomass and maximum seed yield which was at par with two hand weeding and pre-emergence application of Pendimethalin @1000 g ai/ha followed by post emergence Propaquizafop @100 g ai/ha + Chlorimuron ethyl @9 g ai/ha at 30 DAS. All the weed management treatments were significantly superior as compared to weedy check in case of both the soybean based cropping systems. Thus, it may be concluded that weeds in soybean can effectively be managed using a combination of pre and post emergence herbicides under no till condition in conservation agriculture. It has also been observed that after three years of experimentation some of the weeds like *Acalypha indica*, *Alternenthera sessalis* and *Dichanthium annulatum* are able to escape or regenerate after herbicide application in some of the treatments which needs to be taken care to avoid the chances of emergence of herbicide resistant weeds (Plate 2.4.1.9a).

Plate 2.4.1.9a Performance of soybean in herbicide treated plots under zero tillage

In maize based cropping system pre-emergence application of Pendimethalin @ 750 g ai/ha followed by post-emergence application of Atrazine @ 1000 g ai/ha at 30 DAS has recorded lowest weed biomass among the herbicide treated plots and grain yield which was even superior to hand weeding treatment however the differences among them could not attain the level of significance. Thus it may be concluded that weeds in maize can effectively be managed using a combination of pre and post emergence herbicides under no till condition in conservation agriculture. After three years of experimentation it was observed that some of the weeds like *Echinocloa crusgalii, Alternenthera sessalis* and *Dichanthium annulatum* are able to escape or regenerate after herbicide application in some of the treatments (Plate 2.4.1.9b).

International
Decade of Soils
2015-2024

Plate 2.4.1.9b Performance of maize in herbicide treated plots under zero tillage

During the *rabi* season, the major weed flora recorded in the experimental field were *Dichanthium annulatum, Anagallis arvensis, Convolvulus arvensis, Euphorbia geniculata, Parthenium hysterophorus, Alternanthera sessilis* and *Launaea procumbens*. In chickpea, the lowest weed biomass and maximum grain yield were recorded in two hand weeding treatment and it was at par with pre-emergence application of Oxyfluorfen @ 200 g ai/ha under both the soybean and maize based cropping systems.

2.4.1.10 Brown manuring in direct seeded rice (DSR)

Weeds are major concern for success of DSR under no till. Cover crops, good rice crop establishment, planting rice in a clean field can substantially reduce weed menace. "Brown Manuring" practice involved seeding of rice and *Sesbania* crops together and knocking down of *Sesbania* crop using herbicides during 25-30 days after sowing. A field trial was conducted at the experimental farm to raise direct seeded rice under no tillage. Observation showed that for practicing no till based DSR in fields infested with perennial weeds like *Cynodon, Cyperus rotundus etc.* pre emergence application of a combination of Glyphosate @ 2.5 -3 L/ha with Pendimethalin @ 1 kg ai/ha within 48 hrs of sowing in 600 L water per hectare was found effective for controlling weeds. Pendimethalin was effective against a number of monocot weeds and some of the dicot weeds by not allowing them to germinate, while Glyphosate takes care of the weeds already present in the field by its non-selective mode of action. Best results are obtained when weeds are in active growth stages and soil is moist. Later *Sesbania* was allowed to remain as surface mulch. Grain yield of rice cv. kranti was 40 q/ha.

2.4.2 Climate change effects on soil organic carbon change and crop productivity under balanced fertilization in central Indian Vertisols

The climate change effects on soil organic carbon in 106 grids (0.5 degree X 0.5 degree) of central Indian Vertisols under balanced fertilization was studied in soybean-wheat cropping systems. Four climate change scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) and two time slices (2050 and 2080) were considered for the study (Table 2.4.2). The simulation study was carried out using a calibrated and validated APSIM model from a long-term experiment (43 years) for grain yield and soil organic C (Fig. 2.4.2a). The study revealed that under balanced fertilization in soybean and wheat, the change in soil organic C in the soil depth of 0-15 cm and 15-30 cm was non-significant in all the RCPs and time slices under study. This results agreed well with the change in grain yield of soybean and wheat crops. In the year 2050, the soybean yield will increase by 12, 17, 15 and 22% in RCPs 2.6, 4.5, 6.0 and 8.5, respectively (Fig. 2.4.2b). Similar trend in results of soybean grain yield was also observed in the year 2080 in all RCPs under investigation. The yield of soybean was increased by 14, 19, 25 and 37% over base in RCPs 2.6, 4.5, 6.0 and 8.5, respectively. This result showed that soybean yield will increase more in year 2080 than the year 2050. The increased temperature effects in all RCPs and time slices are masked by increase CO_2 concentration, the positive effects of which are reflected in increase soybean yield and minor change in wheat yield. However, the wheat yield increased 2 to 4% over base in the year 2050 whereas it would be 1 to 6% increase in the year 2080 (Fig 2.4.2b).
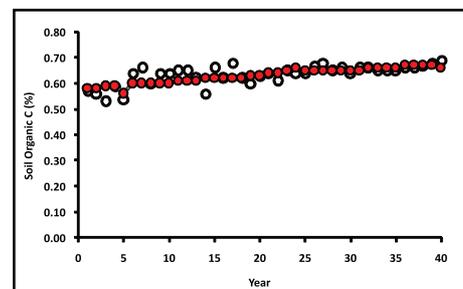
Fig. 2.4.2a Validation of APSIM model for SOC at 0-15 cm soil layer from LTFE

Table 2.4.2 Features of representative concentration pathways (RCPs) used in the study

RCPs	Base	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Time slice			2050		
CO_2 concentration (ppm)	354	441	495	494	572
Change in temperature (º C)		1.4	1.9	1.7	2.6
Change in precipitation (%)		8.2	5.8	3.7	8.8
Time slice			2080		
CO_2 concentration (ppm)	354	429	532	612	799
Change in temperature (º C)		1.5	2.5	2.7	4.4
Change in precipitation (%)		4.7	9.1	12.3	16.0
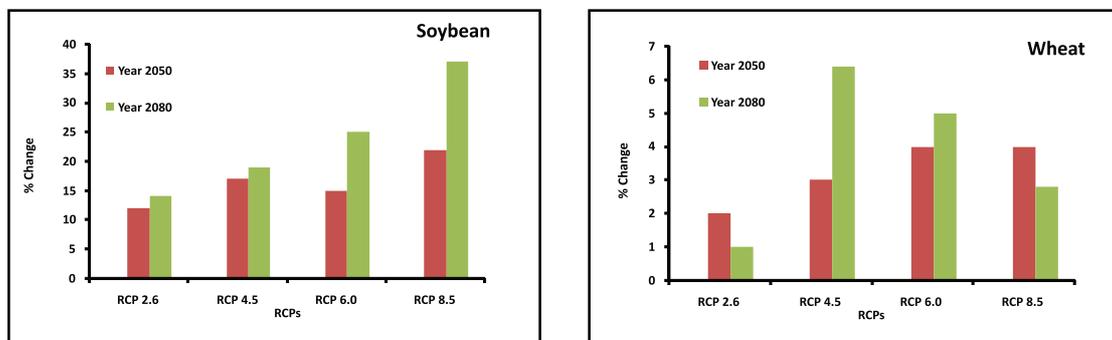
Fig. 2.4.2b Change in yield (%) under the RCPs scenarios of the soybean and wheat in central Indian Vertisols

2.4.3 Nitrogen and water stress effects on wheat crop using hyperspectral remote sensing

Increased water scarcity due to changing climate, population growth, and economic development is a major threat to the agricultural sustainability around the world. Remote sensing of crop canopy temperature could be a useful tool for assessing crop water status and for recommending the more precise water management. However, there is potential that nutrient deficiencies could compound the interpretation of water status from leaf temperature by altering leaf colour and radiation balance. Therefore, a study was undertaken to characterize nitrogen and water status in wheat crop under varying irrigation and nitrogen regimes. Three irrigation, *viz.* I1 (IW/CPE=1), I2 (IW/CPE=0.7), I3 (IW/CPE=0.5) and four nitrogen levels, *viz.* NI (0% RFD), N2 (50% RFD), N3 (100% RFD) and N4 (150% RFD) were considered for this study. Relative nitrogen status in plant canopy was determined using Nitrogen Sufficiency Index (NSI). NSI was calculated by dividing the individual leaf chlorophyll concentration measurements for each treatment on a given measurement day by the chlorophyll concentration measurement of non-stressed reference crop on the same day. Several indices have been developed to relate canopy temperature to crop water status. In this study, we have used two such indices,*viz.* Degrees above Non-Stressed (DANS) (eq 1), and Degrees Above Canopy Threshold (DACT) (eq 2) to evaluate crop water stress during the crop growing period.

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Decade of Soils
2015-2024
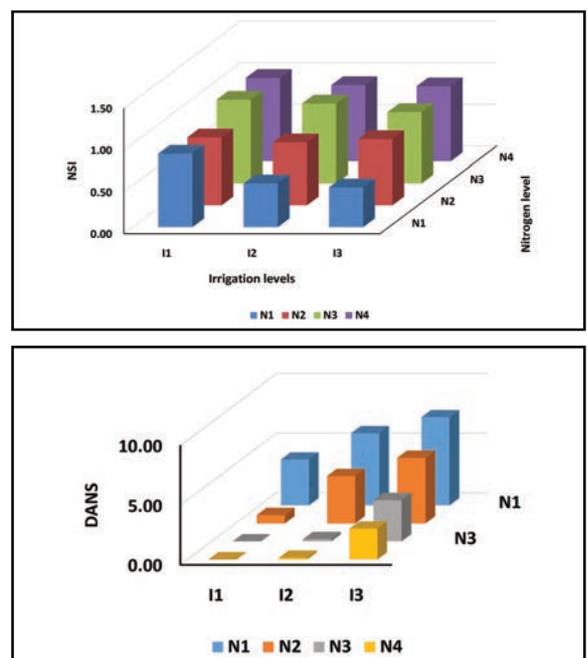
$$\text{DANS} = T_m - T_{NS} \qquad (1)$$
$$\text{DACT} = T_M - T_C \qquad (2)$$

Where, T_M is the measured crop canopy temperature, T_{NS} is the is the non-stressed reference crop canopy temperature, and T_C is the reference canopy threshold temperature. NSI was observed to be higher and lower in N_4 and N_1 nitrogen treatments, respectively across irrigation levels and the highest values of NSI was observed in treatment combination I_1*N_4 (Fig. 2.4.3a). Higher value of NSI indicated that the plants under non-stressed condition in that particular treatment. Further, DANS and DACT values were observed to be higher under the I_3 irrigation level and maximum value was observed in treatment combination I_3*N_1 (Fig. 2.4.3b & 2.4.3c). In general, the well-watered treatment had lower value of DANS and DACT and vice-versa.
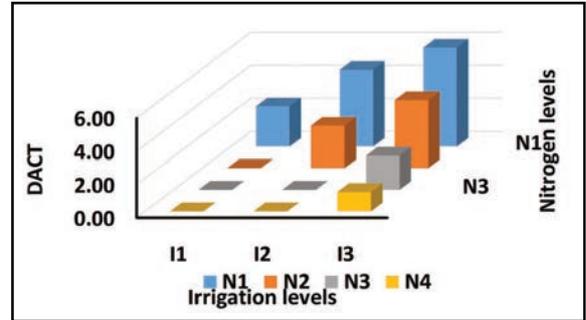
Fig. 2.4.3a (a) NSI, (b) DANS and (c) DACT index under varying water and nitrogen levels

2.4.4 Assessment of soil properties using mid-infrared spectroscopy

The consistent monitoring of soil of a region largely depends on the development and implementation of *in-situ*, low-cost, and fast analytical methods. In this direction, mid-infrared (MIR) spectroscopy combined with statistical techniques such as partial lest squares, random forest regression can provide a platform for rapid assessment of various soil properties. In this study, 127 soil samples were collected from various location of Alfisols region of India with the aim of evaluating the ability of mid-infrared spectroscopy to estimate soil properties such as pH, organic carbon (OC), available nitrogen (Av-N), available phosphorous (Av-P), available potassium (Av-K) and EC. The scatter gram depicting range, frequency, mean and medium of soil properties are presented in (Fig. 2.4.4). The range of soil pH, OC, Av-N, Av-P, Av-K and EC were varied from 3.74 -8.33, 0.19- 1.32%, 56-508 kg ha^{-1}, 1-189 kg ha^{-1}, 57-945 kg ha^{-1} and 0-0.8 ds m^{-1}, respectively in collected soil samples.
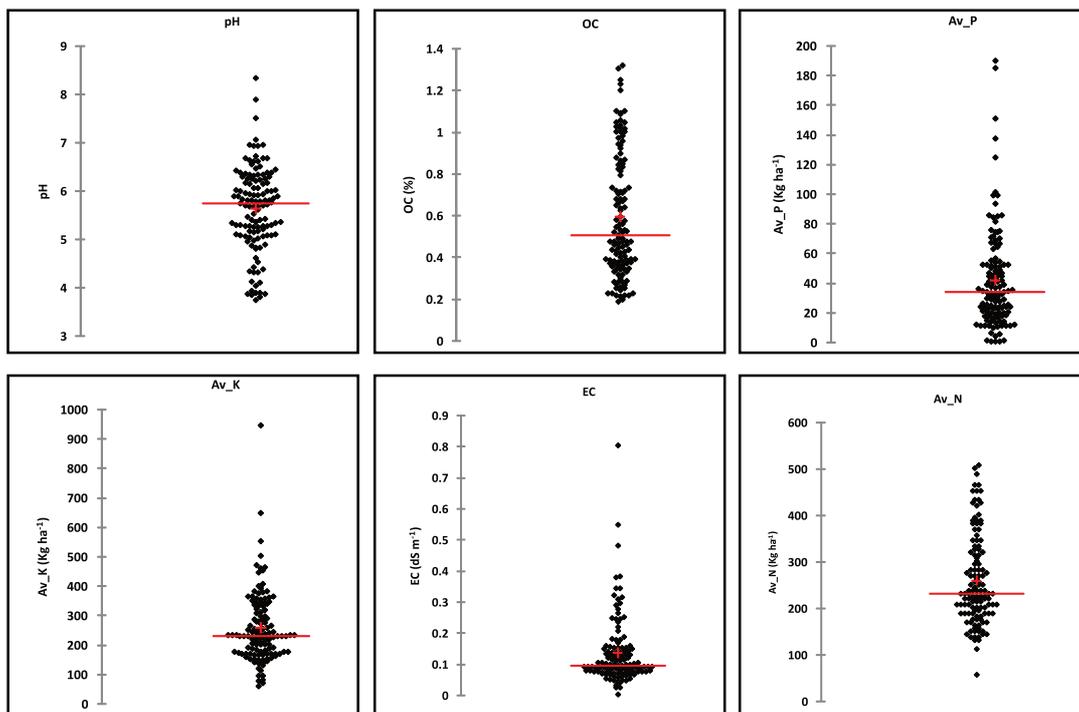
Fig.2.4.4 Scatter gram of various soil properties of collected soil samples of the Alfisols region of India

The soil wet chemistry data showed some outliers value, therefore Dixon test was performed to identify and discard those outliers from further analysis. This step will help to develop more accurate prediction model. Dixon test of outliers was identified 11, 6, 10, 11, 9, and 6 outliers for pH, OC, Av-N, Av-P, Av-K and EC, respectively. Thereafter, generated soil MIR spectra undergone to Kennard-Stone (KS) algorithm for selection of calibration and validation subset. The KS algorithm has been regarded as an effective method for the selection of a representative subset in the soil spectroscopy. In this study, 70% data used for model development and 30% of soil samples were used for the model validation. Before further analysis, the MIR soil spectra was transformed to first derivative using Savitzky-Golay method. Then random forest regression method was used to develop prediction model for the various soil properties. The R^2 of the developed model for the soil properties is varied from 0.91 to 0.96, whereas R^2 of the model validation was ranged from 0.40 to 0.60.

2.4.5 Relationship among soil aggregation, aggregate fractions and other soil properties after eight years of conservation tillage experiment in soybean-wheat cropping system

Correlation matrix was worked out between the soil properties, total organic carbon and different aggregate fractions (micro-aggregates, 53-250μm and macro aggregate, 250-2000 μm) after eight years of conservation tillage experiment in soybean-wheat cropping system (Table 2.4.5). The results indicate that soil aggregate stability was positively correlated with soil organic carbon, labile carbon, soil available N, P and K at 0-5 and 5-15 cm soil and negatively correlated with soil biological properties. Whereas micro-aggregates were positively correlated with soil biological properties like water soluble carbon, fluorescein diacetate, dehydrogenase activity, acid hydrolysable carbon, soil microbial biomass carbon and soil available P and K. The data strongly suggest that stability of macro-aggregates is more controlled by management practices like tillage and fertilizer management. Soil microorganisms and microbial enzymes play an important role in the stability of microaggaregates.

Table 2.4.5 Correlation matrix of different soil properties under CA

	WSA	micro	TOC	Labile C	N	P	K	WSC	FDA	DHA	AHC	SMBC
WSA	1.00											
micro	-0.64	1.00										
TOC	0.70	-0.39	1.00									
Labile-C	0.46	-0.22	0.68	1.00								
N	0.38	-0.24	0.50	0.01	1.00							
P	0.15	0.02	0.21	0.63	-0.11	1.00						
K	0.45	0.00	0.24	0.08	0.17	-0.14	1.00					
WSC	-0.25	0.11	-0.45	-0.14	-0.38	-0.10	0.07	1.00				
FDA	-0.19	0.08	-0.57	-0.18	-0.32	0.13	-0.06	0.80	1.00			
DHA	-0.28	0.12	-0.50	-0.13	-0.39	0.02	-0.04	0.86	0.85	1.00		
AHC	-0.31	0.14	-0.54	-0.22	-0.35	-0.08	0.03	0.94	0.85	0.90	1.00	
SMBC	0.11	-0.13	-0.16	0.14	-0.19	0.34	-0.27	-0.02	0.39	0.17	0.03	1.00

Note: WSA: water stable aggregate; micro: micro-aggregates; TOC: total organic carbon; N: available nitrogen; P: available phosphorus; K: available K; WSC: water soluble carbon; FDA: fluorescein diacetate; DHA: dehydrogenase activity; AHC: Acid hydrolysable carbon; SMBC: soil microbial biomass carbon

Theme -III: Microbial Diversity and Genomics

2.5 Microbial Diversity and Soil Genomics

2.5.1 Nitrifying bacteria and archaea can modulate redox metabolism

Both nitrification and redox metabolism occur in soil. However, very little is known on the linkage between nitrification and soil microbiological processes driving redox metabolism. Experiments were laid out to evaluate

nitrification potential of soil under repeated nitrification and to determine its effect on redox metabolism. Temporal variation in NO_3 concentration undergoing repeated nitrification cycle is presented in (Fig. 2.5.1). There was steady increase in nitrification rate over repeated nitrification cycle. Potential nitrification rate (PNR) increased with nitrification cycle. PNR (mM NO_3 produced g^{-1} soil d^{-1}) was 0.495 in 1st nitrification cycle which subsequently increased to 0.658 and 0.515 in 2nd and 3rd cycle respectively. Declined nitrification over repeated cycle was probably due to product (NO_3) specific inhibition to nitrifying microbial groups.

2.5.2 Role of nitrification on redox metabolism

Nitrified soil samples representing nitrification cycle 1, 2 and 3 were incubated under flooded moisture regime to induce redox metabolic processes. Terminal electron accepting processes (TEAPs) proceeded

Fig.2.5.1 Temporal variation in NO_3 concentration under repeated nitrification cycles

with NO_3 reduction, Fe^{3+} reduction, SO_4 reduction and methanogenesis. However, the TEAPs were inhibited ($p<0.01$) in soils which had undergone nitrification. Soil samples with equivalent amount of NO_3 (KNO_3) were incubated along with urea-N nitrified samples. Temporal variation in the concentration of electron acceptors during redox metabolism is given in Fig.2.5.2a. Reduction of electron acceptors was inhibited over repeated nitrification cycle. Inhibition of Fe^{3+} and SO_4 reduction was due to reduced denitrification rate.

Fig. 2.5.2a Redox metabolism in soil in response to repeated nitrification cycle

To understand the differential response of nitrifying and non-nitrifying soil towards TEAPs, soil samples were further analyzed by Raman spectra (Fig. 2.5.2b). Spectra differentiated nitrified soil from that of the non-nitrified soil, with a higher intensity of reflectance in the range of 1400-1500 nm. These wave numbers represented aliphatic compounds.

2.5.3 Real time PCR quantification of amoA gene of nitrifying bacteria and archaea

Population of nitrifying bacteria and archaea were estimated by real time PCR targeting amoA gene (Table 2.5.3). The abundance of bacterial amoA gene copies doubled over nitrification cycle. Interestingly, the archaeal amoA gene copies increased by about 6 times over nitrification cycle. High abundance of nitrifying archaea over nitrification cycle allowed archaeal multiplication during nitrification. Probably, soil with high N content favored archaeal nitrification than bacterial nitrification.
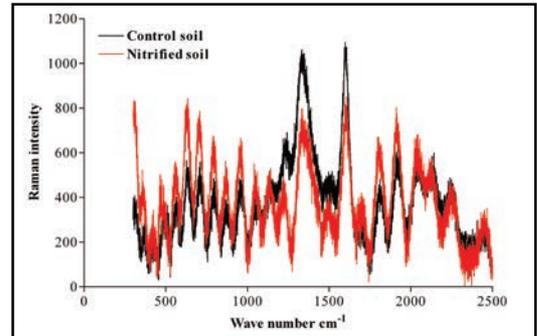
Fig.2.5.2b Raman spectra of soil samples after repeated nitrification cycle

Table 2.5.3 Population of nitrifying bacteria and archaea in soil (Vertisol) under repeated nitrification cycle.

Nitrification cycle	Urea N (mM)	KNO_3 (mM)	Bacterial amoA gene copies (10^4 g^{-1} soil)	Archaeal amoA gene copies (10^4 g^{-1} soil)
1	10	0	158.33±18.23	30±6.24
	0	10	73.67±9.61	6.33±1.53
2	20	0	233±22.07	111.67±11.02
	0	20	92±4	10.33±1.53
3	30	0	294.67±6.54	178.67±19.73
	0	30	116.33±10.21	14.67±2.52

Study concluded that nitrification in soil may inhibit redox metabolism by producing aliphatic compounds. However, the metabolism of these products and their significance in nitrogen cycle need to be better understood to explore nitrification for enhancing nitrogen use efficiency.

2.5.4 Greenhouse gas emission from composting systems and characterization of GHG regulating microbes

Methane consumption at different depth profile of a compost pit was evaluated. The electron donors were Fe^{3+}, NO_3 and SO_4 stimulated methane consumption. However, SO_4 stimulated CH_4 oxidation but inhibited at the later stage resulting in partial CH_4consumption (Fig. 2.5.4a & b). CH_4 oxidation k varied from 0.1 to 0.15 µg g^{-1} compost d^{-1}. There is inverse relation between abundance of pmoA gene and CH_4 consumption. The quality of PCR amplification products were determined by melting curve analysis with temperature increase of 0.3°C per cycle. Standard for the pmoA gene was evaluated using dilutions (10^3-10^8 genes) of PCR products of *Methylomonas sp*.
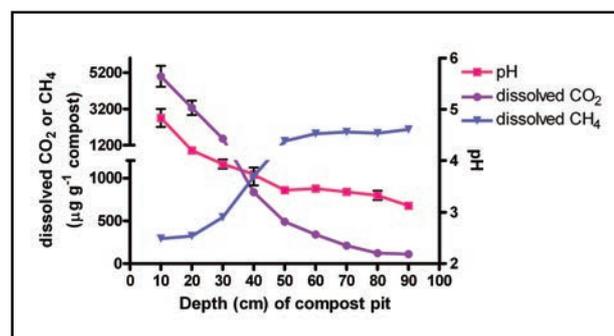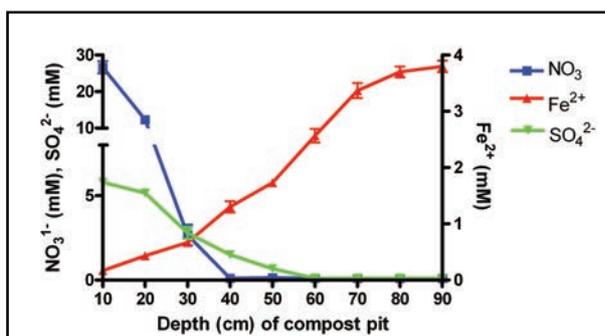
Fig. 2.5.4a CH_4 oxidation at oxic and anoxic zone of compost pit

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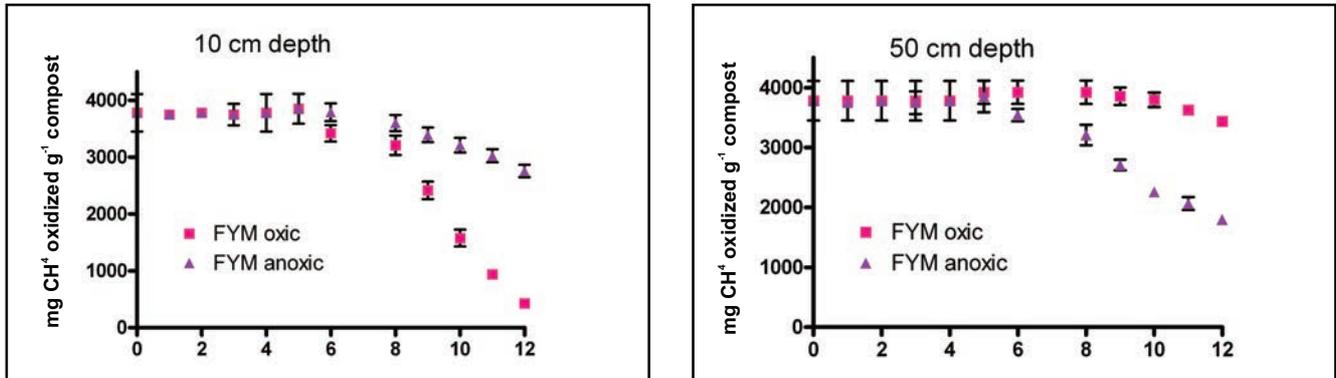
Fig. 2.5.4b CH$_4$ oxidation coupled to reduction of electron acceptors

2.5.5 Biodegradation of pesticides under changing climate and metagenomics profiling of functional microbes

2.5.5.1 Influence of climate change and biochar on the biodegradation of chloropyrifos and imidacloprid

An experiment was carried out to determine degradation of pesticide (imidacloprid, chloropyrifos) under the influence of climate factors and biochar (BC). The climate factors were soil moisture holding capacity (MHC) (60% MHC, 100% MHC), CO_2 concentration (400 ppm, 800 ppm), and temperature (25 ºC and 45 ºC). Soils were incubated in pre-sterilized serum vials. Biochar (pigeon pea biomass) was added at 10% w/w. Sterile distilled water was added to maintain 60% and 100% moisture holding capacity (MHC). Aqueous stock solution of imidacloprid and chloropyrifos were added to soil at 10 ppm final concentrations. CO_2 mixing ratios in the vial head spaces were maintained at ambient (400±20) and at 800±20 µmol mol^{-1} (ppm) CO_2 concentration. Vials were incubated at different temperatures in incubators. Concentration of imidacloprid at 0 and after 30 days of incubation in different soil samples are given in (Fig. 2.5.5.1).Result revealed that pesticide degradation was not complete even after 30 days. Climate factors influenced pesticide degradation. Both pesticides varied in their response to climate changing factors. In general, chloropyrifos degradation was low at 25ºC than 45ºC. Biochar stimulated pesticides degradation irrespective of treatments. Elevated CO_2 negatively impacted biodegradation process. Chloropyrifos concentration (µg g^{-1}) ranged from 3.11 to 8.05 at 25ºC. Similarly, at 45ºC its concentration ranged from 1.48 to 5.39 µg g^{-1}. Imidacloprid concentration ranged from 2.68 to 6.77 µg g^{-1} at 25ºC and 1.03 to 6.74 µg g^{-1} at 45ºC.
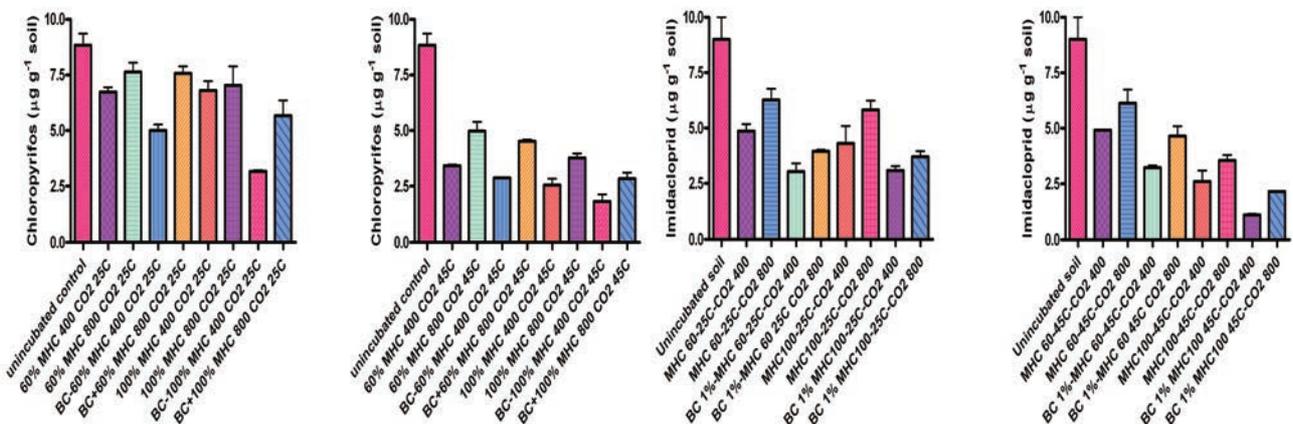
Fig. 2.5.5.1 Effect of climate change factors and biochar on degradation of chloropyrifos and imidacloprid.

2.5.5.2 Effect of imidacloprid and climate changing factors on N_2O production and microbial population

The experiment was carried out to understand the complex interactive effect of the insecticide imidacloprid and climate change on N_2O production and soil microbial population. N_2O production was estimated from the head space of the bottles after 15 days of incubation. Cumulative production of N_2O is presented in Table 2.5.5.2 N_2O production was significantly inhibited by imidacloprid amendment irrespective of treatments. The lowest N_2O production was from soils incubated at 100% MHC-10 ppm imidacloprid and 800 ppm CO_2. Highest N_2O production was observed from soils incubated at 60% MHC-400 ppm CO_2 and no imidacloprid. N_2O production was high at 60% MHC than 100% MHC. Elevated CO_2 inhibited N_2O production. Microbial population was enumerated after end of incubation. Heterotrophs population was the lowest in the treatments of 100% MHC 800 ppm CO_2 and 10 ppm imidacloprid and the highest in the treatment of 60% MHC 400 ppm CO_2 with no imidacloprid. Actinomycetes population was found high in soils treated with imidacloprid. Elevated CO_2 increased their population. Regression analysis indicated that N_2O production was positively correlated ($p < 0.01$) with heterotrophic bacterial population and negatively correlated with actinomycetes population ($p<0.05$) (Fig. 2.5.5.2).

Table 2.5.5.2 Interactive effect of imidacloprid and climate changing factors on N_2O production and microbial population. MHC-moisture holding capacity, SD-standard deviation

MHC (%)	CO_2 (ppm)	Imidacloprid (ppm)	N_2O (ng/g)	SD	Heterotrophs 10^6 CFU g^{-1}	SD	Actinomycetes 10^3 CFU g^{-1}	SD
60	400	0	30.11	2.74	107.33	3.06	45.00	5.57
		10	9.51	4.75	34.33	2.08	221.33	68.01
	800	0	23.77	4.75	63.33	8.33	51.00	9.54
		10	11.09	2.74	15.67	2.08	280.00	12.00
100	400	0	11.09	2.74	50.00	7.21	8.33	1.15
		10	6.34	2.74	12.67	2.08	21.67	3.51
	800	0	14.26	4.75	28.67	5.51	15.00	3.00
		10	6.23	2.74	9.33	2.52	31.33	3.06
60	400	0	57.04	9.51	160.00	10.00	25.33	2.08
		10	12.33	1.44	52.67	2.52	285.33	10.12
	800	0	38.61	9.81	94.00	8.00	48.33	2.52
		10	9.39	1.41	23.67	3.21	295.67	5.86
100	400	0	29.62	6.04	35.67	14.01	12.67	2.08
		10	12.33	1.44	7.33	0.58	39.00	5.57
	800	0	22.18	2.74	54.67	6.66	29.33	2.31
		10	9.51	4.75	3.00	1.00	53.00	2.00
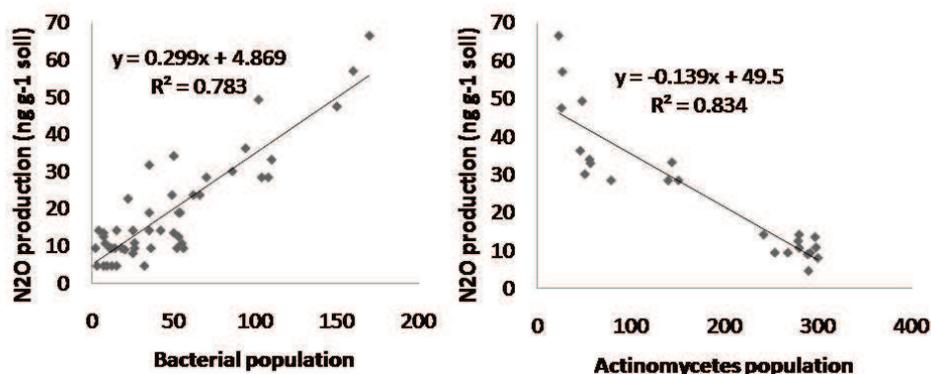
Fig. 2.5.5.2 Regression analysis of N_2O production and population of bacteria (left) and actinomycetes (right)

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2.5.6 Long-term effect of fertilizer and manure amendments on soil functional diversity and nutrient supplying capacity under different soil and cropping systems

The effect of long term continuous application of fertilizer and manure on soil functional diversity related to nutrient supply capacity was assessed. Three Long Term Fertilizer Experiment (LTFE) centres representing three dominating

(1) Barrackpore   (2) Parbhani
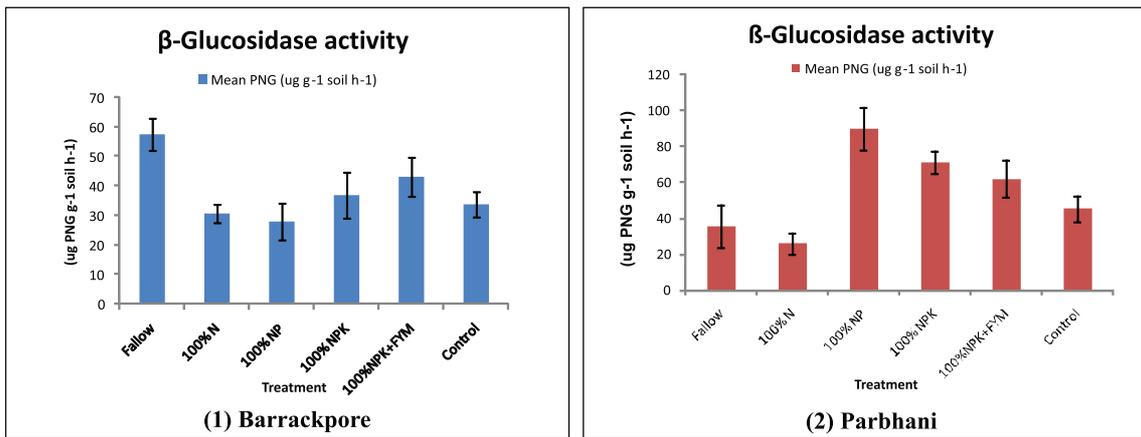
Fig. 2.5.6a β Glucosidase activity
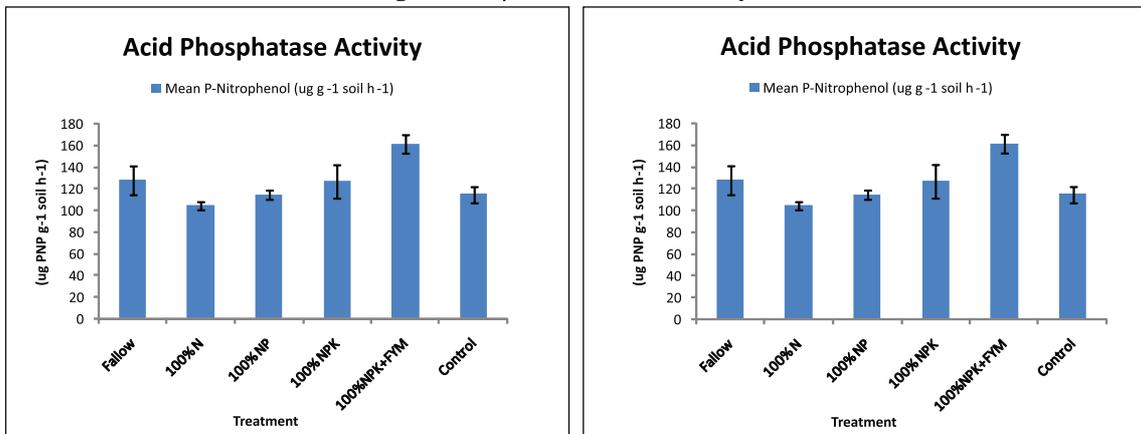
Fig. 2.5.6b Acid Phosphatase activity
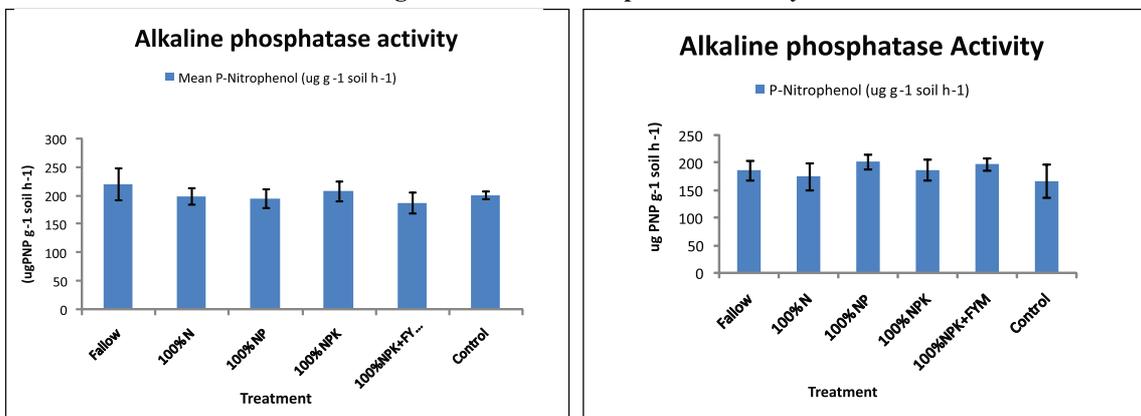
Fig. 2.5.6c Alkaline Phosphatase activity

soil orders of India, were chosen for this study such as ICAR-CRIJAF, Barrackpore (Inceptisol; Rice-Wheat-Jute, continuing for 46 years), CSKHPKV, Palampur, Himachal Pradesh (Alfisol; Maize-Wheat, continuing for 45 years) and MPKV, Parbhani, Maharashtra (Vertisol; Soybean-Safflower, continuing for 21 years). Targeted treatments are (1) Fallow; (2) Control; (3) 100% N; (4) 100% NP; (5) 100% NPK; (6) 100% NPK + FYM.

Soil samples were collected from LTFE Barrackpore and LTFE Parbhani centres and analyzed for initial pH, EC, soil organic carbon, available N, P, K. Moreover, β-glucosidase activity (Fig. 2.5.6a), acid phosphatase (Fig. 2.5.6b) and alkaline phosphatase (Fig. 2.5.6c) activity were also assessed in the collected soil samples.

2.5.7 Impact of TiO$_2$ nano particles (<50 nm) on different soil enzymes and microbial community

From the eco-toxicological point of view, it is very important to uncover the mechanisms of interactions between nano materials and plants, since plants are an important component of ecosystems, exhibiting close interactions with other living organisms as well as with inorganic components such as air, soil and water. Moreover, numerous applications are under way using nano materials for the development of novel plant growth stimulators, fertilization and plant protection. Soils are facing new environmental stressors, such as titanium dioxide nano particles (TiO$_2$-NPs). Titanium dioxide nano particles (TiO$_2$-NPs) are widely used in commercial products such as sunscreens and toothpastes, industrial products like paints, lacquers and paper, and in photo-catalytic processes such as water treatment. Consequently, TiO$_2$-NPs are indirectly discharged in agricultural soils through irrigation or sewage-sludge application and directly as nano fertilizers or nano pesticides and eventually affecting soil microbial communities. While these emerging pollutants are increasingly released into most ecosystems, including agricultural fields and their potential impacts on soil and its function remain to be investigated. Thus, response of the microbial community of an agricultural soil exposed over 30 days to TiO$_2$-NPs (0, 5, 10, 20, 40, 80, 100 mg kg^{-1} dry soil) was studied. After addition of different graded doses of TiO$_2$ (<50 nm) nano particles in 500 g soil (Vertisol, ICAR-IISS Research Farm), it was incubated for one month and different enzymatic studies such as (urease, dehydrogenase, alkaline and acidic phosphatase, ß-Glucosidase, FDA Hydrolysis) were carried out in laboratory. Experimental results (Table 2.5.7a to 2.5.7g) revealed that enzyme activity was aggravated up to 40 ppm and drastically   reduced at 100 ppm TiO$_2$ NP. PLFA analysis of the soil samples depicted that fungi (Signature of fatty acid) (18: 2 W 6, 9C), bacteria (18: 1 W, 9C) and actinomycetes (10 Methyl) all were affected and reduced in numbers with higher doses TiO$_2$ NP.

Table 2.5.7a   Effect of TiO$_2$ nano particle (<50 nm) and temperature on dehydrogenase activity of soil (µg TPF g^{-1} soil h^{-1})

Temperature Ti Dose (ppm)	25°C	40°C	Mean
0	1.00	1.24	1.12
5	1.11	1.30	1.20
10	1.40	1.59	1.50
20	1.52	1.67	1.59
40	1.35	1.38	1.36
80	0.98	1.09	1.03
100	0.75	0.79	0.77
Mean	1.15	1.29	
	Ti dose	Temperature	Ti dose X Temperature
SEm±	0.008	0.004	0.011
LSD (0.05)	0.022	0.012	0.031

Table 2.5.7c **Effect of TiO_2 nano particle (<50 nm) and temperature on alkaline phosphatase activity of soil (μg PNP g^{-1} soil h^{-1})**

Temperature / Ti Dose (ppm)	25°C	40°C	Mean
0	141.84	152.62	147.23
5	146.25	157.39	151.82
10	149.30	164.50	156.90
20	155.25	169.32	162.28
40	143.52	155.35	149.43
80	132.29	149.40	140.84
100	128.36	141.23	134.80
Mean	142.40	155.69	
	Ti dose	Temperature	Ti dose X Temperature
SEm±	1.07	0.571	1.51
LSD (0.05)	3.049	1.630	4.312

Table 2.5.7d **Effect of TiO_2 nano particle (<50 nm) and temperature on β-Glucosidase activity of soil (μg PNG g^{-1} soil h^{-1})**

Temperature / Ti Dose (ppm)	25°C	40°C	Mean
0	43.69	44.32	44.00
5	44.17	50.77	47.63
10	46.84	55.35	51.09
20	49.32	58.22	53.77
40	44.55	50.77	47.63
80	41.25	45.25	43.25
100	38.25	40.80	39.53
Mean	44.00	49.14	
	Ti dose	Temperature	Ti dose X Temperature
SEm±	0.365	0.195	0.516
LSD (0.05)	1.041	0.557	1.473

Table 2.5.7e **Effect of TiO_2 nano particle (<50 nm) and temperature on urease activity of soil (mg Urea g^{-1} soil h^{-1})**

Temperature / Ti Dose (ppm)	25°C	40°C	Mean
0	0.39	0.44	0.42
5	0.43	0.50	0.47
10	0.49	0.56	0.53
20	0.53	0.61	0.57
40	0.42	0.48	0.45
80	0.35	0.401	0.38
100	0.30	0.35	0.33
Mean	0.42	0.48	
	Ti dose	Temperature	Ti dose X Temperature
SEm±	0.003	0.002	0.004
LSD (0.05)	0.009	0.005	0.012

Table 2.5.7f **Effect of TiO₂ nano particle (<50 nm) and temperature on fluorescein diacetate hydrolysis of soil (µg fluorescein g⁻¹ soil h⁻¹)**

Temperature Ti Dose (ppm)	25°C	40°C	Mean
0	35.21	65.32	50.27
5	36.09	70.20	53.15
10	41.46	73.26	57.36
20	43.66	75.69	59.68
40	42.31	68.65	55.48
80	39.32	60.33	49.83
100	35.47	55.32	45.39
Mean	39.07	66.97	
	Ti dose	Temperature	Ti dose X Temperature
SEm±	0.351	0.188	0.496
LSD (0.05)	1.001	0.535	1.416

Table 2.5.7g **Effect of TiO₂ nano particle (<50 nm) and temperature on microbial biomass carbon of soil (µg g⁻¹ soil)**

Temperature Ti Dose (ppm)	25°C	40°C	Mean
0	480.23	500.32	490.28
5	491.35	510.35	500.85
10	502.36	526.35	514.36
20	520.36	540.12	530.24
40	483.65	504.35	494.00
80	475.26	491.23	483.24
100	465.35	478.25	471.80
Mean	488.37	507.28	
	Ti dose	Temperature	Ti dose X Temperature
SEm±	3.823	2.044	5.407
LSD (0.05)	10.912	5.833	15.431

2.5.8 Impact of copper oxide nano particles on growth of different bacterial species

An attempt was made to investigate the effect of CuO nano particles (NPs) (<50 nm) on the growth of different bacterial species. Gram positive bacteria *Bacillus subtilis* and gram negative bacteria *Escherichia coli* were cultured on nutrient agar plates and then tested against different concentration of normal copper ion from $CuSO_4.5H_2O$ and copper nano form from CuO (< 50 nm) (0, 2, 4, 6, 8, 10, 20, 40, 60, 80, and 100 mg/L) on nutrient agar plates prepared by using Nutrient Agar Media (Hi Media, India). The growth was determined by plate assay in which first of all dilution series of bacterial isolates were prepared and then from the fifth dilution culture was inoculated on nutrient agar plates of various copper concentration in both the forms through spread plate method and then incubated at 30°C for 24 h. The colonies grown were then counted. The CuO nano particles (NPs) were purchased from Sigma-Aldrich Company, St. Louis, MO, USA with a purity of 99.5 %, particle size of <50 nm and a surface area of 45 10 m²/g. The morphology of the CuO nano particles was examined using transmission electron microscopy (TEM, JEOL, 100 CX, Japan).The TEM image of the copper oxide NPs revealed at their spherical, truncated and uneven nature with an average size of approximately 50 20 nm. The TEM micrographs indicated that the copper oxide nano particles were mono dispersed with a narrow size distribution and near spherical morphology. Analysis of particles in TEM monograph indicated

hexagonal particles with the average size of 50 nm. In the tangential interaction of copper oxide NPs, the existence of a lateral force causes the aggregation of the NPs. The zeta potential of CuO nano particles was -1.91 mv. Antimicrobial action of copper in both ionic and nano particle form varied with each bacterial isolate. *Bacillus subtilis*, a gram positive bacteria having ability to form a tough endospore, allowing the organism to tolerate extreme environmental conditions, when grown against normal copper ion showed tolerance level at 20 mg Cu/kg while when grown against copper in nano particle form showed tolerance level at 10 mg Cu/kg. Gram negative bacteria*, Escherichia coli* showed tolerance level at 20 mg Cu /kg when grown against normal copper ion doses. However, when grown against copper in nano particle form showed tolerance level at 40 mg/kg. In this study, the copper oxide nano particles showed remark-able antibacterial activity against both Gram-positive (*B. subtilis*) and Gram-negative (*E. coli*) bacteria (Plate 2.5.8). Growth inhibition occurs already after one day metal treatment. The mode of action of copper ions was shown by its action on enzymes. Under laboratory conditions, copper have been shown to eliminate up to 99 % of germs in the shortest period of time. Copper ions affect bacteria in two sequential steps (a) direct interaction between the surface and the bacterial outer membrane (b) second is related to holes in the outer membrane, through which the cell loses vital nutrients and water, causing a general weakening of cells. It is strongly suspected that when a bacterium comes in contact to Cu surface, a short circuiting of current in cell membrane can occur. This weakens the membrane and creates hole. It is clear from the experimental results that CuO nano particles have shown greater antimicrobial activity against *B. subtilis.* The variation in the sensitivity or resistance to both Gram-positive and -negative bacteria populations could be due to the differences in the cell structure, physiology, metabolism, or degree of contact of organisms with nano particles. Greater sensitivity among Gram-positive bacteria such as *B. subtilis* to the CuO nano particles has been attributed to the greater abundance of amines and carboxyl groups on their cell surface and greater affinity of copper towards these groups.Alternatively, Gram-negative bacteria like *E. coli* have a special cell membrane structure which possesses an important ability to resist antimicrobial agents.Furthermore, other factors such as nano particle diffusion rates may also affect bacterial strain differently. Nevertheless, further studies are required to illustrate the mechanism properly.
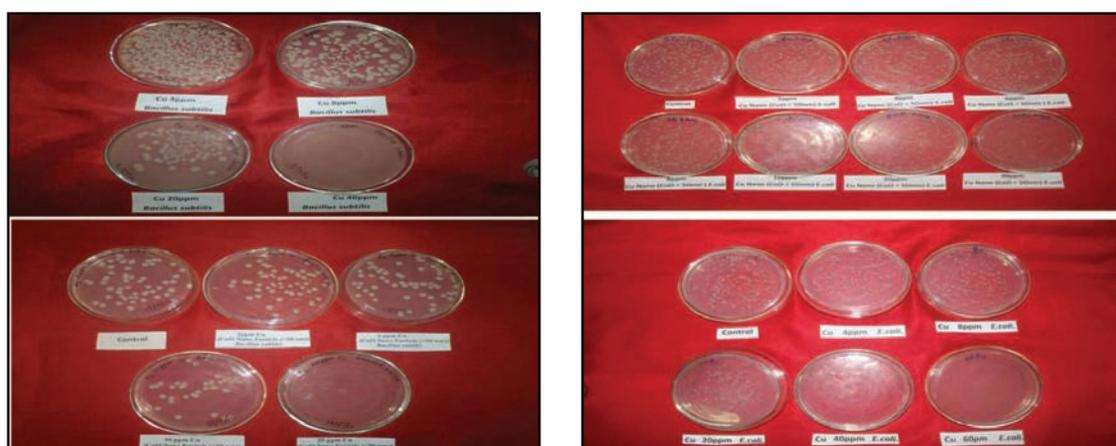
Plate 2.5.8 Effect of copper in both ionic and nano form on growth of *Bacillus subtilis and Escherichia coli*

2.6 AINP on SBB

2.6.1 Microbial Diversity for Biofertilizers

● Rhizobial diversity of 20 major legumes assessed from arid regions of Rajasthan and Haryana; acid soils of Jharkhand, 'Taal' lands of Bihar, and soils of Uttarakhand. Of more than 2000 strains, nearly 500 strains sequenced for 16S rRNA gene, nod and nif genes.

● Molecular diversity of nod+ rhizobial isolates of mungbean, mothbean and clusterbean evaluated from hyper-arid zone of Rajasthan. Three isolates nodulated all the three crops. Some isolates grew at 45^0C and with 40% polyethylene glycol. Rhizobia inoculation increased seed yield of clusterbean by 20%, and cowpea by 10% - (HAU, Hisar)

- A total of 397 rhizobial stains isolated from pigeon pea nodules grown in south Rajasthan (MPUAT, Udaipur). PGPR activities of the isolates were mostly ammonia production (50), IAA production (25), Phosphate solubilization (19) and siderophore production (21). Majority of Rhizobia could grow in 7-10% NaCl. Diversity of cry genes and gene copies in Bacillus thuringiensis evaluated.

- Diversity of *Rhizobium* associated with French bean at varying altitudes (500-4000 m above MSL) in the District of Udham Singh Nagar and Nainital (GBPUAT, Pantnagar) explored. Out of fifty rhizobial isolates 27 were slow growers.

- Seventy-three endophytic bacteria from different chickpea genotypes (BGD-72, Pusa-372, GNG-1581, Pusa-547, BG-112, Pusa-362, Pusa-1103 and BG-256) were isolated at IARI, New Delhi. These strains improved shoot dry weight by 30-50 % in controlled conditions.

- Rhizobia (116 strains) were characterized from acid soils of Jharkhand (BAU, Ranchi), nodulating pigeonpea, groundnut, black gram, soybean, cowpea, mung, pea, chickpea, french bean, broad bean, berseem and lentil. 16S rRNA analysis of 3 strains of pigeonpea done. Proteomic analysis of unique protein spots identified genes for acid-soil tolerance, chemo-taxis, virulence export/import of a wide variety of substrates and cellular metabolism.

- *Pseudomonas fluorescens* bio-control strains were evaluated against soil-borne fungal pathogens at DGR, Junagadh. Recommendation of application dose for different groundnut growing regions made during 2016-17.

- Out of ten non-symbiotic fungal endophytes isolated from rice rhizosphere grown under upland rice ecology of Jharkhand (CRURRS, Hazaribagh), three were found to be potentially useful to impart moisture stress tolerance to rice at vegetative stage. DNA sequence of the three selected fungal strains showed similarity to *Plageostoma euphorbiaceum*, *Aspergillus carneus* and *Hypocrea virens.*

- *Arthrobacter* isolates significantly improved grain yield of paddy (13%), maize (15%), soybean (10%), chickpea (11%) and wheat (17%) in Vertisol at JNKVV, Jabalpur, Madhya Pradesh, Consortia of Arthrobacter, Streptomyces and PGPR improved wheat yield by 24%.

- Inoculation of *Bacillus subtilis* (SIR1) to wheat and *Bacillus* spp. (B1N1 and DHK) to maize induced drought tolerance. *Bacillus subtilis* isolated fromsea-buckthorn enhanced growth of tomato seedlings. Inoculation of these PGPRs to apple, cauliflower, capsicum and pea increased yield by 35 %, 25%, 20 % and 28% respectively over recommended package in mid and high hills of YSPUHF, Solan, Himachal Pradesh. *Frankia* sp. isolated from *Casuarina equisetifolia* exhibited antagonistic activity against *Fusarium* sp. causative agent of damping-off in *Alnus* and *Casuarina.*

- Integration of biofertilizers with liming increased the yield of cereal-vegetable-pulse cropping system by 45% in acid soils of Odisha (OUAT, Bhubaneswar). This practice also raised the recovery of applied fertilizers: N, P, K and S up to 65 %, 37%, K 93 % and 30%, respectively.

- Arbuscular mycorrhizal fungi (AMF) population in rhizosphere of seven rice varieties grown under submerged conditions in Assam (AAU, Jorhat) ranged from 210-400 spores100g^{-1}soil.

2.6.2 Soil Genomics for Soil Health Assessment

- Diversity of bacteria in maize under different organic farming recommendation (farm yard manure, sheep manure, poultry manure, vermicompost, RDF) analyzed by DGGE (UAS, Dharwad). Microbial species richness found highest in FYM.

- In the long term fertilizer experiment in Alfisol (TNAU, Coimbatore), soil DNA and autoclaved citrate extractable protein evaluated as soil biological health parameters along with 7 other indices and found reliable.

- In organic nutrient management in hot chilli, continuous application of compost and enriched compost (EC) significantly increased the oxidizable soil organic pools (very labile, labile, less labile and non-labile) and total organic carbon over control (AAU, Jorhat). After five years of applying EC (@10 t/ha, a larger proportion (55%) of applied C was stabilized in the passive pool of TOC along with highest Carbon Pool Index (1.5) and Sustainable Yield Index of (0.93) of hot chilli.

2.6.3 Improvement of biofertilizer technology

- Microbial consortia developed for rapid composting at ANGRAU, Amaravathi. The consortia formulation

International
Decade of Soils
2015-2024

(Decompo A and Decompo B) enabled complete decomposition of maize straw in 50 days.

- Liquid biofertilizer (*Rhizobium* + PSB) along with 50% RDF increased pigeonpea yield by 24% over solid carrier biofertilizer at ANGRAU, Amaravathi. Over all, the application of biofertilizers saved 50% of chemical fertilizers along with 15% yield increase over 100% RDF. Liquid biofertilizers (*Rhizobium*+PSB) enhanced black gram grain yields by 33% compared to carrier based biofertilizer which enhanced yields by 23% over the control. Inoculation of KRB strain to sorghum compensated 25% of RDF with extra grain yield of 400 kg ha^{-1} during drought stress situations–

- Arbuscular mycorrhizae applied at 5kg per acre increased cotton yields and also glomalin content (8 mg^{-1} soil) in the rhizosphere soil at ANGRAU, Amaravathi.

- Suitable polymers for inoculants (*Azospirillum*, *Rhizobium*, Phosphobacteria), identified for soybean and maize at TNAU, Coimbatore. The initial population of 10^8/seed achieved for *Azospirillum* and Phosphobacteria for maize irrespective of the polymers. After one month, 10% Hydroxy Propyl Methyl cellulose coated seeds had 10^6 cells per seed.

- Application of improved on-farm produced soil-root based AMF inoculums of native origin was demonstrated under direct seeded upland rice in tribal village of Kanha Band (Block- Churchu of Hazaribag District, Jharkhand) giving about 15-20% yield increase over control.

- An economic carrier for biofertilizer (*Bacillus* and *Mesorrhizobium*) developed using boiled rice water, pulse and vegetable wash, and glucose solutionat RAU, Pusa. The formulation recommended to use within a week to the targeted crop.

Theme - IV: Soil Pollution, Remediation and Environmental Pollution

2.7 Soil Pollution and Remediation

2.7.1 Determination of critical limits for identifying heavy metals contamination and their threats in major soil types of India

Bulk soil samples were collected from Kanpur (Rarha series; Sub-order: Udic Ustochrept; alluvial soil type); Indore (Jindakheri series; Sub-order: Typic Haplustert; Black soil type) and Ranchi (Ranchi series; Sub-order: Typic Haplustalf; Lateritic soil type) for conducting screen house experiments. Physical and chemical properties as well as heavy metals contents of the soils were analyzed. Soils collected from 3 soil types were treated with 7 levels of Cr as Cr^{3+} (50-800 mg/kg) and Pb (50-600 mg/kg) and stabilized through alternate wetting and drying for one month. Subsequently, spinach crop was grown for 50 days on the treated soils.

Lead application up to 600 mg/kg had no significant effect on above ground biomass of spinach in Red and laterite soil of Ranchi. Phytotoxicity of lead was more in alluvial soil of Kanpur as compared to black soil of Indore (Plate 2.7.1a). Dry weights of aboveground biomass of spinach at highest level of Pb application were about 40% and 69% as compared to control in alluvial and black soils respectively. Chromium (Cr) up to application of 800 mg/kg had no adverse effect on the growth of spinach in both black soil and red and laterite soil; but had significant adverse effect in alluvial soil causing about 47% decrease in aboveground biomass (Plate 2.7.1b). Soil Pb contents causing 20% reduction in aboveground biomass yield of spinach were computed as 393 mg/kg for black soil and 168 mg/kg for alluvial soil. Similarly, soil Pb content causing 20% reduction in aboveground biomass yield of spinach was computed as 265 mg/kg for alluvial soil. Application of both lead and cadmium in soils laid to their accumulation in plant biomass in all the three soil types (Fig. 2.7.1a). Transfer coefficient of lead in alluvial soil was higher as compared to black and red and laterite soils indicating more uptake of Pb by spinach in the former soil (Table 2.7.1a; Fig. 2.7.1b). Transfer coefficient of chromium was lower in red and laterite soil as compared to black and alluvial soil. Heavy metals extracted by dilute (0.01M) CaCl$_2$ are considered available for plant uptake. In the present experiment, dilute (0.01M) CaCl$_2$ extracted very small amount of total soil Pb (0.006 to 0.054% in case of black soil; trace to 0.005% in case of red & laterite soil and trace to 0.009% in case of alluvial soil). Similarly, fractions of total Cr extracted by dilute CaCl$_2$ were 0.015 to 0.063% in case of black soil; 0.012 to 0.031% in case of red and laterite soil and 0.025 to 0.074% in case of alluvial soil. This indicates that Pb is soil is fixed more strongly as compared to Cr. Dilute (0.01M) CaCl$_2$ extractable Pb and Cr were strongly correlated to their concentrations in aboveground biomass of spinach. Critical limits of Pb and Cr

in different soils were determined and mentioned in Table 2.7.1b.

Table 2.7.1a Transfer coefficients of Pb and Cr during their uptake by spinach biomass in different soil types

	Lead	Chromium
Black soil	0.021	0.004
Red and laterite soil	0.029	0.002
Alluvial soil	0.036	0.005

Table 2.7.1b Maximum safe concentration limits (based on food contamination approach) of total and available (0.01M CaCl$_2$ extractable) Pb and Cr in different types of experimental soils

	Critical limits of total heavy metals		Critical limits of 0.01M CaCl$_2$ extractable heavy metals	
	Pb	Cr	Pb	Cr
Black soil	143	52	0.007	0.018
Red & laterite soil	78	332	0.002	0.071
Alluvial soil	84	87	0.006	0.034
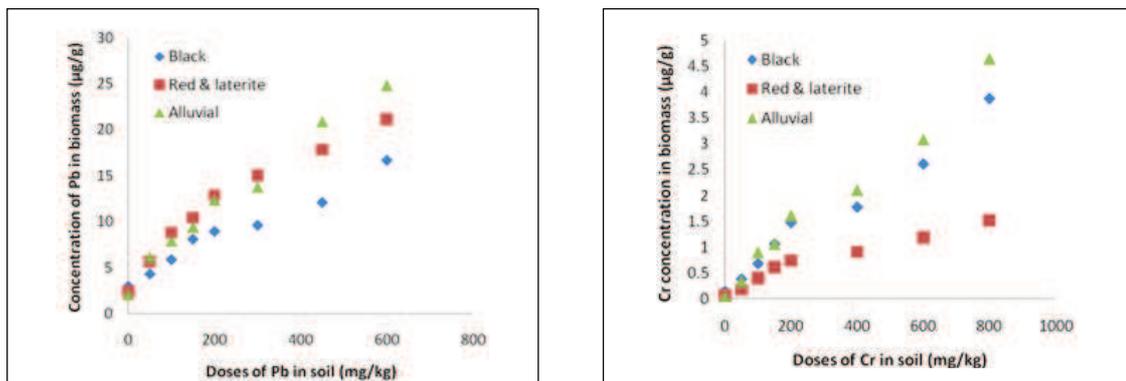
Fig. 2.7.1a   Effect of Pb and Cr applications in different soil types on their concentration in aboveground biomass of spinach
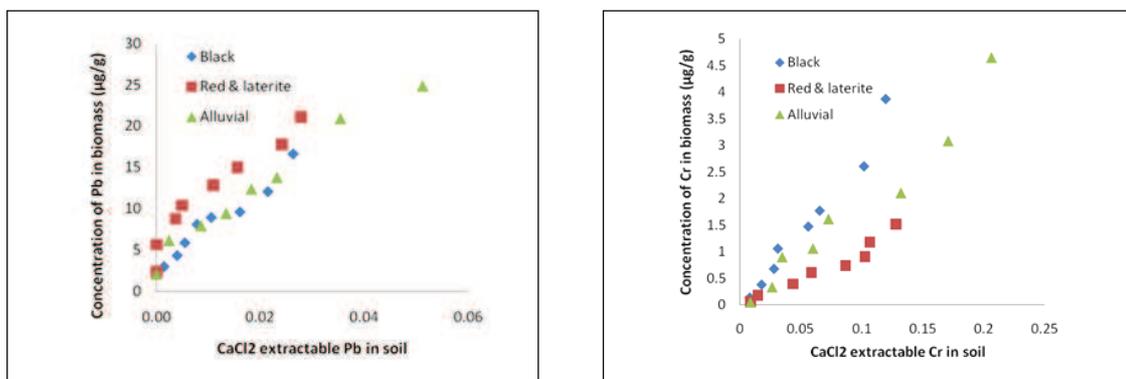
Fig. 2.7.1b   Concentrations of Pb and Cr in aboveground biomass of spinach as influenced by their CaCl$_2$ extractable contents in soils

Plate 2.7.1a Effect of Pb on spinach biomass growth in Kanpur soil

Plate 2.7.1b Effect of Cr on Spinach biomass growth in Kanpur soil

2.7.2 Assessment of cotton for the remediation of soils contaminated with heavy metals

Cotton (Bt)(RCH-2) was evaluated for its suitability for the remediation of soils contaminated with three heavy metals such as Cd, Pb and Cr (Plate 2.7.2). The plant was exposed to different levels of Cd (0,50,100 and 200 mg kg^{-1}soil), Pb (0, 500, 750 and 1000 mg kg^{-1} soil) and Cr (0,12.5,25 and 50 mg kg^{-1} soil). Data were recorded on various physiological parameters (plant height, leaf area, number of leaves/plant, photosynthesis rate and dry matter production), biochemical parameters (proline, ascorbic acid, electrolyte leakage, nitrate reductase activity) and yield components. Similar to previous year, the application of all the heavy metals didn't affect the emergence of cotton seedlings, but there was some reduction in the growth of plants at the highest level in each element. Among the three heavy metals, the reduction in growth of the plants was more severe with Cr soil enzymes, *viz.* dehydrogenase, acid phosphatase and alkaline phosphatase decreased with the application of all the three heavy metals. The data on the partitioning of Cd, Pb and Cr revealed that, the heavy metals mainly concentrated in root followed by shoot, seed and lint. Based on the data on partitioning of the heavy metals, the cotton plant was found to be an excluder of all the heavy metals and therefore could not classified as a hyper-accumulator of Cd, Pb and Cr. However, the plant could be a potential crop for phytostabilization of Cd, Cr and Pb.

Plate 2.7.2 A view of cotton crop grown in contaminated soils

2.7.3 Geo-accumulation Index for tanner contaminated area of Kanpur

Amongst the different heavy metals, chromium (Cr) is largely found in tannery effluent and is one of the most detrimental elements to plant growth. Tannery effluent is the major source of influx of Cr into the biosphere. About 40% of the total Cr used in the tannery industry is released in to the environment as hazardous element. Higher Cr in soil further affects the germination, growth of root and shoots as well as crop yield. Over the years, soil and water pollution in the Kanpur region has drastically reduced the crop yields by 25 to 40%. On the basis of geo-accumulation index (I_{geo}), land can be assessed on whether it is contaminated with heavy metals or not. For this, geo-referenced soil and groundwater samples collected from long-term (>50 years) tannery effluent irrigated areas of Kanpur were analyzed for heavy metal concentration (Table 2.7.3). The indicated significant buildup of heavy metals such as Cr, Ni, Cd, Pb, Zn, and as in soil. Geo-accumulation index indicates the heavy metal contamination level of a particular metal in agricultural fields. Soil samples were found uncontaminated to moderately contaminated with Cu, Ni, Zn, Pb and as; moderately contaminated in case of Cd and heavily to extremely contaminated by Cr.

Table 2.7.3 Geo-accumulation index of heavy metals in tannery effluent irrigated soils of Kanpur

Elements	Value	Class	Description
Cu	0.22	II	Uncontaminated to moderate contaminated
Cd	1.49	III	Moderate contaminated
Pb	0.95	II	Uncontaminated to moderate contaminated
Cr	4.32	VI	Heavily to extremely contaminated
Ni	0.47	II	Uncontaminated to moderate contaminated
Zn	0.84	II	Uncontaminated to moderate contaminated
As	0.46	II	Uncontaminated to moderate contaminated

2.7.4 Impact of sewage water irrigation on food chain contamination

Shortfall of rain and the depletion of groundwater forced farmers to use poor quality water for crop production. This situation is common in the peri–urban areas of developing countries for vegetable cultivation. The sewage effluent using for crop production in these areas are raises serious concern about its safety and potential limits heavy metals. Whether the crops raised using poor quality water are safe for consumption of human and animal health? or its impacts on soil health. In this study sewage, sediment, soil and crop samples were collected and analyzed for physico-chemical properties. Sewage water samples contained ample amount of organic matter and significant amount of plant macro and micro nutrients. The samples of sewage water also contained heavy metals in trace amount. Long-term application for crop production may build up a significant amount of trace metals in soil. The DTPA extractable heavy metals. *viz.* Cu ranged from 2.7-7.59, Cd 0.04-0.06, Pb 1.29-2.05, Cr 0.01-0.04, Ni 0.24-1.03 and Zn 0.63-2.59 mg kg^{-1} soil. Among the crops, like wheat, spinach, coriander, radish, chenopodium, mustard, the high metal accumulation of Cu, Cd, Pb, Cr and Zn was reported in mustard. The heavy metal risk assessment (Hazard Quotient, HQ) was calculated for all the crops and found that all the crops having heavy metal value in safe level.

2.7.5 Reclamation and rehabilitation of copper mining affected land in Malanjkhand area of Madhya Pradesh

The collaborative project with Hindustan Copper Limited, Malanjkhand, entitled "Reclamation and Rehabilitation of Copper Mining Affected Land in Malanjkhand Area of Madhya Pradesh" was started on April, 2016. A scientific team from ICAR-IISS, Bhopal, visited the site on Jun 26 to Jun 28, 2014, for preliminary survey (Plate 2.7.5) and collected soils samples and tailings for analysis. Subsequently samples were analyzed and results was presented in (Table 2.7.5). The intervention like sowing of plant (monocot) is required to enhance the growth potential and bring more contaminated area into the green area, which we have started (Plate 2.7.5) by sowing Vetiver (*Chrysopogon zizanioides*) grass in the contaminated site.

Plate 2.7.5 Preliminary visit and Vetiver plantation in mine site affected area

International
Decade of Soils
2015-2024

Table 2.7.5 Representative sample analysis of Tailings

Parameter	Unit	Value
Bulk density	g/cc	1.55
Sp. gravity	-	2.675
pH	-	6.945
Cd	mg/kg	11.75
Co	mg/kg	20.5
Pb	mg/kg	18.5
Ni	mg/kg	36.5
Zn	mg/kg	67.5

2.7.6 Management of municipal solid waste contaminated dumping area of Bhanpur, Bhopal

A preliminary survey of the Bhanpur dumping site (Plate 2.7.6) was conducted and soils and sewage water samples were collected. The area (2500 sq. m) was selected as per the request of Bhopal Municipality Corporation (Nagar Nigam, Bhopal) and establishment of experimental block, soil collection and land preparation were initiated.

Plate 2.7.6 Photograph of Bhanpur dumping site, Bhopal

3. Transfer of technology

A. Main Institute

3.1 Frontline Demonstration

To demonstrate the benefits of nutrient management technologies developed by ICAR-IISS to the farming community frontline demonstrations were carried out in seven farmers' fields of Mengra Kalan village of Bhopal district for wheat crop (Plate 3.1). The technologies demonstrated in each farmer field included Integrated Plant Nutrient Supply System, Biofertilizers (dry and liquid formulations), Phospho-nitro-sulpho compost, and Fertilizer recommendation based on Soil Test Crop Response Correlations.

Plate 3.1 FLDs of nutrient management technologies developed by ICAR-IISS in Mengra Kalan village of Bhopal district for wheat crop

3.2. Method Demonstrations

The institute scientists conducted method demonstrations (Plate 3.2) in the farmer fields of Mengra Kalan village of Bhopal on soil sample collection procedure and seed treatment of biofertilizers for the *rabi* wheat season.

Plate 3.2 Demonstration of soil sampling and use of biofertilizers as seed treatment

3.3 Farmers' Field Surveys

A farmer field survey was carried out in Mengra Kalan village of Bhopal to identify the severity of various constraints in the field level adoption of nutrient management technologies developed by the institute as a part of the project on 'Integrated Assessment of some ICAR-IISS Technologies for Enhancing Agro-Ecosystem Productivity. Another farmer field survey was conducted in the Khamkheda village of Bhopal in connection with the project entitled Demonstration of best-bet conservation agriculture (CA) practices on farmers' fields in Vertisols of central India in order to understand the socio-economic status as well as land management practices of the farming community.

International Decade of Soils 2015-2024

B. All India Coordinated Research/ Network Projects

3.4 AICRP on STCR (FLDs)

a) CCSHAU, Hisar, Haryana

Frontline demonstrations on oilseed (raya) were conducted at three irrigated locations and in dryland conditions on balanced nutrition through soil testing. The mean response yardstick in different treatments followed almost the same trend as that of mean seed yield under both irrigated and dryland conditions (Table 3.4a). The mean response yardstick was 4.66 in farmers' practice (FP). treatment under irrigated conditions which improved to 5.27, 5.49, 5.37, 6.25 and 5.82 kg kg^{-1} in GRD, TY-20, TY-25, TY-20 FYM and TY-25 FYM, respectively. The mean response yardstick was higher under targeted yield and GRD treatments than F.P. treatment indicating the higher yield and response per unit of fertilizer nutrients applied. In irrigated conditions, the mean response yardstick was higher under IPNS suggesting the beneficial effect of FYM on crop yield. Under dryland conditions also, the mean response yardsticks were 5.43 and 6.94 in FP and GRD treatments, respectively, whereas under targeted yield treatments, the mean response yardstick varied from 6.55 to 8.03. So the farmers should adopt target yield approach for higher yield, higher response of fertilizers and ultimately resulting in higher net benefit.

Table 3.4a Result of Mean seed yield, response, response yardstick, per cent deviations and benefit cost ratio in raya (Laxmi) in follow up experiments under irrigated condition (Mean of 3 locations)

Treatment	Raya seed yield (kg ha^{-1})	Response (kg ha^{-1})	Response yardstick (kg kg^{-1})	B/C ratio
Irrigated				
Control	1203			
Farmers' Practice	1653	450	4.66	9.19
GRD	1888	685	5.27	9.00
STCR (Target 20 q ha^{-1})	1987	784	5.49	9.53
STCR (Target 25 q ha^{-1})	2383	1180	5.37	9.23
STCR (Target 20 q ha^{-1}) + 15 t FYM ha^{-1}	2100	897	6.25	8.84
STCR (Target 25 q ha^{-1}) + 15 t FYM ha^{-1}	2480	1277	5.82	8.74
Unirrigated				
Control	820			
Farmers' Practice	1010	190	5.43	9.43
GRD	1237	417	6.94	11.25
STCR (Target 20 q ha^{-1})	1425	605	8.03	12.79
STCR (Target 25 q ha^{-1})	1615	795	6.55	10.67
STCR (Target 20 q ha^{-1}) + 15 t FYM ha^{-1}	1450	630	8.36	11.82
STCR (Target 25 q ha^{-1}) + 15 t FYM ha^{-1}	1630	810	6.67	10.06

b) CSHPKVV, Palampur, Himachal Pradesh

Soybean (PK 472)

In order to popularize the prescription based fertilizer application, nineteen frontline demonstrations were taken up with nine on soybean in *kharif* and eight on toria in *zaid* (Table 3.4b & c; Plate 3.4b & c). Four FLDs on soybean were laid out in Hamirpur district and five in Kangra district of the state. All (10) FLDs on toria were conducted at Una district representing low hills sub-montane zone of Himachal Pradesh. Five treatments were tested in both the crops. In soybean, the treatments were control, farmers' practice, general recommended dose, two pre- fixed yield targets of 20 and 25q ha^{-1}.

Table 3.4b Fertilizer adjustment equations used in front line demonstrations on farmers' fields with soybean and toria

Soybean	Toria
FN=20 kg N ha^{-1} FP$_2$O$_5$=6.97 T-6.30SP FK$_2$O=4.36 T-0.36 SK	FN =5.33 T-0.06SN FP$_2$O$_5$=3.67 T-0.73 SP FK$_2$O=5.63 T-0.69 SK

Table 3.4c Fertilizer demonstrations on soybean (PK 472) on farmers' fields in Hamirpur and Kangra district of HP (Average of 9 locations, *kharif*)

Treatment	Yield (q ha^{-1})	Cost of yield (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Control	7.6	23268	16250	7018	1.43
FP	11.5	35465	22763	12702	1.56
GRD	16.8	51523	21821	29703	2.36
Target 20 q ha^{-1}	19.2	59108	18125	40983	3.26
Target 25 q ha^{-1}	24.6	75645	21023	54622	3.60

Fertilizer rate: N=Rs. 11.8 kg^{-1}, P$_2$O$_5$= Rs.65.6 kg^{-1}, K$_2$O=Rs.28 kg^{-1}, and FYM= Rs 100 q^{-1} (Fresh weight basis), sale price of soybean: grains= Rs. 3000 q^{-1} and straw= Rs. 100 q^{-1}. In FP, FYM was applied @ 3t ha^{-1} on dry weight basis Farmers:

Plate 3.4a Scientist interacting with farmer

Plate 3.4b Performance of soybean under STCR approach of fertilizer application

Toria (Bhawani)

Similar to soybean, in case of *toria*, application of fertilizers as per target yield approach, in general, resulted in higher yield of toria in comparison to farmers' practice and general recommended dose (Table 3.4d; Plate 3.4c). Highest yield (14.9 q ha^{-1}) was recorded under pre fixed target of 15 q ha^{-1}. Although, the yield levels recorded under GRD and 10 q ha^{-1} yield target were comparable but the higher net returns and B:C ratio under later treatment. The per cent deviations under both the pre-fixed targets were within the permissible range of $\pm$10. 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 advocated that STCR equations can be successfully used for raising toria crop and harnessing better profits. The highest benefit cost ratio was obtained in 15 q ha^{-1} target (3.35) followed by 10 q ha^{-1} target (2.81), GRD (2.20), farmers' practice (1.45) and least in control (1.35).

Table 3.4d Fertilizer demonstrations on toria (Bhawani) on farmers' fields in Una district, (average of 10 locations)-*zaid*

Treatment	Yield (q ha^{-1})	Cost of yield (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Control	3.8	9734	7200	2534	1.35
FP	7.6	19647	13585	6062	1.45
GRD	10.7	27527	12484	15043	2.20
Target 10 q ha^{-1}	10.5	26909	9576	17333	2.81
Target 15 q ha^{-1}	14.9	38445	11463	26981	3.35

In FP, FYM was applied @ 3t ha^{-1} on dry weight basis, sale price of toria seed = Rs. 25.00 kg^{-1} Cost of fertilizers (Rs. kg^{-1}): N=11.8, P$_2$O$_5$ = 65.6, K$_2$O=28 and FYM
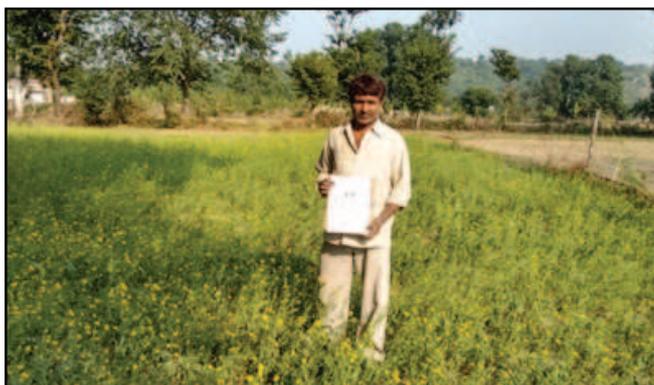
Plate 3.4c Frontline demonstration on toria at farmers' field

c)   JNKVV, Jabalpur, Madhya Pradesh

Soybean (JS 97-52)

Transfer of innovative technology to the farmers for attaining higher economic yield is the need of the present day, which needs motivation for its adoption. In all twelve frontline demonstrations were taken in different crops (Table 3.4e) during both seasons (*kharif* and *rabi*). In the *kharif* season, three demonstrations were taken up in soybean, three in paddy. In *rabi* five frontline demonstrations were taken in wheat and one in gram in villages on farmer's field of Jabalpur and Seoni districts.

The fertilizer adjustment equations used for the application of fertilizer based on soil test values for fixed targeted yield of different crops of *kharif* and *rabi* seasons were as follows:

Soybean		Paddy	
FN = 5.19 T − 0.48 SN		FN = 4.25 T − 0.45 SN	
FP$_2$O = 5.20 T − 4.10 SP		FP$_2$O$_5$ = 3.55 T − 4.89 SP	
FK$_2$O = 3.90 T − 0.22 SK		FK$_2$O = 2.10 T − 0.18 SK	
Wheat		**Gram**	
FN = 4.40 T − 0.40 SN		FN = 3.73 T − 0.18 SN	
FP$_2$O$_5$ = 4.00 T − 5.73 SP		FP$_2$O = 5.00 T − 2.50 SP	
FK$_2$O = 2.53 T − 0.16 SK		FK$_2$O = 3.80 T − 0.17 SK	

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Table 3.4e Economics of treatments included in FLDs

Treatments	Nutrient applied (kg ha^{-1})			Response (kg ha^{-1})	Cost of production (Rs. ha^{-1})	Cost of fertilizer (Rs. ha^{-1})	Profit (Rs. ha^{-1})	B:C ratio	Yard stick value
	N	P$_2$O$_5$	K$_2$O						
1	2	3	4	5	6	7	8	9	10
Paddy (Kranti), Village : Tikariya, Jabalpur									
GRD	80	50	30	800	12800	4355	8445	1.94	5.00
T.Y. 30 q ha^{-1}	26	42	3	1510	24160	2332	21828	9.36	21.27
T.Y. 30 q + FYM 5 t ha^{-1}	26	42	3	1900	30400	8832	21568	2.44	11.59
Paddy (Kranti), Village : Temerbita, Jabalpur									
GRD	80	50	30	1310	20960	4355	16605	3.81	8.19
T.Y. 30 q ha^{-1}	15	37	4	1680	26880	1974	24906	12.62	30.00
T.Y. 30 q + FYM 5 t ha^{-1}	15	37	4	2000	32000	8474	23526	2.78	13.42
Paddy (Sahbhagi), Village : Simariya, Seoni									
GRD	80	50	30	1410	22560	4355	18205	4.18	8.81
T.Y. 30 q ha^{-1}	9	46	7	1830	29280	2371	26909	11.35	29.52
T.Y. 30 q + FYM 5 t ha^{-1}	9	46	7	2060	32960	8871	24089	2.72	13.29
Wheat (GW-273), Village : Temerbita, Jabalpur									
GRD	120	80	60	1330	22610	7227	15383	2.13	5.12
T.Y. 50 q ha^{-1}	130	119	80	2230	37910	9718	28192	2.90	6.78
T.Y. 50 q + FYM 5 t ha^{-1}	130	119	80	2900	49300	16218	33082	2.04	6.87
Wheat (GW-322), Village : Bhinjawada, Seoni									
GRD	120	80	60	1040	17680	7227	10453	1.45	4.00
T.Y. 50 q ha^{-1}	110	134	70	2290	38930	9754	29176	2.99	7.29
T.Y. 50 q + FYM 5 t ha^{-1}	110	134	70	2670	45390	16254	29136	1.79	6.56
Wheat (GW-3211), Village : Simariya, Seoni									
GRD	120	80	60	1130	19210	7227	11983	1.66	4.35
T.Y. 50 q ha^{-1}	130	119	72	2080	35360	9465	25895	2.74	6.48
T.Y. 50 q + FYM 5 t ha^{-1}	130	119	72	2490	42330	15965	26365	1.65	6.01
Wheat (GW-3211), Village : Tikariya, Jabalpur									
GRD	120	80	60	1430	24310	7227	17083	2.36	5.50
T.Y. 50 q ha^{-1}	130	123	75	2330	39610	9735	29875	3.07	7.10
T.Y. 50 q + FYM 5 t ha^{-1}	130	123	75	2650	45050	16235	28815	1.77	6.29
Wheat (GW-273), Village : Simariya, Seoni									
GRD	120	80	60	1123	19091	7227	11864	1.64	4.32
T.Y. 50 q ha^{-1}	116	125	70	1893	32181	9451	22730	2.40	6.09
T.Y. 50 q + FYM 5 t ha^{-1}	116	125	70	2553	43401	15951	27450	1.72	6.32
Gram (JG-311), Village : Bhinjawada, Seoni									
GRD	30	60	30	190	9500	4032	5468	1.36	1.58
T.Y. 15 q ha^{-1}	13	34	0	540	27000	1685	25315	15.02	11.49
T.Y. 15 q + FYM 5 t ha^{-1}	13	34	0	680	34000	8185	25815	3.15	4.86

* 5 t FYM ha^{-1} = 30.0 kg N + 27.5 kg P + 35.5 kg K

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Rates for economic produce (Rs. kg^{-1})

Soybean: 50.0; Paddy: 16.0; Wheat: 17.0 and Gram: 50.0

Rates for nutrients (Rs. kg^{-1})

Nitrogen: 15.22; Phosphorus: 43.75 and Potassium: 31.67

Rates for FYM (Rs. t^{-1}): 1300

The targeted yields were achieved within ± 3.85 to ± 15.25 percent deviation range from affixed target (Table 3.4e). In thirty-five per cent cases the targets were achieved within ± 10% deviation. When the fertilizer recommendation based on targeted approach coupled with 5 t FYM ha^{-1} i.e. IPNS mode was achieved in 60% cases.

d) TNAU, Coimbatore, Tamil Nadu

A long-term experiment with the objective of monitoring the changes in soil fertility as influenced by the continuous adoption of STCR-IPNS technology and demonstrating the possibility of achieving the aimed yield targets under STCR-NPK alone and Integrated Plant Nutrition System (IPNS) was carried out in Typic Haplustalf, Noyyal series. Two crops are being raised every year during *kharif* and *rabi* and thirty six crops have been raised so far. The treatments imposed were i) Blanket recommendation ii) STCR - NPK alone for 6 t ha^{-1} for *kharif* rice and 5 t ha^{-1} for *rabi* rice iii) STCR - NPK alone for 7 t ha^{-1} for *Kharif* rice and 6 t ha^{-1} for *rabi* rice iv) STCR - IPNS for 7 t ha^{-1} for *kharif* rice and 6 t ha^{-1} for *rabi* rice and v) Absolute control. The fertiliser doses were calculated based on the available nutrient status of initial soil samples using the fertiliser prescription equations as furnished below:

Kharif

$$FN = 4.39\,T - 0.52\,SN - 0.80\,ON$$
$$FP_2O_5 = 2.22\,T - 3.63\,SP - 0.98\,OP$$
$$FK_2O = 2.44\,T - 0.39\,SK - 0.72\,OK$$

Rabi

$$FN = 4.63\,T - 0.56\,SN - 0.90\,ON$$
$$FP_2O_5 = 1.98\,T - 3.18\,SP - 0.99\,OP$$
$$FK_2O = 2.57\,T - 0.42\,SK - 0.67\,OK$$

For IPNS plots, FYM @ 12.5 t ha^{-1} and *Azospirillum* and Phospho-bacteria each @ 2 kg ha^{-1} were applied and the fertilizer doses were adjusted accordingly. Full dose of P_2O_5 and 25 per cent of N and K_2O were applied basally at the time of transplanting. Remaining N and K_2O were applied in three equal splits *viz.* active tillering, panicle initiation and heading stages and routine agronomic practices were carried out periodically.

The grain yield (Table 3.4f) of *kharif* rice ranged from 2450 kg ha^{-1} in control to 7080 kg ha^{-1} in STCR-IPNS-7 t ha^{-1} treatment. The highest response ratio of 19.1 kg grain yield per kg of nutrient applied was also recorded in STCR-IPNS-7 t ha^{-1} treatment. The achievement of yield targets was more than 95% in all the STCR treatments and the highest achievement (101.1 %) was observed in STCR-IPNS-7 t ha^{-1} treatment.

The grain yield in *rabi* rice ranged from 2350 kg ha^{-1} in control to 6120 kg ha^{-1} in STCR-IPNS 6 t ha^{-1} treatment (Table

Table 3.4f Grain yield, response ratio and percent achievement of *kharif* rice

Treatments	Grain yield (kg ha^{-1})	Response Ratio (kg kg^{-1})	% Achievement
Blanket	5660	12.8	-
STCR –NPK alone -6 tha^{-1}	5750	15.1	95.8
STCR –NPK alone-7 t ha^{-1}	6860	16.5	98.0
STCR-IPNS- 7 t ha^{-1}	7080	19.1	101.1
Absolute Control	2450	-	-

3.4g). The highest response ratio of 19.53 kg grain yield per kg of nutrient applied was recorded in STCR-IPNS 6 t ha^{-1} treatment. The achievements of yield targets were more than 94% in all the STCR treatments, the highest achievement (102.0%) was observed in STCR-IPNS 6 t ha^{-1} treatment. The yield targets achievement in other treatments were 94.4 and 97.9 per cent in STCR 5 t ha^{-1} and STCR 6 t ha^{-1}, respectively

Table 3.4g Grain yield, response ratio and percent achievement of *rabi* rice

Treatments	Grain yield (kg ha^{-1})	Response Ratio (kg kg^{-1})	Achievement %
Blanket	4650	9.20	-
STCR –NPK alone -5 tha[-1]	4720	16.34	94.4
STCR –NPK alone-6 t ha^{-1}	5875	18.17	97.9
STCR-IPNS -6 t ha^{-1}	6120	19.53	102.0
Absolute Control	2350	-	-

3.5 AINP on SBB

3.5.1 Diversification of Biofertilizer Usage and Extension

- Soybean seed inoculation with zinc solubilizing bacteria *Pseudomona striata* increased yield by 22% over RDF and recommended along with application of 30 kg $ZnSO_4$ ha[-1]. Inoculation of AM fungi along with N fixing *Azotobacter* and P solubilizing *Bacillus megaterium* to chilli increased yield significantly over RDF (MAU, Parbhani)

- Biofertilizer for the bio-energy crop *Pongamia* developed. Inoculation with *Rhizobium* improved nodulation by 55% and DM production by 35% over control.- (ANGRAU, Amaravathi)

- Bionutrient package (enriched myco-straw with *Pseudomonas* sp, *Azospirillum* sp, and Cyanobacteria sp) validated at Vaishali, Bhagalpur and Samastipur districts for rice. Improvement in rice grain yield from 5 to 10 % over control (RAU, Pusa)

- Nitrogen fixers *Microbacterium, Cellulosimicrobium, Paenibacillus,* and *Azospirillum lipoferum* tested on black pepper, ginger, cowpea and bitter gourd. *Paenibacillus* was best among all biofertilizer strains. Population of *Trichoderma* was comparatively higher in the rhizosphere of healthy areacanut palms in comparison to those affected by yellow dwarf disease. Biofertilizers *viz. Azotobacter chroococcum, Azospirillum lipoferum* and PGPR mix-I (total 1.5 tonne) distributed to 150 beneficiaries in twelve tribal settlements of Wayanad district. Five training programmes involving 200 farmers conducted in Wayanad (KAU, Thrissur)

- PGPR Mix I enhanced growth of Arecanut seedlings at Puthoor compared to control. One kg each of biofertilizer (PGPR Mix I) was distributed to 400 tribal farmers cultivating vegetables, pulses, banana, sorghum, groundnut, ragi etc., of Attapady, Kerala. One kg each of composting inoculum was also distributed to 50 tribal farmers for decomposing agricultural wastes. About 350 tribal farmers and 54 Agricultural Extension officers were trained from Nellippathy, Ummathambadi and Kozhikoodam, Puthoor and Sholayur in Kerala for biofertilizer application in agriculture (KAU, Vellayani)

- Under TSP Programme 69 families of Odisha state were benefited by adopting biofertilizers. Biofertilizers integration to vegetable crops increased yield up to 40%. The Tribal farmer's expenditure of one rupee on BFs returned Rs. 18.40 paisa - (OUAT, Bhubaneswar)

- During 2016-17, liquid biofertilizers production earned revenue of Rs. 10.53 lakhs at MAU, Parbhani. Biofertilizer production was 93.8 lakhs at JNKVV, Jabalpur. Carrier based biofertilizers (209 metric tonnes) and liquid Biofertilizers (33 metric tonnes) worth Rs.182 lakhs produced at ANGRAU, Amaravathi and supplied to farmers of Andhra Pradesh. Total biofertilizer production worth Rs. 286.3 lakhs in project against outlay of Rs. 199.3 (RE) representing 144% ROI.

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Decade of Soils
2015-2024

3.6 Scheduled Tribe Component (STC) Program

3.6.1 STC under main Institute

3.6.1.1 Soil quality assessment in tribal areas of Madhya Pradesh

Soil quality assessment and monitoring is very necessary to maintain the sustainability of agricultural production system. There are many methods followed for soil quality assessment, however, the expert opinion method is simple and universal and easily adopted. Therefore, soil quality of tribal districts like Jhabua, Alirajpur and Dhar has been assessed using expert opinion method.

Expert opinion method

In order to make some comparative analysis of soils of different agro-ecosystems, experts have worked out the relative soil quality index using 15 important and known physical, biological and chemical indicators with uniform weightage and scoring value (Table 3.6.1.1a). Each of the indicators is divided into four classes namely, Class – I, Class – II, Class - III and Class - IV with an assigned mark of 4, 3, 2 and 1, respectively.

Table 3.6.1.1a Soil quality indicators and their weights and classes for the evaluation of soil quality

Soil quality indicators	Weights	Class I	Class II	Class III	Class IV
Physical indicators					
Soil Depth (m)	10	>2	1-2	0.5-1	<0.5
Texture	10	Loam	CL /SL	Clay/SC	Sand
Bulk Density (Mg m^{-3})	5	1.3-1.4	1.3-1.2/1.4-1.5	1.2-1.1/1.5-1.6	<1.1/>1.6
Biological indicators					
Organic carbon (%)	15	>1	1-0.75	0.75-0.5	<0.5
DHA (µg TPF g^{-1} 24 h^{-1})	10	>20	20-15	15-10	<10
Chemical indicators					
Soil pH	5	6.5- 7.5	6.5- 6/7.5-8	6- 5.5/8-8.5	<5.5 />8.5
Avail. N (kg ha^{-1})	10	>560	560-420	420-280	<280
Avail. P (kg ha^{-1})	10	>25	15-25	15-10	<10
Avail. K (kg ha^{-1})	5	>280	280-200	200-120	<120
Avail. S (mg kg^{-1})	5	>25	25-15	15-10	<10
Avail. Zn (mg kg^{-1})	3	>2.0	2.0-1.0	1.0-0.5	<0.5
Avail. Fe (mg kg^{-1})	3	>10.0	10-5.5	5.5-2.5	<2.5
Avail. Mn (mg kg^{-1})	3	>10.0	10.0-4.0	4.0-2.0	<2.0
Avail. Cu (mg kg^{-1})	3	>2.0	2.0-0.5	0.5-0.2	<0.2
Avail. B (mg kg^{-1})	3	>1.5	1.5-0.7	0.7-0.3	<0.3
Score	100	4	3	2	1

New approach of soil quality assessment

Though the expert opinion method is simple, the weight given to each indicator is not representative. Therefore, an alternative new approach was developed for giving weight to each indicator without any bias. The main factors considered for weighing an indicator were: (1) its relationship with yield (correlation co-efficient), (2) its coefficient of variation, and (3) the percentage of samples under deficiency or lower classes (Table 3.6.1.1b). Based on the above three criteria scores have been given for each indicator. Then addition of these three scores gives the weight of an indicator. Then using the weight and the class value/mark, soil quality index (SQI) is calculated.

Table 3.6.1.1b Criteria for giving scores/weightage to different indicators

Weight/score	Percent samples in lower Classes (III and IV)	Co-efficient of variation for each indicator (%)	Correlation with yield
5	>80	>80	>0.50
4	60-80	60-80	0.4-0.5
3	40-60	40-60	0.3-0.4
2	20-40	20-40	0.2-0.3
1	10-20	10-20	0.1-0.2
0	<10	<10	<0.1

The soil quality index (SQI) is calculated by the following equation:

$$SQI = \Sigma\,(Wi \times Ii)……………………Eq.\,(1)$$

Where, Wi = the weight of the indicator, Ii = the marks/score of the indicators classes

In order to judge the SQI value of any site against the theoretical maximum value of SQI (i.e. 400), the concept of relative soil quality index (RSQI) was used which was calculated by the following equation:

$$RSQI = \frac{SQI_{sample}}{SQI_{max}} \times 100…………………Eq.\,(2)$$

Where, SQI_{sample} = the SQI calculated for particular sample using Eq. (1), SQI_{max} = Maximum possible SQI value (in this case -400)

Table 3.6.1.1c   Classes/Category of soil quality based on RSQI and Soil quality status of study area

RSQI (%)	Classes	Category	Jhabua (% of samples)		Alirajpur (% of samples)		Dhar (% of samples)	
			Expert method	New Method	Expert method	New Method	Expert method	New Method
>90	I	Very Good	-	-	-	-	-	-
80-90	II	Good	-	-	0.37	0.19	1.03	0.90
>70-80	III	Medium	4.07	1.48	4.63	4.44	9.10	9.23
60-70	IV	Moderately Poor	29.44	21.30	10.19	10.00	20.90	22.69
<60	V	Poor	66.29	77.22	84.81	85.37	68.97	67.18

Based on the RSQI value, soils of tribal areas are grouped under different categories as in Table 3.6.1.1c. The results show that most of the soils in these districts have poor soil quality.

3.6.2 STC under AICRP on STCR

AICRP on STCR has implemented STC across the country in various tribal belts.

JNKVV, Jabalpur, Madhya Pradesh

Under tribal sub project, two districts of Jabalpur division *viz*. Dindori and Mandla were selected. In Dindori district frontline demonstrations were conducted on paddy (MTU 1010), lentil (JL 3) (Rhizobium) and chickpea (JG-63) at ten locations each and that the STCR based fertilizer applications increased the yield by 29.6-46.0, 50.0-83.3 and 37.5-60.0 per cent, respectively (Table 3.6.2a). Moreover, in Mandla district in all ten demonstrations were conducted on paddy (MTU 1010) in Tindani, Gajipur, Chatumar villages and ten each in Orai village on wheat (JW 3211, HI 1500) and chickpea (JG-15), respectively. The yield of paddy (MTU 1010) using the STCR based fertilizer applications increased

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2015-2024

by 13.8-26.6, 18.3-30.6 and 11.9-19.9 per cent in Tindani, Gajipur, Chatumar villages, respectively. Whereas, in Orai village the yield of wheat (JW 3211, HI 1500) and chick pea (JG-15) increased by 17.2-79.3 and 38.1-70.8%, respectively.

Table 3.6.2a Result of FLDs on paddy, lentil, wheat and chickpea in Dindori and Mandla tribal district

Crop/variety	Village	No. of FLDs	Yield (q ha^{-1}) IPNS	FP	Increase in yield (%)
Dindori					
Paddy (MTU 1010)	Shiwari	10	34.0-39.0	24.5-29.5	29.6-46.0
Lentil (JL 3) (Rhizobium)	Shiwari	10	5.5-7.0	3.0-4.5	50.0-83.3
Chick pea (JG-63)	Shiwari	10	11.0-12.5	7.5-9.0	37.5-60.0
Mandla					
Paddy (MTU 1010)	Tindani	3	25.0-32.9	19.7-28.9	13.8-26.6
Paddy (MTU 1010)	Gajipur	4	23.5-33.6	18.0-27.5	18.3-30.6
Paddy (MTU 1010)	Chatumar	3	34.0-38.5	29.7-34.4	11.9-19.9
Wheat (JW 3211, HI 1500)	Orai	10	25.5-37.6	20.4-26.3	17.2-79.3
Chick pea (JG-15)	Orai	10	10.4-14.4	6.9-9.7	38.1-70.8

IGKV, Raipur, Chhattisgarh

Frontline demonstrations were conducted for *Gound* tribal group at 80 locations in Gariyaband district in *kharif* season (Table 3.6.2b).

Table 3.6.2b Results of FLDs conducted in Chhattisgarh state during *kharif* season

Crop/variety	Block/village	No. of FLDs	Range of % yield increase over FPD
Rice/ Mahamaya	Devbhog /Mahulkot	20	17.2-35.8
Rice/ Swarna	Mainpur /Kasabay,Phuljhar	20	12.0-27.5
Rice/MTU-1010	Gariyaband /Mohada	20	13.0-48.8
Rice/ Swarna	Chhura / Madeli	10	17.2-47.4
Rice/ Hybrid Swarna	Fingeshwar/Barbhata	10	5.4-25.0

STCR approach over Farmer's practice dose (FPD) was recorded at Chhura block where FPD application was very low as compared to STCR dose that estimated 17.2 to 47.4 times higher yield with Swarna variety of rice. Similarly, the farmers from Gariyaband and Devbhog block also recorded higher increase in rice yield over their own practice in the range of 13.0-48.8 and 17.2-35.8 percent, respectively. Results indicate that soil test based balance fertilizer application to achieve a definite yield target of the crop can be benefited to the farmers in term of net profit and net return as compared to the farmer's fertilizer practice or blanket fertilizer dose which do not account the balance manner of fertilization.

Table 3.6.2c Results of FLDs conducted in Chhattisgarh state during *rabi* season

Name of tribal districts	Village	Crop/variety	Tribal Group	No of beneficiaries	Range of % yield increase over FPD
Gariyaband	Mohanda, Brindanawagarh	Gram	Gound	25	10.2-43
Kondagaon	Badebendri Bhagdeva	Wheat (Kanchan) Maize (Hycell)	Mudiya, Halba, Bhatra	25	23.7-41.4 0.8-23.4
Kanker	Aturgaon Puswada	Maize (PAC 3396) Wheat (GW- 266)	Nag, Netam, Markam, Vatti,	25	16.8-31.4 16.6-39.9

Name of tribal districts	Villages	Crop/variety	Tribal Group	No of beneficiaries	Range of % yield increase over FPD
Ambikapur	Amgaon, Gangapur	Wheat (HI- 1544)	Kawachi, Maravi, Salam, Kange Nageshiya Orav,Gond	25	13.6-41.2
Korea	Dakaipara	Mustard(Bharat Sarson- 2)	Gond, Chekha	2	40.2-49.2
	Mahora	Wheat (HD 2932)	Gond, Chekha	5	29.6-39
	Khada	Potato (Kufri Bahar)	Gond, Chekha	5	9.6-35.8
	Khada	Brinjal (VNR-125)	Gond, Chekha	10	14.5-37.6
	Mahora	Tomato (Vaishnavi -2082)	Gond, Chekha	3	29.2-43.7

Similarly, 125 demonstrations were taken in wheat, maize, tomato, brinjal, potato, gram and mustard crops at five districts of Chhattisgarh (Sarguja, Koriya, Gariyaband, Kanker and Bastar- Kondagaon) during the *rabi* season (Table 3.6.2c). The yield targets of different crop were fixed as per crop variety and farms condition. The crop yields achieved against targeted within the limit of ±10 % variation is considered valid under STCR norms. However, some farmers had wide variation from the targeted due to poor management and moisture stress during crop terminal growth stage of the crop. In the *rabi* season the farmers from Korea District recorded higher increase in yield over their own practice in the range of 40.2-49.2 and 29.2 to 43.7% for mustard (Bharat Sarson-2) and tomato (Vaishnavi- 2082) crop, respectively. Results indicate that soil test based balance fertilizer application to achieve a definite yield target of the crop can benefit to the farmers in term of net profit and net return as compared to the farmer's fertilizer practice or blanket fertilizer dose. Trainings were also conducted (Table 3.6.2d) in Gariyaband, Kanker and Kondagaon ditricts of Chhattisgarh in different villages as enlisted below (Plate 3.6.2a).

Table 3.6.2d List of trainings conducted under STC in Gariyaband, Kanker and Kondagaon district of Chhattisgarh.

Training date	Villages	Districts	Total no. of participants	No. of women farmers
24.12.2015	Mohanda	Gariyaband	40	6
13.01.2016	Mohanda	Gariyaband	30	8
27.01.2016	KVK-Gariaband	Gariaband	30	5
09.01.2016	Bhagdeva	Kondagaon	20	-
10.02.2016	KVK- Kanker	Kanker	20	5
28.01.2016	KVK-Gariaband	Gariaband	100	24
10.02.2016	Bhagdeva	Kondagaon	80	20
11.02.2016	KVK- Kanker	Kanker	110	20

Plate 3.6.2a Field Day Programme at village Bhagdeva, Badebendri, District-Kondagaon and Pushwada, District-Kanker (C.G)

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2015-2024

TNAU, Coimbatore, Tamil Nadu

Field Demonstrations on STCR-IPNS Technology for various crops

A total of 72 field demonstrations on STCR-IPNS technology have been planned with 14 crops at tribal farmer's holdings of Coimbatore (Western zone), Salem (North western zone) and Dindigul districts (Southern zone). The details of the demonstrations are furnished below:

STCR-IPNS demonstrations in Coimbatore District

Gingelly (TMV 3)

Seven field demonstrations were conducted at Gopanari with gingelly *var*. TMV 3. The treatments include blanket recommendation, STCR–NPK- 0.9 t ha^{-1} and STCR-IPNS –0.9 t ha^{-1}, farmers' practice and control. The results revealed that the highest yield of 0.930 t ha^{-1} was recorded in STCR-IPNS treatment followed by 0.850 t ha^{-1} in STCR-NPK alone treatment (Table 3.6.2e) while control and farmers' practice recorded relatively lower yields. The highest response ratio of 6.80 kg kg^{-1} was recorded for STCR-IPNS treatment followed by STCR-NPK alone (5.46 kg kg^{-1}). Both the treatments recorded relatively higher yield and response ratio when compared to blanket recommendation (0.740 t ha^{-1} and 3.38 kg kg^{-1}, respectively) and farmers' practice (0.58 kg ha^{-1} and 2.87 kg kg^{-1}, respectively). The mean increase in yield due to IPNS over blanket and farmers' practice was 25.68 and 60.34 per cent; RR was 3.42 and 3.93 and BCR was 0.26 and 0.60, respectively.

Sorghum (CO 30)

Five field demonstrations were conducted at Gopanari with sorghum (CO 30). The range and mean values of both the locations clearly revealed that the highest mean yield of 3.60 t ha^{-1} was recorded in STCR-IPNS-3.5 t ha^{-1} followed by 3.24 t ha^{-1} in STCR-NPK alone-3.5 t ha^{-1} (Table 3.6.2e) while blanket and farmers' practice recorded relatively lower yields (2.98 & 2.07 t ha^{-1}). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 20.87 and 73.91 per cent; RR was 9.82 and 11.10 kg kg^{-1} and BCR was 0.25 and 0.60, respectively.

Table 3.6.2e Results of STCR-IPNS demonstration on sorghum and gingelly in Gopanari, Village, district Coimbatore

Treatment	Sorghum (CO 30) (target 3.5 t ha^{-1}) (Mean of 5 demonstrations)			Gingelly (TMV3) (target 0.9 t ha^{-1}) (Mean of 7 demonstrations)		
	Grain yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR	Seed yield (kg ha^{-1})	RR (kg kg^{-1})	BCR
GRD	2.98	5.03	1.39	0.740	3.38	1.53
STCR	3.24	11.97	1.59	0.850	5.46	1.74
STCR-IPNS	3.60	14.85	1.64	0.930	6.80	1.79
Farmers' practice	2.07	3.75	1.04	0.580	2.87	1.19
Control	1.73	-	0.95	0.480	-	1.01

IPNS: NPK + FYM @ 12.5 t ha^{-1}

Maize Hybrid (CO 6)

Six field demonstrations were conducted at Gopanari with maize hybrid CO 6. The range and mean values of both the locations clearly revealed that the highest mean yield of 9.98 t ha^{-1} was recorded in STCR-IPNS-10 t ha^{-1} followed by 9.49 t ha^{-1} in STCR-NPK alone-10 t ha^{-1} (Table 1.6) while blanket and farmers' practice recorded relatively lower yields (8.26 & 6.27 t ha^{-1}). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 20.82 and 59.17 per cent; RR was 3.25 and 4.12 kg kg^{-1} and BCR was 0.37 and 0.71, respectively.

Okra (Hybrid Co Bh H1)

Three field demonstrations were conducted at Gopanari with okra Hybrid Co Bh H1. The range and mean values of both

the locations clearly revealed that the highest mean yield of 15.43 t ha^{-1} was recorded in STCR-IPNS-15 t ha^{-1} followed by 14.27 t ha^{-1} in STCR-NPK alone-15 t ha^{-1} (Table 3.6.2f) while blanket and farmers' practice recorded relatively lower yields (13.91 & 9.36 t ha^{-1}). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 10.92 and 64.85 per cent; RR was 24.24 and 24.08 kg kg^{-1} and BCR was 0.29 and 0.80, respectively.

Table 3.6.2f   Results of STCR-IPNS demonstration on maize and okra in Gopanari village, district Coimbatore

Treatment	Okra (Hybrid Co Bh H1) (target 15 t ha^{-1}) (Mean of 3 demonstrations)			Maize (TNAU Hybrid CO 6) (target 10 t ha^{-1}) (Mean of 6 demonstrations)		
	Fruit yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR	Grain yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR
GRD	13.91	17.20	1.99	8.26	9.47	2.01
STCR	14.27	35.69	2.21	9.49	11.58	2.33
STCR-IPNS	15.43	41.44	2.28	9.98	12.72	2.38
Farmers' practice	9.36	17.36	1.48	6.27	8.60	1.66
Control	7.03	-	**1.19**	4.48	-	1.31

IPNS : NPK+FYM @ 12.5 t ha^{-1}

Rice (Bhavani)

Sixteen field demonstrations were conducted in which fourteen at Sadivayal and two demonstrations at Seengapathi were conducted with rice (Bhavani). The range and mean values of both the locations clearly revealed that the highest mean yield of 6.03 t ha^{-1} was recorded in STCR-IPNS-6.0 t ha^{-1} followed by 5.75 t ha^{-1} in STCR-NPK alone-6.0 t ha^{-1} (Table 3.6.2g) while blanket and farmers' practice recorded relatively lower yields (4.75 & 3.74 t ha^{-1}). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 27.12 and 61.52 per cent; RR was 2.37 and 4.04 kg kg^{-1} and BCR was 0.27 and 0.52, respectively.

Turmeric (BSR2)

One field demonstration was conducted at Sadivyal with turmeric (BSR2). The range and mean values of both the locations clearly revealed that the highest mean yield of 29.6 t ha^{-1} was recorded in STCR-IPNS-30 t ha^{-1} followed by 27.2 t ha^{-1} in STCR-NPK alone-30 t ha^{-1} (Table 3.6.2g) while blanket and farmers' practice recorded relatively lower yields (21.6 & 17.2 t ha^{-1}). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 37.04 and 72.09 %; RR was 6.68 and 8.13 kg kg^{-1} and BCR was 0.69 and 1.06, respectively.

Table 3.6.2g   Results of STCR-IPNS demonstration on Turmeric and Rice in Sadivayal and Seengapathi village, respectively, district Coimbatore

Treatment	Turmeric (BSR2) (target 30 t ha^{-1})			Rice (Bhavani) (target 6.0 t ha^{-1}) (Mean of 14 demonstrations)		
	Fresh rhizome yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR	Grain yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR
GRD	21.6	32.70	2.06	4.75	8.77	1.35
STCR	27.2	34.24	2.48	5.75	10.22	1.58
STCR-IPNS	29.6	39.38	2.75	6.03	11.13	1.62
Farmers' practice	17.2	31.25	1.69	3.74	7.09	1.10
Control	11.2	-	1.15	2.55	-	0.82

IPNS : NPK+FYM @ 12.5 t ha^{-1}

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2015-2024

Cotton (Anjali)

Three field demonstrations were conducted on cotton (Anjali), in which one was at Sadivayal and two were at Vellapathi village. The range and mean values of the three locations clearly revealed that the highest mean seed cotton yield of 2 .48 t ha^{-1} was recorded in STCR-IPNS-2.5 t ha^{-1} followed by 2.29 t ha^{-1} in STCR-NPK alone-2.5 t ha^{-1} (Table 3.3.2h) while blanket and farmers' practice recorded relatively lower yields (2.05 & 1.45 t ha^{-1}). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 20.70 and 70.70 per cent, RR was 2.0 and 2.20 kg kg^{-1} and BCR was 0.34 and 0.74, respectively.

Black Gram (MDU 1)

Two field demonstrations were conducted at Sadivayal with Black Gram (MDU 1). The range and mean values of both the locations clearly revealed that the highest mean yield of 0.925 t ha^{-1} was recorded in STCR-IPNS-0.9 t ha^{-1} followed by 0.863 t ha^{-1} in STCR-NPK alone-0.9 t ha^{-1} (Table 3.6.2h) while blanket and farmers' practice recorded relatively lower yields (0.753 & 0.578 t ha^{-1}). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 22.84 and 60.03 %; RR was 0.93 and 1.90 kg kg^{-1} and BCR was 0.31 and 0.67, respectively.

Table 3.6.2h Results of STCR-IPNS demonstration on cotton and Blackgram in Sadivayal , Vellapathi and Seengapathi village, respectively, district Coimbatore

Treatment	Cotton (Anjali) (Target 2.5 t ha^{-1}) (Mean of 3 demonstrations)			Blackgram (MDU 1) (target 0.9 t ha^{-1}) (Mean of 2 demonstrations)		
	Seed cotton yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR	Grain yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR
GRD	2.06	4.58	1.66	0.753	3.20	1.64
STCR	2.32	6.43	1.87	0.863	3.61	1.85
STCR-IPNS	2.54	7.48	2.02	0.925	4.13	1.95
Farmers' practice	1.42	4.28	1.23	0.578	2.23	1.28
Control	0.96	-	0.89	0.433	-	0.99

IPNS : NPK+FYM @ 12.5 t ha^{-1}

Groundnut

Seven field demonstrations were conducted at Sadivayal with Groundnut Co 7. The range and mean values of both the locations clearly revealed that the highest mean yield of 2.57 t ha^{-1} was recorded in STCR-IPNS-2.5 t ha^{-1} followed by 2.43 t ha^{-1} in STCR-NPK 2.5 t ha^{-1} (Table 3.6.2i) while blanket and farmers' practice recorded relatively lower yields (1.94 & 1.62 t ha^{-1}). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 32.47 and 58.64 %; RR was 1.15 and 1.69 kg kg^{-1} and BCR was 0.36 and 0.54, respectively.

Table 3.6.2i Result of STCR-IPNS demonstration Groundnut at Sadivayal Village, Erode District

Treatment	Groundnut (CO 7) (target 2.5 t ha^{-1}) (Mean of 7 demonstrations)		
	Fresh rhizome yield (t ha^{-1})	RR (kg kg^{-1})	BCR
GRD	1.94	4.42	1.34
STCR-NPK	2.43	4.98	1.61
STCR-IPNS[-1]	2.57	5.57	1.70
Farmers' Practice	1.62	3.88	1.16
Control	1.28	-	0.95

STCR-IPNS : NPK+FYM @ 12.5 t ha^{-1}

STCR-IPNS demonstrations in Salem District

Salem District (North Western Zone)

Sugarcane (CO 86032)

Three frontline demonstrations were conducted in which two were at Pethakurichi and one at Kaikanvalavu with sugarcane *var.* CO 86032 having the treatments, blanket recommendation, STCR – NPK - 125 t ha^{-1}, STCR - IPNS – 125 t ha^{-1}, farmers' practice and control. The highest mean cane yield of 125.9 t ha^{-1} was recorded in STCR-IPNS-125 t ha^{-1} followed by 118.7 t ha^{-1} in STCR-NPK alone-125 t ha^{-1} (Table 3.6.2j) while blanket and farmers' practice recorded relatively lower yields (107.6 & 76.1 t ha^{-1}). The highest mean RR of 110.4 kg kg^{-1} and BCR of 2.93 were recorded for STCR-IPNS treatment followed by STCR-NPK alone (99.4 kg kg^{-1} & 2.72 respectively). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 17.0 and 65.4; RR was 20.9 and 41.87 kg kg^{-1} and BCR was 0.41 and 1.02, respectively.

Rainfed Tapioca (Mulluvadi)

Four field demonstrations were conducted at Vengayakurichi, Pethakurichi, Karumandurai and Kaikanvalavu with tapioca *var.* Mullavadi. The treatments include blanket recommendation, STCR – NPK- 30 t ha^{-1}, STCR –IPNS - 30 t ha^{-1}, farmers' practice and control. The highest yield of 30.0 t ha^{-1} was recorded in STCR-INPS -30 t ha^{-1} followed by 28.9 t ha^{-1} STCR – NPK alone 30 t ha^{-1} (Table 3.6.2j) while blanket and farmers' practice recorded relatively lower yields (22.1 & 19.3 t ha^{-1}). The highest RR of 64.53 kg kg^{-1} and BCR of 3.19 were recorded for STCR – NPK treatment followed by STCR – NPK alone (59.82 kg kg^{-1} & 3.04 respectively). The per cent increase in yield due to STCR – IPNS over blanket and farmers' practice was 35.74 & 55.44; RR was 34.11 and 38.86 kg kg^{-1} and BCR was 0.84 and 1.02, respectively.

Table 3.6.2j   Results of STCR-IPNS demonstration on Sugarcane and rainfed tapioca in Pethakurichi and Kaikanvalavu village, respectively, district Salem

Treatment	Sugarcane (CO 86032) (target 125 t ha^{-1}) (Mean of 3 demonstrations)			Rainfed tapioca (Mullavadi) (target 30 t ha^{-1}) (Mean of 4 demonstrations)		
	Cane yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR	Tuber yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR
GRD	107.6	89.5	2.52	22.1	30.42	2.35
STCR	118.7	99.4	2.72	28.9	59.82	3.04
STCR-IPNS	125.9	110.4	2.93	30.0	64.53	3.19
Farmers' practice	76.1	68.53	1.91	19.3	25.67	2.17
Control	53.9	-	1.45	15.0	-	1.88

IPNS : NPK+FYM @ 12.5 t ha^{-1}

Tomato (PKM1)

In all nine frontline demonstrations were conducted consisting of three at Pethakurichi, two at Athimarathuvalavu and one each at Vengayakurichi, Nathampattu, Moongilpattu and Pagudupattu with tomato hybrid Sivam. The treatments include blanket recommendation, STCR – NPK alone-80 t ha^{-1}, STCR - IPNS - 80 t ha^{-1}, farmers' practice and control. The highest mean fruit yield of 80.0 t ha^{-1} was recorded in STCR-IPNS-80 t ha^{-1} followed by STCR-NPK alone-80 t ha^{-1} of 75.8 t ha^{-1}). Blanket and farmers, practice recorded relatively lower yields (69.6 & 43.4 t ha^{-1}). The highest mean RR of 89.33 kg kg^{-1} and BCR of 3.51 were recorded for STCR-IPNS treatment followed by STCR-NPK alone (75.8 t ha^{-1}, 83.12 kg kg^{-1} & 3.37, respectively). Both blanket and farmers' practice recorded relatively lower yield, RR and BCR as compared to STCR treatments (Table 3.6.2k). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 14.9 and 84.3 per cent; RR was 18.85 and 24.74 kg kg^{-1} and BCR was 0.48 and 1.40, respectively.

International
Decade of Soils
2015-2024

Carrot hybrid (Tokito)

Two field demonstrations were conducted one each at Pethakurichi and Moongilpattu with carrot hybrid Tokito. The treatments include blanket recommendation, STCR –NPK alone - 40 t ha^{-1}, STCR - IPNS – 40 t ha^{-1}, farmers' practice and control. The highest root yield of 40.75 t ha^{-1} was recorded in STCR-IPNS-40 t ha^{-1} followed by 38.75 t ha^{-1} in STCR-NPK alone-40 t ha^{-1} (Table 3.6.2k) while blanket and farmers' practice recorded relatively lower yields. The highest RR of 30.81 kg kg^{-1} and BCR of 4.40 were recorded for STCR-IPNS treatment followed by STCR-NPK alone. The per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 37.4 & 61.4; RR was 8.83 and 14.84 kg kg^{-1} and BCR was 0.83 and 1.23 respectively.

Table 3.6.2k **Results of STCR-IPNS demonstration on tomato and carrot in Pethakurichi, Athimarathuvalavu, Vengayakurichi, Nathampattu, Moongilpattu and Pagudupattu village, respectively, district Salem**

Treatment	Tomato (Sivam) (target 80 t ha^{-1}) (Mean of 9 demonstrations)			Carrot (Tokito) (target 40 t ha^{-1}) (Mean of 2 demonstrations)		
	Fruit yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR	Root yield (t ha^{-1})	Mean RR (kg kg^{-1})	Mean BCR
GRD	69.6	70.48	3.03	29.85	21.98	3.57
STCR	75.8	83.12	3.37	38.75	27.03	4.20
STCR-IPNS	80.0	89.33	3.51	40.75	30.81	4.40
Farmers' practice	43.4	64.59	2.11	25.25	15.97	3.17
Control	20.3	-	1.14	20.95	-	2.93

IPNS : NPK+FYM @ 12.5 t ha^{-1}

Cabbage hybrid (Harirani)

A field demonstration was conducted at Moongilpattu village with cabbage hybrid Harirani. The treatments include blanket recommendation, STCR-NPK alone - 70 t ha^{-1}, STCR - IPNS –70 t ha^{-1}, farmers' practice and control. The highest mean head yield of 69.5 t ha^{-1} was recorded in STCR-IPNS-70 t ha^{-1} followed by 67.6 t ha^{-1} in STCR-NPK alone-70 t ha^{-1} (Table 3.6.2l) while blanket and farmers' practice recorded relatively lower yields (55.3 & 45.1 t ha^{-1}). The highest mean RR of 80.29 kg kg^{-1} and BCR of 4.38 were recorded for STCR-IPNS treatment followed by STCR-NPK alone (76.35 kg kg^{-1} & 4.27, respectively). The mean per cent increase in yield due to STCR- IPNS over blanket and farmers' practice was 25.7 and 54.1; RR was 19.8 and 25.29 kg kg^{-1} and BCR was 0.80 and 1.32, respectively.

Table 3.6.2l Result of STCR-IPNS demonstration Cabbage Moongilpattu Village, Salem District

Cabbage (Harirani) (70 t ha^{-1})			
Treatment	Head yield (t ha^{-1})	RR (kg kg^{-1})	BCR
GRD	55.3	60.49	3.58
STCR-NPK	67.6	76.35	4.27
STCR-IPNS^{-1}	69.5	80.29	4.38
Farmers' Practice	45.1	55.0	3.06
Control	30.8	-	2.28

STCR-IPNS : NPK+FYM @ 12.5 t ha^{-1}

STCR-IPNS demonstrations in Dindigul District

Rainfed Maize hybrid (Kanagagold)

Three field demonstrations (Plate 3.6.2b) were conducted at Valichettipatty with TNAU maize hybrid CO 6. The

treatments include blanket recommendation, STCR –NPK alone-5 t ha^{-1} and STCR - IPNS - 5 t ha^{-1}, farmers' practice and control. The mean and range values indicated that the highest mean grain yield of 5.12 t ha^{-1} was recorded in STCR-IPNS-5 t ha^{-1} followed by STCR-NPK alone-5 t ha^{-1} (4.75 t ha^{-1}). Blanket and farmers' practice recorded relatively lower yields (3.72 & 2.97 t ha^{-1}). The highest mean RR of 19.87 kg kg^{-1} and BCR of 1.67 were recorded for STCR-IPNS treatment followed by STCR-NPK alone. Both blanket and farmers' practice recorded relatively lower yield, RR and BCR as compared to STCR treatments (Table 3.6.2m). The mean per cent increase in yield due to STCR-IPNS over blanket and farmers' practice was 37.60 and 72.39 per cent; RR was 3.31 and 5.09 kg kg^{-1} and BCR was 0.37 and 0.62, respectively.

Table 3.6.2m Result of STCR-IPNS demonstration Rainfed maize Valichettipatti Village, Dindigul District

Rainfed maize (TNAU Maize hybrid CO6) (target 5 t ha^{-1}) (Mean of 3 demonstrations)			
Treatment	Grain yield (t ha^{-1})	RR (kg kg^{-1})	BCR
GRD	3.72	16.56	1.30
STCR-NPK	4.75	17.70	1.60
STCR-IPNS^{-1}	5.12	19.87	1.67
Farmers' Practice	2.97	14.78	1.05
Control	1.74	-	0.64

STCR-IPNS : NPK+FYM @ 12.5 t ha^{-1}

Plate 3.6.2b Field demonstrations at Coimbatore Dt.

MPKV, Rahuri, Maharashtra

Kharif season

A preliminary survey was conducted during summer season in selected villages *viz*. Kelungan, Malegaon, Godre, Rajur No.1, Chakore-Beje and Chirapali for conduct of STCR based FLDs. Fertilizer was applied as per STCR prescription equations of respective crop developed by STCR, Rahuri centre. The rest of recommended package of practices were followed. The farmer's practice (respective crops grown on 20 area adjacent to FLD) was taken as control to compare yield from FLD's. The yield was recorded after harvest of the crop. The field demonstration plots were visited during crop growth period and farmers were advised regarding package of practices and plant protection measures. The details of trials conducted and yield recorded are given in Table 3.6.2n. The information about training programme, group discussions and field visits were also presented in Table 3.6.2o.

International
Decade of Soils
2015-2024

Table 3.6.2n   Result of FLDs conducted during _kharif_ and _rabi_ under TSP at Pune, Ahmednagar and Nasik district (Maharashtra)

Crop/ variety	Villages	Yield q ha^{-1}			
		Farmers' Practice		As per STCR target	
		Range	Mean	Range	Mean
Paddy (Indrayani)	Malegaon and Kelungan	17-26	21.87	24-35	30.37
Fingermillet (Phule Nachani)	Chakore-Beje and Chirapali	18-28	23.30	22-39	31.15
Paddy (Indrayani)	Shivali, Rajur No.2 and Aambe	11-30	20.23	18-36	26.67

STCR target for Paddy – 30 q ha^{-1} and STCR target for Fingermillet – 20 q ha^{-1}

Table 3.6.2o   Details of FLDs conducted during _rabi_ under TSP at Pune, Ahmednagar, Nasik and Akola district (Maharashtra)

Name of village, Block & district	No. of tribal farmers participated (Women)	Name of tribe	Any other information
Village: Godre and Rajur, Block: Junner District: Pune	30 (14)	_Mahadev koli_	Training Programme organized for conduct of FLD's and collected soil samples.
Village: Kelungan and Malegaon Block: Akole District: Ahmednagar	55 (12)	_Mahadev koli_	Training Programme organized for conduct of FLD's and collected soil samples.
Village: Godre Rajur, Block: Junner District: Pune	50 (8)	_Mahadev koli_	Input Distribution Programme organized for conduct of FLD's.
Village: Chirapali and Chakore-Beje Rajur, Block: Junner District: Pune	55 (20)	_Mahadev koli and Kokani_	Farmer's training programme and Input Distribution Programme organized for conduct of FLD's.
Village: Kelungan and Malegaon Block: Akole District: Ahmednagar	60 (15)	_Mahadev koli_	Input Distribution Programme organized for conduct of FLD's.
Village: Godre Rajur, Block: Junner District: Pune	25	_Mahadev koli_	Arranged the study tour of Tribal Farmers to Mahatma Phule Krishi Vidyapeeth, Rahuri.
Village: Chakore-Beje, Rajur, Block: Trymbakeshwar District: Nasik	18 (5)	_Mahadev koli and Kokani_	Field visit organized to FLD's at Chakore-Beje, Rajur, Block: Trymbakeshwar, District: Nasik.
Village: Chakore-Beje, Rajur, Block: Trymbakeshwar District: Nasik	55 (22)	_Mahadev koli and Kokani_	Farmer's ralley organized for tribal farmers at Chakore-Beje, Rajur, Block: Trymbakeshwar, District: Nasik.
Block: Junner District: Pune	80 (32)	_Mahadev koli_	Farmer's ralley organized for tribal farmers at – Junner, Dist :- Pune.
Village: Rajur Block: Akole District: Ahmednagar	48 (18)	_Mahadev koli_	Farmer's ralley organized for tribal farmers at Rajur, Tal;- Akole, Dist:- Ahmednagar..
Village: Rajur Block: Akole District: Ahmednagar	48 (18)	_Mahadev koli_	Jai Kisan Jai Vigyan Week organized at Rajur, Tal;- Akole, Dist:- Ahmednagar.

Healthy soils for a healthy life

UAS, Bengaluru, Karnataka

Hybrid Maize

Under STC programme, 109 tribal farmers at Poorani Pod and Kalyani Pod villages, Yallanduru taluk, and Jeerigegadde, Mavathuru and Havinamoole villages of Kolegala taluk, Chamarajanagara district were identified based on the land available with them and collected the soil samples geo-referenced. These samples were analyzed for available major and micro nutrients. Based on the soil test values and yield target fixed, seeds and fertilizers were distributed for one acre each to these farmer's for maize and ragi crops by using the maize and ragi targeted yield equation developed under STCR project at ZARS, Mandya, UAS, GKVK, Bangalore (Table 3.6.2p; Plate 3.6.3).

Maize

$F.N = 3.84\,T - 0.42\,S.N\;(KMnO_4\text{-}N)$

$F.P_2O_5 = 1.57\,T - 1.18\,S.\,P_2O_5(Bray's)$

$F.K_2O = 1.15\,T - 0.11\,S.\,K_2O(Am.\,Ac.)$

Ragi

$F.N. = 9.128239\,T - 0.678209\;STV\;(KMnO_4\text{-}N) - 0.635104\;OM$

$F.P_2O_5. = 1.603342\,T - 0.342016\;STV\;(Bray's\;P_2O_5) - 0.325642\;OM$

$F.K_2O. = 2.329544\,T - 0.174945\;STV\;(Am.\,Ac.\,K_2O) - 0.370249\;OM$

Table 3.6.2p Yield of maize and ragi crops under STC Programme at Mavathuru, Jeerigegadde and Havinamoole villages, Kolegala taluk, Chamarajanagara district for Soliga tribe

Village	Crop	No. of FLDs	Yield obtained in				Yield advantage (%)	
			Farmers practice (q ha^{-1})		STCR approach (q ha^{-1})			
			Range	Mean	Range	Mean	Range	Mean
Poorani Pod	Maize	18	63.00-81.0	71.68	72.00-92.0	82.58	8.70-22.97	15.20
Kalyani Pod	Maize	1	79.0	79.00	91.0	91.00	15.19	15.19
Mavathuru	Maize	10	68.00-84.0	75.40	79.00-94.0	86.70	5.06-27.54	15.19
Havinamoole	Maize	30	62.00-84.0	73.10	76.00-96.0	85.60	9.21-27.42	17.36
Jeerigegadde	Maize	20	65.00-86.0	76.60	78.00-96.0	86.40	9.21-18.57	12.84
Poorani Pod	Ragi	19	26.33-33.0	30.11	36.00-43.0	39.32	15.63-43.33	30.84
Kalyani Pod	Ragi	11	26.00-35.0	31.00	36.00-44.0	40.00	17.14-46.43	29.61
Total		**109**						

In all 109 FLDs were conducted comprising of 79 on maize and 30 on *ragi* crop. In Poorani Pod and Kalyani Pod villages of Yallanduru taluk in Chamarajanagara district, 19 FLDs were conducted on maize, where the mean yield by

Plate 3.6.3 a) Visit of Project Coordinator of STCR and STCR Incharge scientists of different states to STCR experimental plots at ZARS, GKVK, Bangalore

b) Hybrid maize crop with differentforms and levels of potassium at Sothenahalli village of Doddaballapura taluk

c) Influence of phosphorus andpotassium levels on finger millet inlow P and K soilsof Ramanagara district

farmers' practice, yield by STCR approach and percent yield advantage were 71.68, 82.58 and 15.20, respectively. Whereas, in case of FLDs conducted on *ragi* at 30 locations the yield of by farmers' practice, yield by STCR approach and percent yield advantage were 30.43, 39.57 and 30.01, respectively. In Mavathuru, Jeerigegadde and Havinamoole villages of Kolegala taluk in Chamarajanagara district 90 FLDs were conducted on maize and the yield by farmers' practice, yield by STCR approach and percent yield advantage were 74.65, 86.05 and 15.27, respectively.

3.7 MGMG activities undertaken during the year 2016-17

1. Different activities include field demonstrations on organic farming, composting, soil sampling etc. Kisan sangosthi as well as training programmes on organic farming and soil health were also organized. Besides, mobile based advisory to farmers was given on aspects such as crop variety, market price of commodities, fertilizer application etc. Literatures regarding composting were also distributed during the training programme.

2. Soil samples were collected from farmers' field, analysed the samples in the laboratory and data was properly recorded for the preparation of soil health cards. Team members frequently visited the villages. Conducted demonstrations on soybean, rice and wheat crops in some of the villages. Field trials were conducted on 'Response of Crops to Applied Potassium in Vertisols'. Experiments were conducted on the farmers' fields during *kharif* and *rabi* season in these villages by distributing inputs like certified seeds, fertilizers, insecticides, herbicides etc. Time-to-time guidance to the farmers to take proper control measures. Regularly interacted with the farmers through door-to-door interaction, visits, mobile, phones, distribution of literature, meeting, trainings, sangosthi etc.

3. Major problems faced by the farming community were identified, advisories were provided and awareness generated. Literature support in Hindi on improvement in crop productivity, sustainable soil health, bio-fertilizers and their usefulness were provided to some representative farmers. The teams conducted interface meetings with the farmers. Linkage were also made with other government agencies like M.P. State Department of Agriculture, KVK, Raisen, ICAR-CIAE, Bhopal etc. better integration of dissemination of benefits to the farmers. Awareness were also created among the farmers regarding the usefulness of high yielding low water consuming varieties, their availability in nearby government agencies. Some representative farmers were trained on soil sampling techniques and informed about the soil testing methods using '*Mridaparikshak*' (Mini Soil Testing Laboratory). Awareness about rainfall scenario during the monsoon as predicted by IMD, crop type and varieties to be sown, steps to be taken for weed management and removal of excess water from the field, improved nutrient management among the farmers were created through farmer's interaction, booklet distribution and mobile advisories. Time to time advisory on balanced fertilization and integrated nutrient mangement for major crops, water management, rain water harvesting and their efficient recycling was provided during the year through village meetings, sangosties and also through mobile contact with different farmers.

4. Conducted Pre-*kharif* Kisan Sammelan to guide farmers about techniques to enhance crop production, importance of soil testing and to educate the farmers about the linkage between soil health *vis-a-vis* animal and human health

5. Mobile based advisory on soil health card

6. Several literatures were distributed including Bharatiya Mridaon mein sukshm evam gaun poshak tatva: kami ki sthiti, nivaran evam phasalwar sanstutiyan, Zinc: mrida mein kami, prabandhan evam phasalwar sanstutiyan, Gandhak (Sulphur): mrida mein kami, prabandhan evam phasalwar sanstutiyan

7. Participatory conservation agriculture demonstrations conducted in the farmers' fields in selected villages during *kharif* and *rabi* season.

8. Weed management advisories issued to the farmers from time to time by personal visits of experts, mobile messages, telephonic talk and demonstrations.

9. Pest and disease management advisories issued to the farmers from time to time by personal visits of experts, mobile messages, telephonic talk and demonstrations.

10. Demonstration of CA machinery to the farmers and also extended support for general awareness about the adaptation to the climate change.

11. Resource conservation technologies were demonstrated and soil health issues and their management strategies were discussed in farmer meetings and *sangosthi.*

12. Training on different aspects of soil health management, composting and conservation agriculture practices were conducted by bringing the farmers to the institute.

Plate 3.7 Kisan Sangosthi and field visit under MGMG program

Table 3.7 ICAR-IISS, Bhopal Adopted Villages under MGMG

S.No.	Group	Name of five villages adopted by Group Leader
1	Dr. A.K. Patra, Director, ICAR-IISS Dr. A.B. Singh, PS, SBD & Nodal Officer Dr. A.O. Shirale, Scientist, SC&F Dr. Sudeshna Bhattacharjya, Scientist, SBD	Dobra, Khejra, Kurana, Badarkha Sadak, Mubarakpur
2	Dr. M.C. Manna, HOD, SBD Dr. K. Ramesh, PS, SC&F & Co-Nodal officer Dr. N.K. Sinha, Scientist, SPD	Acharpura, Parewakheda, Araweliya, Hazampura and Parewalia sahani
3	Dr. M. Singh PC, LTFE Dr. S. Kundu, PS, ESS Dr. R.H. Wanjari, SS, LTFE Dr. K. Bharati, PS, SBD	Choupdakala, Ghat Kheri, Sayyaid Semara, Emaliya Chopra and Amoni
4	Dr. J.K. Saha, HOD, ESS Dr. N.S. Bhogal, PS (STCR) Dr. M.L. Dotaniya, Scientist, ESS	Islam Nagar, Dewalkhedi, Bharonpura, Kalyanpura, Puraman Bhavan
5	Dr. D.L.N. Rao, AINP, SBB Dr. Sanjay Srivastava, PS, SC&F Dr. K.M. Hati, PS, SPD Dr. K.C. Shinogi, Scientist, ITMU	Bankhedi, Baroda, Sojna, Amaravadi and Kuravadi
6	Dr. A.K. Shukla, PC, MSPE Dr. R. Elanchezhian, PS, SC&F Dr. R.K. Singh, PS, SPD Dr. J.K. Thakur, Scientist, SBD	Sagoni, Munirgarh, Gudawal, Chhattarpura, Chiklod khurd
7	Dr. A. K. Biswas, HOD, SC&F Dr. Brij Lal Lakaria, PS, SC&F Dr. Asha Sahu, Scientist, SBD Dr. Bharat P. Meena, Scientist, SC&F	Golkhedi, Binapur, Kanchbavli, Khamkheda and Raslakhedi
8	Dr. R.S. Choudhary, HOD, SPD Dr. P. Jha, PS, SC&F Dr. S.R. Mohanty, PS, SBD Dr. A.K. Vishwakarma, PS, SPD	Raipur, Kanera, Momanpur, Kadhaiya and Karod Khurd
9	Dr. P. Dey, PC, STCR Dr. N.K. Lenka, PS, SC&F Dr. M. Mohanty, Scientist, SPD Dr. M. Vassanda Coumar, Scientist, ESS	Ratibad, Rasuliya Pathar, Mugaliahat, Ratanpur Sadak, Chandukhedi
10	Dr. A.K. Tripathi, PS, SBD Dr. S. Ramana, PS, SBD Dr. J. Somasundaram, PS, SPD Dr. A. Mandal, Scientist, SBD	Dobra Jagir, Kolua Khurd, Sagoni Kalan, Chor Sagoni, Adampur Chhawni
11	Dr. Ajay, PS, ESS Dr. Tapan Adhikari, PS, ESS Dr. S. Lenka, Scientist, ESS Dr. S. Rajendiran, Scientist, ESS	Shahpur, Devpur, Kasi Barkeda, Sagoni, and Barkedi Hajam

International
Decade of Soils
2015-2024

4. Training and Capacity Building

4.1. Training Attended by Staff

a.   Participation in Training (Category-wise)

S. No.	Category	No. of employees undergone training during April 2016–March 2017
1	Scientist	13
2	Technical	7
3	Administrative & Finance	2
4	Skilled Supporting Staff	10
	Total	**32**

b.   HRD fund allocation and utilization (Rs. in Lakhs)

S.No.	RE for HRD 2016-17	Actual Expenditure 20117 for HRD6-17 for HRD
1.	3.70	3.69230

c.   Training attended during 2016-17

Category: Scientists

S.No.	Name of employee	Title	Organizer	Duration
1	Dr. K. Ramesh	ICAR sponsored short course on "Personality Development".	NAARM, Hyderabad	11-21 July, 2016
2	Dr. Sudeshna Bhattacharjya	SAARC Training on Climate Change	ICAR-IISS Bhopal	16-23 August, 2016
3	Dr. Priya Gurav	ICAR sponsored short course on 'Advances in Soil testing and soil test crop response based fertilizer management".	ICAR-IISS, Bhopal	23 August- 1 September, 2016
4	Dr. M. C. Manna	Endeavour Executive Fellowship	The University of Newcastle, Callaghan Campus, GCER, NSW, Australia	1 June - 30 September, 2016
5	Dr. M. Vassanda Coumar	Endeavour Research Fellowship	The University of Newcastle, Callaghan Campus, GCER, NSW, Australia	1 June - 30 September, 2016
6	Dr. N. K. Sinha	Roth-C model experience training program	NBSSLUP, Nagpur.	22-23, June, 2016
7	Dr. R. Elanchezhian	ICAR sponsored short course on "Recent advances in crop physiology".	TNAU, Coimbatore	14-23 September, 2016
8	Dr. Pradip Dey, Dr. R.S. Chaudhary, Dr. K.M. Hati and Dr. N.K. Sinha	Advanced training on "MIR Spectroscopy Technology".	ICRAF Nairobi, Kenya	21-25 November, 2016
9	Dr. M. L. Dotaniya	CAFT training on "Ecological Agriculture For Sustainability".	GBPUA&T Pantnagar	9 February, 2017 to 1 March, 2017

Healthy soils for a healthy life

S.No.	Name of employee	Title	Organizer	Duration
10	Dr. A.K. Patra	Training programme on "Managerial Effectiveness".	IIM, Ahmedabad	9-14 January, 2017
11	Dr. B. P. Meena	ICAR sponsored short course on "Advances in engineering tools and techniques for precision agriculture".	ICAR-IISS, Bhopal	10-19 January, 2017
12	Dr. Sonalika Sahoo	Professional Attachment Training	CESCRA, ICAR - IARI, New Delhi	11 May, 2016 to 27 August, 2016
13	Dr. Sonalika Sahoo	ICAR-NICRA sponsored workshop cum training programme on "Crop Simulation models in Climate Change Impact Assessment".	ICAR-IISS, Bhopal	14-18 February, 2017
14	Dr. Abhay Omprakash Shirale	ICAR short course on "Advances in Assessment of Soil Pollution and its Remediation".	ICAR-IISS, Bhopal	16-25 March, 2017

C2 Category: Technical staff

S.No.	Name of employee	Title	Organizer	Duration
1	Mr. R. K. Mandloi, Mr. V.B. Pal and Mrs. Seema Sahu	ICAR staff training programme on "Use & maintenance of advanced instrument in soil & plant analysis".	ICAR-IISS Bhopal	8-13 August, 2016
2	Mr. O.P. Shukla	ICAR staff training programme on "Selection, Adjustment, Operation and Maintenance of Agricultural Implements for Field and Horticultural Crops".	ICAR-CIAE Bhopal	7-16 August, 2016
3	Mr. Deepak Kaul	ICAR staff training programme on 'Statistical Techniques for Agricultural Data Analysis for Technical Personnel".	ICAR-IASRI, New Delhi	2-11 November, 2016
4	Mr. D.R. Darwai and Mr. K.S. Raghuvanshi	Model Training Programme on "Precision Agriculture Technologies".	ICAR-IARI, New Delhi	16-21 January, 2017

C3 Category: Administrative staff

S.No.	Name of employee	Title	Organizer	Duration
1	Mr. Venny Joy	Enhancing Efficiency and Behavioural Skills for Stenographers Grade III, Pas, PSs, & PPSs	ICAR-NAARM, Hyderabad	24-30 November, 2016
2	Mr. Thomas Joseph	Enhancing Efficiency and Behavioural Skills for Stenographers Grade III, Pas, PSs, & PPSs	ICAR-NAARM, Hyderabad	4-10 January, 2017

International
Decade of Soils
2015-2024

C4 Category: Skilled Supporting Staff (SSS)

S.No.	Name of employee	Title	Organizer	Duration
1	Mr. Harish Kumar Mr. Rambharose Mr. Bhagwat Prasad Mr. A. K. Mishra Mr. Bhoi Lal Uikey Mr. Janak Singh Mr. Kalicharan Mr. A. B. Mate Mr. Sanjay N. Gharde Mr. Pramod K. Raut	Microsoft office & ERP (FMS-MIS) training	ICAR-CIAE, Bhopal	17-19 May, 2016

4.2. Professional Attachment Training Organized for Scientist Probationers

Name of the Scientist	Name of the College/Institute/University	Duration (month)	Name of the Scientist/Mentor
Ms. Suvana Sukumaran	ICAR-Central Institute of BrackishwaterAquaculture, Chennai	11.05.2016 to 10.10.2016	Dr. Pramod Jha
Dr. Vakada Manasa	ICAR-Indian Rice Research Institute, Hyderabad.	21.11.2016 to 20.02.2017	Dr. Sanjay Srivastava
Dr. Abhijeet Sarkar	ICAR-Indian Institute of Water Management, Bhubaneswar	21.11.2016 to 20.02.2017	Dr. A. K. Biswas
Dr. Kirti Saurabh	ICAR-Research Complex for Eastern Region, Patna	22.11.2016 to 21.02.2017	Dr. J.K. Saha
Dr. K. K. Reddy	Directorate of Groundnut Research, Junagadh	10.11.2016 to 9.02.2017	Dr. M. Mohanty

4.3. Research Guidance for Degree Students

Name of the Student	Name of the College/Institute/University	Degree	Name of the Co-Guide
Mr. Milap Ram Sahu	IGKV Raipur, Chhattisgarh	M.Sc. (Plant Physiology)	Dr R. Elanchezhian
Ms. Priyanka Jadon	RVSKVV, Gwalior (M.P.)	M.Sc (Agri)	Dr. Rajendiran S.
Mr. Sunil Kumar Malviya	RVSKVV, Gwalior (M.P.)	M.Sc.(Soil Science)	Dr. Sangeeta Lenka
Mr. Rameswar Solia	RVSKVV, Gwalior (M.P.)	M.Sc. (Soil Science)	Dr. N. K. Sinha
Mr. Rahul Chandel	RVSKVV, Gwalior (M.P.)	M.Sc. (Agronomy)	Dr. A. K. Vishwakarma
Ms. Diksha Viswakarma	RVSKVV, Gwalior (M.P.)	M.Sc. (Soil Science)	Dr. J. K. Thakur

Training to farmers

- Dr. A. B. Singh provided training to the farmers under ATMA project on 06 July, 2016 and on 04, 06 and 09 August, 2016 sponsored by Department of Agriculture, Bhopal, Madhya Pradesh.
- Dr. A. B. Singh provided training on "Organic Farming and Soil Health" to the farmers from Pipaliya Junnardar Berasia and Bhopal. Thirty five farmers were participated in the programme, arranged by M P Jan Abhiyan Parishad, Bhopal on 16 November, 2016.
- Dr. A. B. Singh delivered a TV talk on "Organic farming and Mridha Swasthya and Jaivik Khad utpadan Vidhi" on 18 November, 2016 at Krishi Doordarshan Kendra, Bhopal.
- Dr. A. B. Singh conducted training on "Unnat Jaivik Krishi Ka Mahatav" to the farmers at Rasla khedi village on 27 December, 2016, organized by Trimurti Adarsh Shiksha Evam Samaj Kalyan Samiti, Bhopal. Thirty five farmers were participated in the training.
- Dr. A. B. Singh conducted training on "Vermicomposting techniques and Organic Farming" organised by ICAR-IISS, Bhopal Madhya Pradesh on 17 March, 2017.

5. AWARDS, HONOURS AND RECOGNITIONS

Awards

1. ICAR-IISS received "Cashless ICAR Institute Award" with a cash prize of Rs 5.00 lakh from ICAR, New Delhi on 14 February, 2017.
2. AICRP on Micro- and Secondary Nutrients and Pollutant Elements in Soils and Plants received Chaudhary Devi Lal Outstanding AICRP Award-2016 by ICAR, New Delhi.
3. Dr. A. K. Shukla has been conferred with NAAS Fellowship 2017.
4. Dr. A. K. Shukla has received IPNI-FAI Award (2016) by FAI, New Delhi.
5. Dr. Pramod Jha, Dr. B.L. Lakaria and Dr. Ritesh Saha awarded Dr. J. S. P. Yadav Memorial award for Excellence in Soil Science from the Indian Society of Soil Science, New Delhi in 2016.
6. Dr. Pradip Dey received "12th International Congress Commemoration Award" of the Indian Society of Soil Science, New Delhi in 2016.
7. Dr. D.L.N. Rao, Pr. Scientist conferred with Emeritus Scientist Award of ICAR on 13 January 2017.
8. Dr. Asha Sahu received M.P. Young Scientist Award 2017 held at MPCST, Bhopal.
9. Dr. B. P. Meena, Dr A.K. Shukla, Dr.A. K. Biswas and Mr. Sahab Siddique received the Shri Ram Award (2016) by FAI, New Delhi.

Dr. Asha Sahu (Left) received young scientist award and Dr. B.P. Meena (Right) received Shri Ram Award

1. Dr. Pankaj K Tiwari received Prof. J. P. Trivedi Award (2015) of Shri Hari-Om-Ashram Trust, Nadiad sponsored by The Gujarat Association for Agricultural Sciences, Ahmedabad.
2. Dr. S. Rajendiran has been awarded Young Scientist Award by Aufau Periodicals during 2nd National Conference on Fundamental and Applied Chemistry on 4th June 2016 held at Salem, T.N.
3. Dr. S. Rajendiran has been awarded Certificate of Excellence by Education Expo TV, Noida (U.P.) during 4th Science and Technology Awards -2016.
4. Dr. S. R. Mohanty received Excellence in Research Award, Samagra Vikas welfare Society, September, 2016.
5. Dr. S. Rajendiran and Dr. M.L. Dotaniya have received Young Scientist Award 2016 from Samagra Vikas Welfare Society (SVWS), Lucknow.
6. Dr. Sangeeta Lenka received Best Research paper award in the "International Conference on Water, Environment, Energy and Society" jointly organized by AISECT University, Bhopal and ATM Texas A & M University, USA, during 15 to 18 March 2016.
7. Dr. Muneshwar Singh and Dr. R.H. Wanjari received the Best Poster Presentation Award in The "1st International Agrobiodiversity Congress"at Vigyan Bhawan and NAAS Complex, New Delhi during 6-9 November, 2016.
8. Dr. M.L. Dotaniya received Excellence in Research Award-2016 by EET CRS Science & Technology, Bangalore.
9. Dr. A. K. Vishwakarma received Distinguished Scientist Award by Science and Technology Society for Integrated Rural Improvement, Thorur, Warangal, Telengana.

International Decade of Soils
2015-2024

10. Dr. Pankaj K Tiwari received "S. N. Ranade Memorial Encouragement Award -2017" by IMT Technologies Ltd., Pune.

Honours and Recognitions

1. Dr. A.K. Patra acted as a President of the Agriculture and Forestry Sciences Section for the period of 2016-17 at the 105th Indian Science Congress.
2. Dr. A.K. Patra elected as a Vice President of the Indian Society of Soil Science, New Delhi for the period of 2016-17.
3. Dr. A.K. Patra elected an Associate Editor, European Journal of Soil Science, UK.
4. Dr. A.K. Patra acted as Thesis Examiner, University of Helsinki, Finland.
5. Dr. A.K. Shukla elected as a Vice President of the Indian Society of Soil Science, New Delhi for the period of 2017-18.
6. ICAR-IISS, Bhopal was awarded Consolation Prize for Best Stall (amongst 77 ICAR Institute) in Krishi Unnati Mela held at ICAR-IARI New Delhi during 15-17 March 2017. Dr RH Wanjari and Mr. D. Kaul participated in the event.
7. Dr. M. C. Manna received Endeavour Executive Fellowship for post-doctoral research in Australia during the year 2016.
8. Dr. M. V. Coumar received Endeavour Research Fellowship for post-doctoral research in Australia during the year 2016.
9. Dr K Ramesh acted as Member of the sectional committee of the section of Agriculture and Forestry Sciences for 2017-18 (105th Indian Science Congress at SVU Tirupati).
10. Dr. Sanjay Srivastava, Dr P. Jha, Dr. I. Rashmi, Dr. T. Adhikari, Dr. A.K. Biswas, Dr. Pradip Dey, Dr. M.V. Coumar and Dr. A.O. Shirale recognized with a certificate of commendation for their significant contribution for the development of Mridaparikshak mini-lab during the National Seminar on "Soil health assessment with Mridaparikshak", at ICAR-IISS, Bhopal on 5 November, 2016.
11. Dr. Brij Lal Lakaria acted as rapporteur of the session during review meeting of the 28th Annual Workshop of AICRP (MSPE) and Pollutant Elements in Soils and Plants during 21-23 March, 2017.
12. Dr. R. Elanchezhian and Dr. J. Somasundaram acted as rapporteur of the session during review meeting of the 28th Annual Workshop of AICRP (MSPE) and Pollutant Elements in Soils and Plants during 21-23 March, 2017.
13. Dr. Sanjay Srivastava acted as Jury member of Zonal Award of Best doctoral presentation (West Zone) of Indian Society of Soil Science at PDKV, Akola on 7September, 2016.
14. Dr. Brij Lal Lakaria received "Reviewer Excellence Award" from Legume Research- An International Journal, Agricultural Research Communication Centre (ARCC) in November, 2016
15. Dr. Brij Lal Lakaria received Certificate of Honor for support to Agri Clinic and Agri Business Scheme of MANAGE, GOI by IECCI (Indo European Chamber of Commerce and Industry), Bhopal.
16. Dr. Sanjay Srivastava acted as Member of India-Afghanistan Task Force for Agriculture Cooperation held at Kabul, Afghanistan.
17. Dr. Pradip Dey acted as Member of IMC, Central Soil Salinity Research Institute, Karnal.
18. Dr. Pradip Dey received Certificate for significant contribution as Lead Team Member of ESP Biome Working Group of BWG 4A- Shrubland under Drylands of Ecosystem Services Partnership.
19. Dr. Pradip Dey acted as panelist in Brainstorming Session on "Efficient utilization of soil test kits for the assessment of soil health" during National Seminar on "Soil Health Assessment with *Mridaparikshak*" on 5 November, 2016.
20. Dr. Pradip Dey acted as steering Committee Member for National Level Programme Management & Review Committee of *KfW & GIZ Soil Projects* at NABARD, Mumbai on 10 March, 2017.
21. Dr. Pradip Dey acted as Member, Research Council, Bihar Agricultural University, Sabour
22. Dr. Pradip Dey elected as a Vice President, Indian Society of Agrophysics, New Delhi.
23. Dr. B. P. Meena and Dr. M.L. Dotaniya acted as rapporteurs during training cum workshop on soil health and fertility management at ICAR-IISS, Bhopal during 21-23 April 2016.
24. Dr. M.L. Dotaniya acted as a Rapporteur in the session of ISSS Best Doctoral Research Presentation Award Contest at 81st Annual Convention of the Indian Society of Soil Science held at RVSKVV, Gwalior during 20-23 October, 2016.

6. Linkages and Collaboration

The Institute has linkages with several ICAR institutes and SAUs located throughout the country. The three AICRPs (LTFE, STCR & MSPE) and one Network Project (BNF) located at IISS Bhopal have 82 cooperating centers spread across almost all the SAUs of the country. As lead centre, the Institute is undertaking platform project of CRP on Conservation Agriculture and external funded projects (INDO-UK Nitrogen centre, Extramural fund of the ICAR, National Agricultural Science Fund) involving linkage with several ICAR Institutes. Also, efforts have been made to strengthen research collaborative activities with SAUs through guidance of PG students by the Institute scientists. Besides, several private firms, *viz*. Nagarjuna Fertilizers and Chemicals Pvt. Ltd., Hyderabad; BASF Pvt. Ltd. (Mumbai); PRII, Gurgaon; Zuari Agro Chemicals Ltd.; Indofil Industries Ltd.; Aquasorb Pvt. Ltd, Vishakhapatanam; and Hindustan Copper Ltd., Malanjkhand are collaborating with the Institute on various R&D activities.

List of Cooperating Centres under AICRPs/AINP

AICRPs/AINP	No. of cooperating centres		
	ICAR	SAUs/S GUs	Total
AICRP on LTFE: PJTSAU, Hyderabad; IGKVV, Raipur; IARI New Delhi, GAU, Junagarh; CSKHPKV, Palampur; BAU, Ranchi; UASGKVK, Bangaluru; KAU, Vellankkara; JNKVV, Jabalpur; PDKV, Akola; VNMKV, Parbhani; OUAT, Bhubaneshwar; PAU, Ludhiana; MPUAT, Udaipur; TNAU, Coimbatore; GBPUAT, Pantnagar; CRIJAF, Barrakpore; IASRI New Delhi	3	15	18
AICRP on STCR: ANGRAU, Hyderabad; RAU, Pusa; IGKVV, Raipur; New Delhi, CSSHAU, Hisar; CSKHPKVV, Palampur; UASGKVK, Bangaluru; KAU, Vellanikkara; JNKVV, Jabalpur; MPKV, Rahuri; OUAT, Bhubaneshwar; PAU, Ludhiana; SKRAU, Bikaner; TNAU, Coimbatore; GBUAT, Pantnagar; BCKV, Kalyani; CRIJAF, Barrackpore; PJNCARI, Puduchery; BHU Banaras; AAU, Gujarat; SKUAT, Srinagar; BAU, Ranchi; IISR, Lucknow; ICAR Complex, Manipur.	4	21	25
AICR on MSPE: PJTSAU, Hyderabad; RAU, Pusa; AAU, Anand; CSSHAU, Hisar; JNKVV, Jabalpur; PDKV, Akola; OUAT, Bhubaneshwar; PAU, Ludhiana; TNAU, Coimbatore; GBPUAT, Pantnagar; IISR, Lucknow; AAU, Jorhat; BCKV, Kalyani; BAU, Ranchi; CSKHPKV, Palampur; CSAUAT, Kanpur; KAU Kerala; UAS, Bengaluru; CAU, Manipur; NIANP, Bengaluru; IARI New Delhi.	2	19	21
AINP on Soil Biodiversity-Biofertilizers: AAU, Jorhat; ANGRAU, Amaravathi; BAU, Ranchi; HAU, Hisar; JNKVV, Jabalpur; KAU, Thrissur ; KAU, Vellayani, MAU, Parbhani; MPUAT, Udaipur; OUAT, Bhubaneswar; RAU, Pusa; TNAU, Coimbatore; YSPUHF, Solan; CRRI, Hazaribagh; University of Delhi; IARI, New Delhi; DGR, Junagarh; GBPUAT, Pantnagar; UAS, Dharwad; Coordinating Unit, ICAR-IISS, Bhopal**.**	3	15	18

7. Ongoing Research Projects

Programme I: Soil Health and Input Use Efficiency

(A) Institute Project

1. Long-term evaluation of integrated plant nutrient supply modules for sustainable productivity in Vertisol.
   Muneshwar Singh, A. K. Biswas, A. B. Singh, R. S. Chaudhary, B. P. Meena

2. Biochar on soil properties and crop performance
   Brij Lal Lakaria, Pramod Jha, A.K. Biswas, K.M. Hati, J. K. Thakur, Vassanda Coumar, A. K. Dubey (CIAE) and S. Gangil (CIAE)

3. Integrated assessment of some IISS Technologies in enhancing Agro-Ecosystems productivity and livelihood sustainability
   Shinogi K.C., Sanjay Srivastava, A.B. Singh, D.L.N. Rao, Radha T.K, B.P. Meena, N.K. Sinha and Hiranmoy Das (On study leave)

4. Nano particle delivery and internalization in plant systems for improving nutrient use efficiency
   R. Elanchezhian, A.K. Biswas, Tapan Adhikari, K. Ramesh, S. Kundu, A.K. Shukla and K. Raju Kumar

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

6. Evaluating rock phosphates for their suitability for direct application
   Sanjay Srivastava, K. Ramesh, A.K. Tripathi, I. Rashmi and P Dey

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

8. Standardization of foliar feeding of zinc for correcting its deficiency and grain enrichment in wheat
   Pankaj K. Tiwari, A. K. Shukla, R. Elanchezhian and B. P. Meena

9. Assessment of important soil properties of India using mid-infrared spectroscopy
   K.M. Hati, M. Mohanty, Pramod Jha, R.S. Chaudhary, Nishant Sinha, J.K. Thakur, M. Vassanda Coumar, Pradip Dey, Muneshwar Singh, A.K. Patra and Javed Rizvi

(B) Externally Funded Projects

10. Network Project on Organic Farming
    A. B. Singh, K. Ramesh, Brij Lal Lakaria, S. Ramana and J.K. Thakur

11. CRP on Nanotechnology (ICAR funded)

a. Use of nano sensors network for field detection of temperature and moisture stress in plant and soil
   Tapan Adhikari, S. Kundu, C.D. Singh, Ajay, N.K. Sinha, A.K. Patra, Navkanta Bhat, K.S. Subramanium and Bajendra

b) Conversion of naturally occurring plant nutrient containing minerals into nano form by top down approach to enhance the availability of plant nutrients in soil and faster reclamation of problem soils
   Tapan Adhikari, S. Kundu, A.K. Shukla, K. Ramesh, Sudeshana Bhattacharya, J.K. Saha, A.K. Patra

12. Simulating the effect of elevated CO_2 and temperature on water productivity and nutrient use in soybean-wheat cropping system (NASF funded)
    N.K. Lenka, Sangeeta Lenka, A.K. Shukla, R. Elanchezhian, J.K. Thakur, I. Rashmi and Pradip Dey

13. Soil quality assessment and developing indices for major soil and production regions of India funded by ICAR-Extra Mural Project
    N.K. Lenka, A.K. Biswas, Rajendiran S, S. Kundu, S. Lenka, N.K. Sinha, Abhay Shirale, A.K. Viswakarma, R.H. Wanjari, B.L. Lakaria, B.P. Meena, A.B. Singh, A.K. Patra, Muneshwar Singh, D.L.N. Rao, A.K. Shukla, Pradip Dey.

14. Ensuring food security, sustainability and soil health through resource conservation based farmer FIRST approach in central India, sponsored by ICAR New Delhi
A.K. Vishwakarma, R.K. Singh, A.B. Singh, B.L. Lakaria, R.H. Wanjari, K. Bharati, Asha Sahu, Shinogi K.C. and Abhay O. Shirale

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

A. Institute Projects

15. Assessing impacts of climate change on different cropping systems in Central India and evaluating adaptation studies through crop simulation models
M. Mohanty, K.M. Hati, N.K. Sinha, Sangeeta Lenka, Pramod Jha, R. S. Choudhary and R. Elanchezhian

B. External funded projects

16. CRP-Conservation Agriculture (LCPC: Dr. A.K. Biswas and DLCPC: Dr. R.S. Chaudhary)
a. Development, refinement and validation of conservation agriculture in Vertisols of central India and quantifying impact of CA practices on soil and environment"
K M Hati (PPI), J Somasundaram, A.K. Vishwakarma, Sanjay Srivastava, Pramod Jha
b. Demonstration of best-bet conservation agriculture practices on farmers' fields in Vertisols of central India
AK Vishwakarma, R.H. Wanjari, R.K. Singh, KC Shinogi, AK Tripathi
c. Fine-tuning of conservation agricultural practices for Vertisols of central India
J Somasundaram, K Ramesh, S. Ramana, B.P. Meena and A.O. Shirale
d. Development of water and nutrient management practices in conservation agriculture for Vertisols of central India
Sanjay Srivastava, KV Ramana Rao and NK Sinha
e. Impact of conservation agricultural practices on soil health, carbon sequestration and greenhouse gas emissions in different production systems
Pramod Jha, B. L. Lakaria, M Mohanty, JK Thakur and K. Bharati
17. Integrated assessment of soil and crops for enhancing productivity and C-sequestration potential of Vertisols of central India under changing climate scenarios
M. Mohanty, Pramod Jha, Sangeeta Lenka, J. Somasundaram, N.K. Sinha, R.S. Chaudhary and Muneshwar Singh

Programme III – Soil Microbial Diversity and Biotechnology

18. Greenhouse gas (GHG) emission from composting systems and characterization of GHG regulating microbes
K. Bharati, J.K. Saha, S.R. Mohanty and Shinogi K. C.

B. Externally Funded Projects

19. Archaea and Actinobacteria in Vertisols of Central India-Assessment of Diversity, Bigeochemical Processes and Bioinoculant Potential funded by AMAAS
D.L.N. Rao, S.R. Mohanty, K. Bharati
20. Biodegradation of pesticides under changing climate and metagenomic profiling of functional microbes funded by Depratment of Biotechnology, New Delhi
K Bharati, T K Radha, and S R Mohanty
21. In-situ residue decomposition of rice-wheat and sugarcane for enhancing crop productivity and soil health funded by ICAR-Extra Mural Project
M.C. Manna, Asha Sahu, R.C. Singh, Jyoti Thakur, Asit Mandal, Sudeshna Bhattacharjya, A.K. Tripathi, A.K. Patra, D.H. Phalkel
22. India-UK nitrogen Fixation Centre (IUNFC), sponsored by BBSSRC DBT, New Delhi
S.R. Mohanty, D.L.N. Rao

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International
Decade of Soils
2015-2024

Programme IV: Soil Pollution, Remediation and Environmental Security

A.   Institute Project

23.   Interaction among tannery effluents constituents on heavy metals uptake by spinach.
       M. L. Dotaniya, J. K. Saha, Rajendiran S, M. Vassanda Coumar and S. Kundu
24.   Impact of long term use of sewage water irrigation on soil and crop quality in Bhopal region of Madhya Pradesh.
       Vasudev Meena, M. L. Dotaniya, Vassanda Coumar, Rajendiran S, Asha Sahu and S. Kundu
25.   Determination of baseline concentration for delineating contaminated areas in black soils of central India
       Rajendiran S., J.K. Saha, S. Kundu, Hironmoy Das, M. L. Dotaniya
26.   Potential of cotton for the remediation of soils contaminated with heavy metals
       S. Ramana, A.K. Tripathi, K. Bharati and Asha Sahu
27.   Critical limits for Cd, Pb and Cu to eco-toxicological effects on soil organisms and plants for major soil orders in India
       M. Vassanda Coumar, Rajendiran S., M.L. Dotaniya, J.K. Saha, Tapan Adhikari, Ajay and S. Bhattacharya

B.   Externally Funded Projects

28.   Determination of critical limits for identifying heavy metals contamination and their threats in major soil types of India funded by ICAR-Extra Mural Project
       J.K. Saha, M.V. Coumar, S. Rajendiran, M.L. Dotaniya, N.S. Bhogal
29.   Management of Municipal Solid Waste (MSW) contaminated landfill area of Bhanpur, Bhopal sponsored by Municipal Corporation of Bhopal
       Ajay, Tapan Adhiakari, K. Bharati, Asit Mandal and J.K. Saha
30.   Reclamation and rehabilitation of copper mining affected land in malanjkhand area of madhya pradesh, sponsored by Hindustan Copper Ltd. Malanjkhand
       Ajay, Tapan Adhikari, Asit Mandal and J. K. Saha

Collaborative projects in other institutes where IISS scientists are associated in

31.   Enhancing Resource Use Efficiency in Pulse Based Cropping System in Central India.Collaborating with ICAR-Indian Institute of Pulses Research, Kanpur (U.P.)
       R. Elanchezhian and A.O. Shirale
32.   Isolation and characterization of heavy metal resistant bacteria & evaluation for their use in agriculture. Collaborating with NBAIM, Mau (U.P.)
       M.C. Manna, A. Mandal, Asha Sahu, J.K. Thakur
33.   Development of an Automated Soil Nutrient Sensing System", NASF funded
       S. Srivastava and A.O. Shirale

8. Consultancies, Contractual Services, Patents and Technology commercialization

Consultancies Contractual Services

S. No.	Title	Sponsorer	Project team
1	Evaluation of urease inhibitor product (limus) for nutrient use efficiency in cereal crops	BASF Pvt. Ltd., Mumbai	B. L. Lakaria, Pramod Jha, B.P. Meena, A.K. Biswas
2	Evaluation of efficacy of sulphur and zinc containing complex fertilizers for maximizing yield through balanced nutrition of different crops in India	Zuari Agro Chemicals Limited	A.K. Shukla, A.K. Biswas, Sanjay Srivastava, Pankaj K. Tiwari, B.P. Meena
3	Evaluation of efficacy of zinc metalosate and boron metalosate foliar supplements for maximizing yield through balanced nutrition of important crops grown in India	Indofil Industries Limited	A.K. Shukla, A.K. Biswas, B.P. Meena, Pankaj K. Tiwari
4	Response of crop to applied Potassium in Vertisols of India.	PRII, Gurgoan	Muneshwar Singh, R.H. Wanjari, B.L. Lakaria, A.O. Shirale
5	Effect of aquasorb on water and nutrient use efficiency & crop productivity of soybean & tomato in selected soils of India	SNF India Pvt. Ltd. Vishakhapatanam	R.S. Chaudhary, R.K. Singh, K.M. Hati, B.P. Meena, A.K. Biswas, M. Mohanty and A.K. Patra

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International
Decade of Soils
2015-2024

9. PUBLICATIONS

A.   Papers in Research Journal (National/International)

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International
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2015-2024

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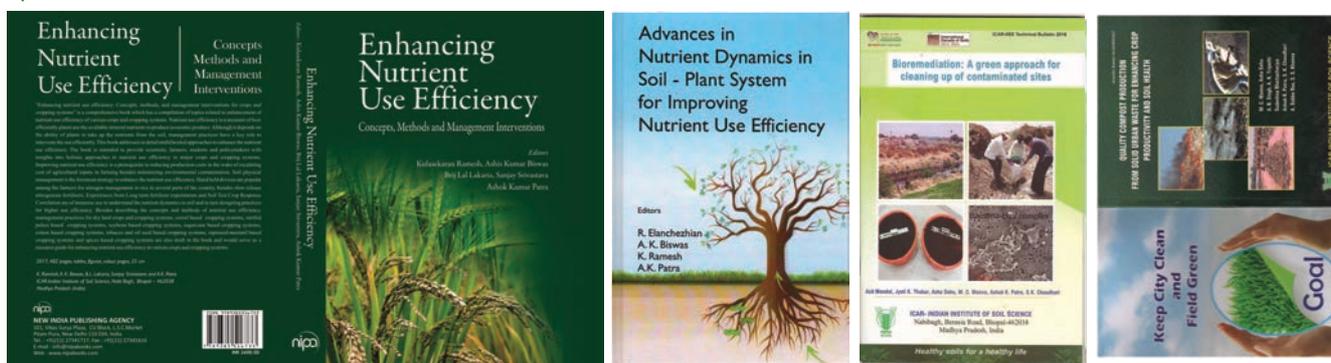
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10. Institute Committees/Cells/Sections/Units

Research Advisory Committee

1	Dr. C.L. Acharya	Chairman
2	Dr. T.K. Adhya	Member
3	Dr. N.S. Raghuwanshi	Member
4	Dr. S.K. Chaudhari, ADG (S&WM), ICAR	Member
5	Dr. A.K. Patra, Director, ICAR-IISS, Bhopal	Member
6	Dr. Pradip Dey, PC (STCR)	Member -Secretary

Institute Purchase Committee

1	Dr. M.C. Manna, HOD (SB) Dr. Pradip Dey PC (STCR) (Alternate)	Chairman
2	Dr. K. M. Hati, Pr. Scientist Dr. R. Elanchezhian, Pr. Scientist (Alternate)	Member
3	Dr. N.K. Lenka, Pr. Scientist Dr. Tapan Adhikari, Pr. Scientist (Alternate)	Member
4	Dr. J.K. Thakur, Scientist Dr. N.K. Sinha, Scientist (Alternate)	Member
5	FAO or AF&AO	Member
6	AO or AAO	Member-Secretary

Institute Technology Management Committee

1	Dr. Ashok K. Patra, Director	Chairman
2	Dr. J.K. Saha, HOD (ESS)	Member
3	Dr. A.K. Biswas, HOD (SC&F)	Member
4	Dr. Pradip Dey, PC (STCR)	Technical Expert
5	Dr. M.C. Manna, HOD (SB)	Technical Expert
6	Dr. Niranjan Mishra, Pr. Scientist & I/c ITMU, NIHSAD	Outside Expert
7	Dr. Sanjay Srivastava, Pr. Scientist & I/c ITMU	Member-Secretary

Institute Technology Management Unit

1	Dr. Sanjay Srivastava, Pr. Scientist	Incharge
2	Dr. M. Vassanda Coumar, Scientist	Member
3	Dr. Asit Mandal, Scientist	Member
4	Dr. Shinogi K.C., Scientist	Member

Technology Assessment & Transfer Unit

1	Dr. K. Ramesh, Pr. Scientist	Incharge
2	Dr. R.H. Wanjari, Sr. Scientist	Member
3	Dr. A.K. Vishwakarma, Pr. Scientist	Member
4	Dr. S. Rajendiran, Scientist	Member
5	Dr. Shinogi K.C., Scientist	Member

PME Committee

1	Dr. Ashok K. Patra, Director	Chairman
2	Dr. R.S. Chaudhary, HOD (SP)	Member
3	Dr. J.K. Saha, HOD (ESS)	Member
4	Dr. M.C. Manna, HOD (SB)	Member

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| 5 | Dr. A.K. Biswas, HOD (SC&F) | Member |
| 6 | Dr. R. Elanchezhian, Pr. Scientist & I/c PME | Member-Secretary |

PME Cell

1	Dr. R. Elanchezhian, Pr. Scientist	Incharge
2	Dr. K.M. Hati, Pr. Scientist	Member
3	Dr. A.K. Vishwakarma, Pr. Scientist	Member
4	Dr. Monoranjan Mohanty, Sr. Scientist	Member
5	Dr. M. Vassanda Coumar, Scientist	Member
6	Mr. Sanjay Kumar Kori, Steno Gr.-III	Member

RFD Cell

1	Dr. R. Elanchezhian, Pr. Scientist	Nodal Officer
2	Dr. J. Somasundaram, Pr. Scientist	Member
3	Dr. Asit Mandal, Scientist	Member
4	Sh. P.S. Sunil Kumar, AAO	Member
5	Mr. Sanjay Kumar Kori, Steno Gr.-III	Member

Institute Building Committee

1	Dr. Ashok K. Patra, Director	Chairman
2	Dr. A.K. Shukla, PC (MSPE)	Member
3	Dr. R.S. Chaudhary, HOD (SP)	Member
4	Dr. J. K. Saha, HOD (ESS)	Member
5	Dr. Pradip Dey, PC (STCR)	Member
6	Dr. Muneshwar Singh, PC (LTFE)	Member
7	Dr. M.C. Manna, HOD (SB)	Member
8	Dr. A.K. Biswas, HOD (SC&F)	Member
9	AO or AAO	Member
10	FAO or AF&AO	Member

Institute Works Committee

1	Dr. Muneshwar Singh, PC (LTFE)	Chairman
2	Dr. N.K. Lenka, Pr. Scientist	Member
3	Dr. A.K. Vishwakarma, Pr. Scientist	Member
4	AO or AAO	Member
5	FAO or AF & AO	Member

Farm & Water Management Committee

1	Dr. A.K. Vishwakarma, Pr. Scientist	Chairman
2	Dr. R.H. Wanjari, Sr. Scientist	Member
3	Dr. R.K. Singh, Pr. Scientist	Member
4	Mr. O.P. Shukla, T-5	Member
5	Mr. C.T. Wankhede, Electrician	Member
6	Mr. D.R. Darwai, I/c Farm Superintendent	Member-Secretary

Farm Advisory Committee

1	Dr. A.K. Shukla, PC (MSPE)	Chairman
2	Dr. R.S. Chaudhary, HOD (SP)	Member
3	Dr. K. Ramesh, Pr. Scientist	Member
4	SAO or AAO	Member

International
Decade of Soils
2015-2024

| 5 | FAO or AF&AO | Member |
| 6 | Dr. A.K.Vishwakarma, Pr. Scientist & I/c Farm | Member-Secretary |

Horticulture Maintenance Committee

1	Dr. S. Ramana, Pr. Scientist	Chairman
2	Dr. Nishant Kumar Sinha, Scientist	Member
3	Mr. R.K. Mandloi, T-7-8	Member
4	Mr. D.R. Darwai, T-5, I/c Farm Superintendent	Member

Inter-Institutional Transfer Committee

1	Dr. Pradip Dey, PC (STCR)	Chairman
2	Dr. M.C. Manna, HOD (SB)	Member
3	Dr. K.M. Hati, Pr. Scientist	Member
4	Administrative Officer	Member

Mridaparikshak Technology Management Committee

1	Dr. Pradip Dey, PC (STCR)	Chairman
2	Dr. A.K. Biswas, HoD (SC&F)	Co-Chairman
3	Dr. Tapan Adhikari, Pr. Scientist	Member
4	Dr. Monoranjan Mohanty, Sr. Scientist	Member
5	Dr. Sanjay Srivastava, Pr. Scientist & PI (Mridaparikshak)	Member Secretary

Consultancy Processing Cell

1	Dr. Pradip Dey, PC (STCR)	Chairman
2	Dr. R. Elanchezhian, Pr. Scientist	Member
3	Dr. Tapan Adhikari, Pr. Scientist	Member
4	Dr. A.K. Vishwakarma, Pr. Scientist	Member
5	Dr. Kollah Bharati, Pr. Scientist	Member
6	AO or AAO	Member
7	FAO or AF&AO	Member

Civil and Electrical Maintenance Committee

1	Dr. A.K. Tripathi, Pr. Scientist	Chairman
2	Dr. S. Ramana, Pr. Scientist	Member
3	Dr. R.H. Wanjari, Sr. Scientist	Member
4	Mr. Deepak Kaul, T-7-8	Member
5	Mr. P.S. Sunil Kumar, AAO	Member
6	Mr. C.T. Wankhede, Electrician	Member
7	Mr. Sanjay Kumar Kori, Steno Gr.-III	Member

Library Committee

1	Dr. M.C. Manna, HOD (SB)	Chairman
2	Dr. Pramod Jha, Pr. Scientist	Member
3	Dr. J. Somasundaram, Pr. Scientist	Member
4	Dr. S.R. Mohanty, Pr. Scientist	Member
5	Dr. Asha Sahu, Scientist	Member
6	Mrs. Nirmala Mahajan, Librarian	Member
7	SAO or AAO	Member
8	FAO or AF&AO	Member
9	Dr. S. Ramana, Pr. Scientist & I/c Library	Member-Secretary

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Library Advisory Committee

1	Director	Chairman
2	All PCs	Member
3	All HODs	Member
4	I/c PME Cell	Member
5	Finance & Account Officer	Member
6	Senior Administrative Officer	Member
7	Librarian	Member
8	I/c Library	Member Secretary

Campus Security Committee

1	Dr. Mohan Lal Dotaniya, Scientist	Chairman
2	Dr. S. Rajendiran, Scientist	Member
3	Senior Administrative Officer	Member
4	Mr. Anurag, Security Supervisor	Member-Secretary

Academic Cell

1	Dr. S. Kundu, Pr. Scientist & Ex-HOD (ESS)	Incharge
2	Dr. K.M. Hati, Pr. Scientist	Member
3	Dr. Kollah Bharati, Pr. Scientist	Member
4	Dr. Pramod Jha, Pr. Scientist	Member

Contractual Research Project Monitoring Committee

1	Director, ICAR-IISS, Bhopal	Chairman
2	Project Leader of the Contractual Research Project	Member
3	Co-PI/Associate	Member
4	One representative of the contracting party	Member

Women Cell

1	Dr. Kollah Bharati, Pr. Scientist	Chairperson
2	Dr. Asha Sahu, Scientist	Member
3	Mrs. Geeta Yadav, Private Secretary	Member
4	Mrs. Kirti Bais, Personal Assistant	Member
5	Mrs. Raksha Dixit, LDC	Member
6	Mrs. Nirmala Mahajan, T-6	Member
7	Mrs. Kavita Bai, SSS	Member

Committee for Prevention of Sexual Harassment of Women Employees

1	Dr. (Mrs.) Sangeeta Lenka, Scientist	Chairperson
2	Dr. (Mrs.) Shalini Chakraborty, Scientist, Fruit Research Station, Itkhedi	Member-External
3	Dr. (Mrs.) Shinogi K. C., Scientist	Member
4	Mrs. Yojana Meshram, Personal Assistant	Member
5	Mrs. Babita Tiwari, Assistant	Member
6	SAO or AAO	Member-Secretary

Hindi Samiti

1	Dr. Ashok K. Patra, Director	Chairman
2	Dr. A.K. Tripathi, Pr. Scientist	Member
3	Dr. S. Ramana, Pr. Scientist	Member

International Decade of Soils
2015-2024

4	Dr. Asha Sahu, Scientist	Member
5	Senior Administrative Officer	Member
6	Mrs. Babita Tiwari, Assistant	Member Secretary

Renewable Bio/Solar Energy Committee

1	Dr. A.K. Biswas, HOD (SC&F)	Chairman
2	Dr. K. Ramesh, Pr. Scientist	Member
3	Dr. A. K. Vishwakarma, Pr. Scientist	Member
4	Senior Administrative Officer	Member
5	Dr. Panna Lal Singh, Pr. Scientist, CIAE, Bhopal	Member (External Expert)
6	Mr. C.T. Wankhede, Electrician	Member

Condemnation of Permanent Articles Committee

1	Dr. M.C. Manna, HOD (SB) Dr. A.B. Singh, Pr. Scientist (Alternate)	Chairman
2	Dr. K. Ramesh, Pr. Scientist	Member
3	Dr. N.K. Sinha, Scientist	Member
4	AAO	Member
5	AF&AO	Member

STC Programme Implementation Committee

1	Dr. J.K. Saha, HOD (ESS)	Chairman
2	Dr. M.L. Dotania, Scientist	Member
3	Dr. S. Rajendiran, Scientist	Member
4	Dr. Abhay Omprakash Shirale, Scientist	Member
5	Dr. R.H. Wanjari, Sr. Scientist	Member-Secretary & Nodal Officer

Foreign Deputation Committee

1	Dr. D.L.N. Rao, Network Coordinator	Chairman
2	Dr. Tapan Adhikari, Pr. Scientist	Member
3	Dr. K.M. Hati, Pr. Scientist	Member
4	Dr. Kollah Bharati, Pr. Scientist	Member
5	Dr. Pramod Jha, Pr. Scientist	Member
6	Senior Administrative Officer	Member

Estate Committee (Including quarter allotment)

1	Dr. A.B. Singh, Pr. Scientist	Chairman
2	Dr. R.H. Wanjari, Sr. Scientist	Member
3	Mr. R.K. Mandloi, T-7-8	Member
4	Mr. Anurag, Security Supervisor	Member
5	Senior Administrative Officer	Member

Seminar Committee

1	Dr. Ajay, Pr. Scientist	Chairman
2	Dr. N.S. Bhogal, Pr. Scientist	Member
3	Dr. Sangeeta Lenka, Scientist	Member
4	Dr. Bharat Prakash Meena, Scientist	Member

Sports Promotion Committee

1	Dr. Brij Lal Lakaria, Pr. Scientist	Chairman
2	Dr. S. Rajendiran, Scientist	Member
3	Mr. Thomas Joseph, Private Secretary	Member
4	Mrs. Babita Tiwari, Assistant	Member

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| 5 | Mr. Anurag, Security Supervisor | Member |
| 6 | Mr. Sanjay Katenga, LDC | Member |

Monitoring/Utilization of Plant/Machinery/Equipments/Instruments

| 1 | Dr. A.B. Singh, Pr. Scientist | Incharge |
| 2 | Dr. K. Ramesh, Pr. Scientist | Member |

Remote Sensing and GIS Laboratory

1	Dr. Monoranjan Mohanty, Sr. Scientist	Incharge
2	Dr. N.K. Sinha, Scientist	Member
3	Dr. B.P. Meena, Scientist	Member

Central Lab

| 1 | Dr. S.R. Mohanty, Pr. Scientist | Incharge |
| 2 | Dr. J.K. Thakur, Scientist | |

Training Hostel

1	Dr. Monoranjan Mohanty, Sr. Scientist	Controlling Officer
2	Dr. B.P. Meena, Scientist	Incharge
	Dr. Asit Mandal, Scientist (Alternate)	
3	Mr. Vinod Choudhary, T-4	Care Taker
4	Mr. Sunny Kumar, Stenographer	Asstt. Care Taker

Swachh Bharat Mission

| | Dr. R.S. Chaudhary, HOD (SPD) | Nodal Officer |

AKMU

| | Dr. J. Somasundaram, Pr. Scientist | Incharge |
| | Dr. N.K. Sinha, Scientist (Alternate) | |

Vehicle Operation Committee

| | Dr. Asit Mandal, Scientist | Incharge |
| | Mr. Vinod Babu Pal, T-7-8 (Alternate) | |

RTI Cell

| | Dr. R. Elanchezhian, Pr. Scientist | Nodal Officer & CPIO |
| | Mr. PS Sunil Kumar, AAO | APIO |

Screen House

| | Dr. S. Ramana, Pr. Scientist | Incharge |
| | Dr. Asha Sahu, Scientist (Alternate) | |

Library

| | Dr. S. Ramana, Pr. Scientist | Incharge |
| | Dr. (Mrs) Shinogi K.C., Scientist (Alternate) | |

HRD (Training)

| | Dr. K.M. Hati, Pr. Scientist | Nodal Officer |

Mera Gaon Mera Gaurav

| 1 | Dr. A. B. Singh, Pr. Scientist | Nodal Officer |
| 2 | Dr. K. Ramesh, Pr. Scientist | Co-Nodal Officer |

Weed Management

| | Dr. A.K. Vishwakarma, Pr. Scientist | Nodal Officer |

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International Decade of Soils 2015-2024

11. Important Meetings/Activities

Institute Research Council Meeting

The Institute Research Council (IRC) meeting of the institute was held during 19-20 July, 29-30 July, 2016 and 22-23 February, 2017 in the committee room of the institute. The Member-Secretary (IRC), Dr. A.K. Biswas welcomed the participants and requested the scientists to take the IRC as a platform for discussion on scientific matter for overall improvement of research activities. Dr. R. Elanchezhian (I/c PME Cell) requested all the scientists to present the salient research findings for ten minutes followed by discussion for 5-10 minutes. Dr. A.K. Patra, Director and Chairman of the IRC congratulated the award winning scientists. He stressed that all scientists must submit quality research proposals. Thereafter, the ongoing and concluded projects were presented and reviewed.

ICAR-IISS Foundation Day

The 29th Foundation Day of ICAR-IISS Bhopal was celebrated on 16 April, 2016. The programme was graced by Dr. I.P. Abrol, Director, Centre of Advancement of Sustainable Agricultural, New Delhi as the Chief Guest. The program was also attended by Dr. A. Subba Rao, former Director of the ICAR-IISS; Dr. PK Ghosh, Director, ICAR-IGFRI, Jhansi and Dr. K. K. Singh, Director, ICAR-CIAE, Bhopal. Dr A.K. Patra, Director, ICAR-IISS appraised about the progress made by the institute. Progessive farmers were felicitated in the program.

Independence Day

The 70th 'Independence Day' was celebrated on 15th August, 2016 in the Institute premises with great gaiety and fervor. Different cultural events were organized for the family members of the staff on the day and program was concluded with distribution of prizes to the winners.

World Soil Day

World Soil Day was celebrated with gaiety and fervour at the institue on December 05, 2016 with the theme: "Soils and pulses, a symbiosis for life". The programme was graced by Dr. Rajesh Prasad Mishra, IAS, and Director, Water and Land Management Institute (WALMI), Bhopal who emphasized the importance of soil and stressed upon the need to increase awareness of soil management among the children. Dr. A.K. Tiwari, Director of Pulse Development, DAC, Madhya Pradesh talked about the importance of pulses in improving the soil fertility. He also elaborated on some new pulse production technologies and told that currently pulse productivity is about 33 to 70% lower than the expectation in different parts of the country. Mr. B M Sahare, Additional Director, Department of Agriculture and Farmers Welfare, Madhya Pradesh talked about the soil health card scheme and the current progress of Madhya Pradesh in the distribution of soil health cards. Dr A.K. Patra, Director of the institute apprised the gathering about the activities of the institute. The event was attended by several farmers and school students among others. Soil Health Cards were distributed to farmers by the Chief Guest. A debate competition of the school students on the theme "Waste to wealth-a dream for clean India" was also organized. Kisan Gosthi on soil health management was held in which scientists interacted with the farmers.

Hindi Pakhwada

Government of India encourages its organizations and the employees to participate in Hindi Pakhwada celebrations to promote and spread the use of Hindi as a common medium of language throughout the country. Accordingly, Hindi

Pakhwada was celebrated in the Institute during 14-28 September, 2016. Several competitions such as Debate, Quiz, Hindi vocabulary (Sabda Gyan), typing were conducted in the Institute premises during the fortnight in which majority of staff members participated. The Director, ICAR-IISS distributed prizes to the winners of different competitions.

Swachch Bharat Mission

The Institute staff members participated in the nation-wide program of "Swachh Bharat Mission" launched by the Government of India. The Swachhta Sapath was administered to all the staff members by the Director of the Institute on 2nd October, 2016. This was followed by the voluntary cleaning of the Institute premises by the staff members. Afterwards, an intensive campaign was started with finalization of the weekly plan and timely execution for keeping the surrounding of the Institute premises clean.

Vigilance Week

As per the directive of the Central Vigilance Commission, vigilance awareness week was observed in the Institute during 31Octobar to 05 November, 2016 with the theme on "Public participation in promoting integrity and eradicating corruption". A debate competition on the theme "Importance of vigilance to maintain unity and integrity of the country" was organized on 03 November, 2016, and an essay competition was organized for the staff members on 1 November, 2016. The concluding function of the Vigilance Awareness Week was held on 5 November, 2016. Mr. Ashok Khalkho, AIG (Cyber Crime), Govt. of M.P., Bhopal was the Chief Guest.

New Year Day

The Staff Recreation Club (SRC) organized the 'New Year Day' celebration on 02 January, 2017 in which various cultural and sports programs were organized for the staff of the institute.

Republic Day

The 68th '*Republic Day'* was celebrated on 26th January, 2017 in the Institute premises with great gaiety and fervor. Different sports and cultural events were organized for the family members of the staff on the occassion and the activities included racing and drawing competition for children, musical chair for adults etc.

Women's Day

The Institute organized Krishak Mahila Sanghosti on the occasion of International Women's Day on 8 March, 2017 at Village Amoni, near Vidisha road, Bhopal. The participants were farm women, housewives, girls, anganwadi and health workers from village Amoni and Prempura. Dr. A. K. Patra, Director, ICAR-IISS addressed the gathering on gender equality and empowerment of all women and girls. Women are important element of society and society should recognize the individual identity of women.

ICAR-IISS

National Productivity Week Celebration (12-18 Feb., 2017)

National Productivity Week was orgaized at ICAR-IISS, Bhopal during 12-18 February, 2017. Dr. R. Elanchezhian, Organizing Secretary, briefed about the purpose of National Productivity Week and details of programs to be organized during the weeklong celebration. Dr. A.K. Patra, Director, ICAR-IISS gave his insightful thoughts on productivity enhancement in agriculture and soil science in particular. An Essay and painting competition on the theme "Waste to Profits through Reduce, Recycle and Reuse" and Slogan competition on the theme "Soil Health" was organized during the week. A farmer-scientist interaction meet was organized on 14th Feb 2017 wherein 120 farmers from villages adopted by the institute under Mera Gaon Mera Gaurav participated. TV show was recorded in which technologies like Mridaparikshak, Conservation Agriculture, organic farming practices, Composting methods and Importance of soil health and balanced nutrition were presented. An exposure visit to organic farming was arranged for a group of 50 farmers from Datia district on 16/02/2017. On-farm farmer-scientist interaction meet was organized at Village Mugaliahat, Bhopal on 17th February 2017 wherein a group of 60 farmers participated. A workshop cum training program on "Crop simulation model in climate change impact assessment" was also organized during the week (14-18 Feb., 2017), wherein 19 participants from different ICAR institutes were trained on simulation modeling to enhance the farm productivity. The valedictory function was held on 18th Feb 2017 wherein Director ICAR-IISS felicitated the winners of various competitions.

Sports activities

A cricket match was organized on 26th January, 2017 in which sports persons from IISS took part. The Director, Dr. A.K. Patra inaugurated the event and praised the efforts in this direction. He appreciated the efforts being made to the sports activities and assured to provide necessary facilities.

ICAR-IISS Sports contingent participated in the ICAR central zone sports meet at ICAR-IARI New Delhi during 7-11 Nov 2016. The contingent was led by Chief-de-Mission Dr. R. Elanchezhian and Team Manager Dr. R.H. Wanjari. Sh. Zaffer Iqbal, former Olympian Hockey player inaugurated the event. The contingent participated in several events and the basketball team secured Runners up position in team event. Besides, the team also stood runners up in Chess (Sh. Thomas Joseph), Carrom (Sh. Pramod Rout)and second in Javelin throw (Smt. Babita Tiwari). On the eve of Indepence day, ICAR-IISS organized a basketball match on 15th August, 2016 at the institute.

12. PARTICIPATION OF SCIENTISTS IN CONFERENCES /SYMPOSIA/SEMINARS/WORKSHOPS/MEETING

Name	Programme	Venue	Period
Dr. M. Mohanty	Group Meeting cum Workshop on Climate Change Impact Studies in Agriculture and Food Security	New York University, New York, USA	11-14 April, 2016
Dr. A. K. Vishwakarma	National conference on "Agriculture for *kharif* Campaign -2016"	NASC complex New Delhi	11-12 April, 2016
Dr. A.K. Patra	International Conference on Pulses	Marrakesh, Morocco	18-20 April, 2016
All Scientists	Training-Cum-Workshop on "Soil Health & Fertility Management"	ICAR-IISS, Bhopal	21-23 April, 2016
Dr. N.K. Lenka & Dr. M. Mohanty	Workshop on DST's Knowledge Network on "Climate Change and Agriculture"	NASC Complex, New Delhi	28-29 April, 2016
Dr. A.K. Patra	Roundtable discussion on "Policy reform options to improve soil nutrient management in India"	New Delhi	2 May, 2016
Dr. Sanjay Srivastava	India-Afghanistan task force for Agriculture Cooperation	Kabul, Afghanistan	9 May, 2016
Dr. AK Vishwakarma	National Conference on "Agricultural and Rural Innovation for Sustainable Empowerment, ARISE-2016"	BALA VIKASA, Kazipet, Warangal	21 -22 May, 2016
Dr. A. K. Shukla	FAI-IZA Roundtable on "Zinc in Crop and Human Health"	FAI, New Delhi	24 May, 2016
Dr. Sanjay Srivastava	Meeting of team of experts for validating soil testing results through mobile phones technique with that of conventional laboratory analysis	Krishi Bhavan, New Delhi	2 June, 2016
Dr. A.K. Patra	Foundation Day and General Body Meeting of NAAS	NASC, New Delhi	4-5 June, 2016
All Scientists	Interface Meeting on "Enhancing the Preparedness of Agricultural Contingencies in kharif 2016 for Madhya Pradesh"	ICAR-IISS, Bhopal	21 June, 2016
Dr. Pradip Dey	"Workshop to review the status of nutrient use efficiency (NUE) in different crops " under the Chairmanship of Honourable Secretary, DARE &DG, ICAR.	Krishi Bhavan, New Delhi	21 June, 2016
Dr. R. S. Chaudhary	State Level Advisory committee Meeting	CRDE- KVK Sehore	23 June, 2016

Healthy soils for a healthy life

International Decade of Soils
2015-2024

ICAR-IISS

Name	Programme	Venue	Period
Dr. R.S. Chaudhary, Dr. K.M. Hati, Dr. M. Mohanty, Dr. N. K. Sinha	Coordination cum review meeting ICAR-ICRAF collaborative program	ICAR, New Delhi	29 June, 2016
Dr. A.K. Patra	RAC meeting	ICAR-NBSS&LUP, Nagpur	10-12 July, 2016
Dr. K.M. Hati	Workshop on "Sensors for Agriculture and Food Technology"	IIT Madras	14-15 July, 2016
Dr. A.K. Patra	Meeting for Indo-African collaborative programme	NASC, New Delhi	25 July, 2016
Dr. R. Elanchezhian	9th NABS National Conference	MKU, Madurai	11-12 August, 2016
Dr. Sudeshna Bhattacharjya	SAARC Regional Training on "Climate Change impact on soil carbon storage and turnover under different land use systems and adaptation strategies"	ICAR-IISS, Bhopal	16-23 August, 2016
Dr. Sanjay Srivastava	The Meeting to develop Action Plan for 2016-20 for establishment of laboratories/centres/Universities under IAFS-III	Krishi Bhavan, New Delhi	17 August, 2016
Dr. K. Ramesh	Round table discussion on "Researchable issues in organic farming and integrated organic farming systems"	ICAR-IISS, Bhopal	17 August, 2016
Dr. A. B. Singh, Dr. N.K. Lenka, Dr. K. Ramesh, Dr. Brij Lal Lakaria, Dr. S. Ramana, Pradip Dey and Dr. J. K. Thakur	11th Annual Group Meeting of "Network Project on Organic Farming"	ICAR-IISS, Bhopal	17-19 August, 2016
Dr. A.K. Patra, Dr. P. Dey and Dr. S. R. Mohanty	Group meeting of AINP on Soil Biodiversity – Biofertilizers	OUAT, Bhubaneswar	18-23 August, 2016
Dr. M.C. Manna	International Conference on "Agricultural Sciences and Food Technologies for Sustainable Productivity and Nutritional Security"	University of Agricultural Sciences, Bengaluru	25-27 August, 2016
All Scientists	Workshop on "Safe Utilization of Fly Ash in Agriculture"	Hotel Jehan Numa Palace, Bhopal	31 August, 2016
Dr. A.K. Biswas and Dr. A. K. Vishwakarma	23rd zonal workshop of KVKs under ATARI Zone -VII	ICAR-CIFA, Bhubaneshwar	2-5 September, 2016

Name	Programme	Venue	Period
Dr. Pradip Dey	2nd Knowledge Exchange Workshop of the global programme "Soil Protection and Rehabilitation for Food Security", organized by GIZ	Pune, Maharashtra	6 September, 2016
Dr. A.K. Patra, Dr. Muneshwar Singh, Dr. A.K. Shukla and Dr. Pradip Dey	24th Meeting of ICAR Regional Committee No. V	Goa	8-9 September, 2016
Dr. A.K. Patra	Global Open Data for Agriculture and Nutrition (GODAN) Summit	New York	15- 16 September, 2016
Dr. N. K. Sinha	Financial and technical review workshop under NICRA program	ICAR-CRIDA, Hyderabad.	15-17 September, 2016
Dr. Sanjay Srivastava	Councillor meeeting of ISSS	Division of SS&AC, IARI, New Delhi	17 September, 2016
Dr. Muneshwar Singh	V.B. Mehta Memorial lecture of ISSS	RAU, Ranchi.	27 September, 2016
All Scientists	DBT-BBSRC Bhabha Newton Fund project "India-UK Nitrogen Fixation centre"	ICAR-IISS, Bhopal	6-7 October, 2016
Dr. Pramod Jha, Dr. B.L. Lakaria, Dr. J.K. Thakur, Dr. M. Mohanty, Dr. K. Bharati, Dr. J. Somasundaram, Dr. A.K. Biswas, Dr. K.M. Hati, Dr. B.P. Meena, Dr. K. Ramesh, Dr. S. Kundu and Dr. A.K. Patra, Dr. A.K. Tripathi, Dr. A.B. Singh, Dr. Rajendiran S, Dr. J.K. Saha, Dr. M. V. Coumar, Dr. N.K. Sinha	81st ISSS Annual Convention of ISSS	RVSKVV Gwalior.	20-23 October, 2016
Dr. R. Elanchezhian	RTI-MIS for Nodal Officers of RTI	NASC, New Delhi	21 October, 2016
Dr. M.L. Dotaniya	National Seminar on Education for sustainable development	RIE, Bhopal	21-23 October, 2016
Dr. S. Ramana	Workshop on Improving Plant Performance by Measuring TOC Process and Waste Water	Hotel Marriot, Bhopal	25 October, 2016

Healthy soils for a healthy life

International
Decade of Soils
2015-2024

Name	Programme	Venue	Period
Dr. A.K. Patra and Dr. M.C. Manna	Sangosthi on "Creating Wealth from Waste: Key ICAR Technologies"	KVK Sikohpur, Gurgaon	27 October, 2016
All Scientists	National Seminar on "Soil Health Assessment with Mridaparikshak"	ICAR-IISS, Bhopal	4-5 November, 2016
Dr. Sanjay Srivastava	Councillor meeeting of ISSS	Division of SS&AC, IARI, New Delhi	5 November, 2016
Dr. R.H. Wanjari	First International Agrobiodiversity Congress (1IAC 2016	New Delhi	6-9 November, 2016
Dr. M. Mohanty	Indo-UK Roundtable Workshop on Precision Farming	India Habitat Centre,British High Commission, New Delhi	7 November, 2016
Dr. A. B. Singh	National Science Seminar in Hindi on "Prachin Evam Aadhuneek Bharat mein Vigyan Evam Urja ke Aayam"	Atal Bihari Vajpayee Hindi Vishwa Vidyalaya, Bhopal	09-11 November, 2016
Dr. K. Ramesh	International seminar on "Widening organic values, value chains and challenges"	New Delhi	10-12 November, 2016
Dr. A. O. Shirale	International Conference on "Integrated Land Use Planning for Smart Agriculture- An Agenda for Sustainable Land Management"	Indian Society of Soil Survey and Land Use Planning, Nagpur	10-13 November, 2016
Dr. Sanjay Srivastava, Dr. Brij Lal Lakaria Dr. A.O. Shirale, Mr. Deepak Kaul, Mr. Vinod Babu Pal and Mr. Jai Singh	36th India International Trade Fair (IITF) 2016	Pragati Maidan, New Delhi	14-27 November, 2016
Dr. Ajay	National Seminar on "Strategies Fostering Systematic and Sustainable Growth in Non-ferrous Mineral Industry"	Malanjkhand, Balaghat (M.P.)	18 November, 2016
Dr R. S. Chaudhary, Dr. K. M. Hati, Dr. Pradip Dey and Dr. N.K. Sinha	Five days advanced training in MIR soil spectroscopy	World Agro forestry Centre, ICRAF, Nairobi, Kenya	20 – 25 November, 2016
Dr. K. Ramesh, Dr. R.H. Wanjari, Dr. A.K. Vishwakarma and Dr. B.P. Meena	Fourth International Agronomy Congress (IAC)	ICAR-IARI, New Delhi	22-26 November, 2016

Name	Programme	Venue	Period
Dr. A.K. Patra	The interactive workshop on "Administrative and Financial Matters" of the ICAR institutes located in West Zone	ICAR-CIFE, Mumbai	24 November, 2016
Dr. M.C. Manna	Global Agriculture and Innovation Conference (GAIC-2016)	Noida Internaitonal University, Greater Noida	27 -29 November, 2016
Dr. R. K. Singh	Regional Agriculture Fair (Krishi Kumbh-2016)	Government Inter College, Muzaffarnagar, U.P.	28-30 November, 2016
Dr. A.K. Shukla, Dr. A.K. Biswas and Dr. B.P. Meena	FAI ANNUAL SEMINAR on "Fertilizer: make in India"	Fertilizer Association of India (FAI), New Delhi	30 November – 2 December, 2016
Dr. M. Mohanty	One day workshop on "Virtual Modelling Group under NICRA project"	CESCRA, NRL Building, IARI, Pusa	30 November, 2016
Dr. A.K. Patra	National symposium on "Managing Agriculture in Changing Environment"	ICAR-IARI, New Delhi.	2 December, 2016
Dr. A.K. Patra	Review workshop of AICRP (STCR)	MPKV, Rahuri	3 December, 2016
Dr. R.S. Chaudhary	One day Crop Symposium	KVK Ichhawar, Sehore, MP	5 December, 2016
Dr. M. Mohanty	4th Annual Review Workshop of NICRA	NASC Complex, New Delhi	9-10 December, 2016
Dr. A. B. Singh	Krishi Mela	KVK, Rajgarh, Madhya Pradesh	11December, 2016
Dr. M.C. Manna and Dr.Tapan Adhikari	International Conference on "Contaminated Site Remediation and Workshops"	Department of Environmental Sciences, TNAU, Combatore	13-16 December, 2016
Dr. B.L. Lakaria	Farmers Day programme	EICHER Tractors, Bhopal	14 December, 2016
Dr. M. Mohanty	Central Indian Landscape Symposium	Pench Tiger Reserve, Madhya Pradesh	14-17 December, 2016
Dr. B.L. Lakaria	National Summit for Farmer Producer Organizations and Agri-startups 2016	SIAET, Govt. of M.P., Bhopal	15-16 December, 2016
Dr. A.B. Singh, Dr. K. Ramesh, Dr. Brij Lal Lakaria, Dr. S Ramana, Dr. J. K. Thakur and Dr. A.K. Patra	International Conference on "Environment and Agriculture in the U. N Sustainable Development Goals"	Noor-us-Sabah, Bhopal	17-19 December, 2016
Dr. M. Mohanty and Dr. N. K. Sinha	Training cum Workshop for network program of Imaging Spectroscopy and Application (NISA)	NASC Complex, IARI, New Delhi	20-24 December, 2016

Healthy soils for a healthy life

International Decade of Soils
2015-2024

Name	Programme	Venue	Period
Dr. Pradip Dey	National Conference on "Management of Microbial Resources for Food Security under Climate Smart Agriculture"	Dr. Rajendra Prasad CAU, Pusa, Samastipur, Bihar	22 December, 2016.
Dr. A.K. Patra, Dr. P. Dey, Dr. R. Elanchezhian, Dr. K. Ramesh and Dr. S.R. Mohanty	104th Indian Science Congress	SV University, Tirupati	3-7 January, 2017
Dr. Pradip Dey	National Seminar on "Climate Resilient Saline Agriculture: Sustaining Livelihood Security	Bikaner, Rajasthan	22 January, 2017
Dr. K. Ramesh	State level symposium on "Current research and ways of their extension"	SIAET, Bhopal	24 January, 2017
Dr. A. K. Vishwakarma.	Rashtriya Krishi Mela	Chattishgarh	27-31 January, 2017
Dr. M.L. Dotaniya	CAFT training on "Ecological Agriculture for Sustainability"	Department of Agronomy, GBPUA&T, Pantnagar	9 February-1 March, 2017
Dr. Sonalika Sahoo	Workshop cum training programme on "Crop Simulation Models in Climate Change Impact Assessment"	ICAR-IISS, Bhopal	14-18 February, 2017
Dr. K.M. Hati	Training programme on "Competency Enhancement Programme for Effective Implementation of Training Function"	NAARM, Hyderabad.	16-18 February, 2017
Dr. Pradip Dey and Dr. Tapan Adhikari	20th Annual Convention of the Clay Minerals Society of India (CMSI) and National Symposium on Harnessing Clay Science for Human Welfare	NBSS&LUP, Nagpur	17-18 February, 2017
Dr. N.K. Lenka and Dr. Sangeeta Lenka	XIII Agricultural Science Congress on 'Climate Smart Agriculture'	University of Agricultural Sciences, Bangalore	21-24 February, 2017
Dr. A. K. Vishwakarma	Regional workshop under Jal Kranti abhiyaan organized by CGWB	Samanvayan Bhawan, Bhopal	23 February, 2017
Dr. Pradip Dey	National Conference on Climate Change Adaptation	Spoorthy Engineering College, Hyderabad	24-25 February, 2017
Dr. Asha Sahu	31st M.P. Young Scientist Congress	Vigyan Bhawan, MPCST, Bhopal	28 -29 February, 2017
Dr. R.H. Wanjari	6th Bhopal Vigyan Mela	BHEL Ground, Bhopal	3-7 March, 2017
Dr. R.S. Chaudhary	Panel discussion on "Bharat ka Jalkshetra- Neetiyanaur Chunotiyan"	Ravindra Bhavan, Bhopal	4-5 March, 2017
Dr. Asha Sahu and Dr. Sudeshna Bhattacharjya	Advanced course on Genotyping and DNA Sequencing	MPCST, Bhopal	7-9 March, 2017
Dr. R.H. Wanjari	6th Krishi Unnati Mela	ICAR-IARI, New Delhi	15-17 March, 2017

Name	Programme	Venue	Period
Dr. A.O. Shirale and Dr. Sonalika Sahoo	ICAR Short course training on 'Advances in Assessment of Soil Pollution and its Remediation'	ICAR-IISS, Bhopal	16-25 March, 2017
Dr. A. K. Vishwakarma	National Review Workshop of Farmer FIRST Programme (FFP)	NAARM, Hyderabad	18-19 March, 2017
All Scientists	28th Workshop of All India Coordinated Research Project on Micro &Secondary Nutrients and pollutant elements	ICAR-IISS, Bhopal	21-23 March, 2017
Dr. R. S. Chaudhary	State level credit seminar (2017-18) and Water campaign	New Market Bhopal	21 March, 2017
Dr. N. K. Sinha	Training program on KRISHI portal	ICAR-IASRI, New Delhi	24-25 March, 2017
Dr. B. P. Meena	Capacity Building Training on "Utility of Soil Health Card in Managing Soil Health"	ICAR-IISS, Bhopal	27-28 March, 2017
Dr. J. Somasundaram	ICAR- KRISHI Geoportal Worksop	NBSS& LUP, Nagpur.	27 March, 2017

Demonstration of Mridaparikshak mini-lab technology, developed by ICAR-IISS, Bhopal at 36th India International Trade Fair (IITF) 2016 at Pragati Maidan, New Delhi during November 14-27, 2016.

International
Decade of Soils
2015-2024

13. WORKSHOPS, SEMINARS AND TRAININGS ORGANIZED

Training/Short Courses Conducted

Programme	Course Directors/Coordinators	Duration	Sponsored by
One day Kisan Sangosthi under MGMG	Dr. Ajay, Dr T. Adhikari, Dr. S. Lenka & Dr. S. Rajendiran	16 May 2016	ICAR-IISS, Bhopal
One day Kisan Sangosthi on "Soil & Plant Nutrients Management in Pulse Crop Production"	Dr. J.K. Saha, Dr. N.S. Bhogal & Dr. M.L. Dotaniya	3 June, 2016	ICAR-IISS, Bhopal
One day Kisan Sangosthi on "Soil Health Management" under MGMG	Dr. A.K. Shukla, Dr. R. Elanchezhian, Dr. R.K. Singh and Dr. J.K. Thakur	23 June 2016	ICAR-IISS, Bhopal
Training on Soil Health Assessment and Management	Dr. Brij Lal Lakaria Dr. Pramod Jha and Dr. B.P. Meena	6-10 June, 2016	Department of Farmers Welfare and Agriculture Development, Jhabua
Training on Soil Testing for Soil Health Assessment	Dr. Pramod Jha, Dr. B.L. Lakaria and Dr. A.O. Shirale	4-8 July, 2016	Department of Farmers' Welfare & Agriculture Development, Govt. of M.P
ICAR Sponsored training on "Use & Maintenance of advanced instruments in soil and plant analysis"	Dr. J.K. Saha, Dr. M.L. Dotaniya and Dr. K.M. Hati	8-13 August 2016	ICAR-IISS, Bhopal
SAARC training on "Climate change impact on soil carbon storage and turnover under different land use systems and adaptation strategies"	Dr. S. Lenka, Dr. N. K. Lenka, Dr. J. K. Saha and Dr. A. K. Patra	16-23 August 2016	SAC, Dhaka and ICAR-Indian Institute of Soil Science, Bhopal
11th Annual Group Meeting of Network Project on Organic Farming	Dr. A. B. Singh	17-19 August, 2016	ICAR-IISS, Bhopal
ICAR sponsored short course "Advances in Soil Testing and Soil Test Crop Response (STCR) Based Fertilizer Management"	Dr. Sanjay Srivastava, Dr. Pradip Dey and Dr. Shinogi K.C	23 August to 1 September, 2016	ICAR-IISS, Bhopal
MTC on "Best Nutrient Management Practices for Enhancing Input Use Efficiency and Soil Health"	Dr. Brij Lal Lakaria, Dr. Pramod Jha, Dr. B.P. Meena and Dr. AK Biswas	30 August to 6 September, 2016	Ministry of Agriculture and Farmers Welfare, DAC, GOI, New Delhi
Training on Soil health assessment and management under Soil Health Card Mission	Dr. R Elanchezhian, Dr. K. Ramesh and Dr. B P Meena	2-6 September, 2016	Department of Farmers' Welfare & Agriculture (Khandwa) Govt. of M.P.
Training on Soil Health Assessment and Management	Dr. K. Ramesh, Dr. A.K. Biswas and Dr. A.O. Shirale	26-30 September, 2016.	Department of Agriculture, Govt. of M.P.
Training programme on Soil Testing Technologies	Dr. Pramod Jha	26 September to 3 October, 2016	RKDF University, Bhopal

Healthy soils for a healthy life

Annual Report
2016-17

Programme	Course Directors/Coordinators	Duration	Sponsored by
Launch meeting of India UK Nitrogen Fixation Centre (IUNFC) project	Dr. D.L.N. Rao and Dr. S. R. Mohanty	6-7 October, 2017	ICAR-IISS, Bhopal
National Seminar on "Soil Health Assessment with Mridaparikshak"	Dr. Sanjay Srivastava, Dr. Pradip Dey and Dr. A.K. Biswas	4-5 November, 2016	ICAR-IISS, Bhopal
Training on Organic farming	Dr. K. Ramesh	8-12 November, 2016	SHUATS, Allahabad
Winter school on Assessing natural resource management, climate risk, and environmental sustainability using simulation models	Dr. M. Mohanty, Dr. R. S. Chaudhary, Dr. J. Somasundaram and Dr. N.K Sinha	8-28 November, 2016	ICAR-IISS, Bhopal
World Soil Day and International Year of pulses-2016	Dr. A. B. Singh	5 December, 2016	ICAR-IISS, Bhopal
ICAR sponsored short course"Advances in microbial bio-fertilizers for sustainable agriculture in diverse soil and cropping systems".	Dr. M.C. Manna, Dr. J. K. Thakur, Dr. A.K. Patra	10-19 January, 2017	ICAR-IISS, Bhopal
Training Soil health assessment and management	Dr. R. Elanchezhian, Dr. K. Ramesh and Dr. A.K. Biswas	2-6 February, 2017	Department of Agriculture, Govt. of M.P.
National Productivity Week on "Waste to Profit through Reduce, recycle and reuse	Dr. R. Elanchezhian, Dr. A. B. Singh and Dr. A.K. Patra	12-18 February, 2017	ICAR-IISS, Bhopal
NICRA- workshop cum training programme on "Crop simulation models in climate change impact assessment"	Dr. M. Mohanty, Dr. N.K Sinha, Dr. J. Somasundaram, Dr. R. S. Chaudhary, Dr. Sangeeta Lenka and Dr. Pramod Jha	14-18 February, 2017	ICAR-IISS, Bhopal
Skill Development Training Programme on "Vermicompost Production"	Dr. A. B. Singh	22 February to 2 March, 2017	ICAR-IISS, Bhopal
Farmers training Programme on "Organic Farming and Soil Health"	Dr. A. B. Singh	27 February to 3 March, 2017	ICAR-IISS, Bhopal
Kisan Sangosthi under MGMG	Dr. A. B. Singh	4 March, 2017	Mugalia Hut, Bhopal
Kisan Sangosthi on CA and soil health under MGMG	Dr. B P Meena and Dr. A K Biswas	4 March, 2017	Khamkheda village, District, Bhopal

Healthy soils for a healthy life

International Decade of Soils
2015-2024

Programme	Course Directors/Coordinators	Duration	Sponsored by
Training Soil Health Assessment and Soil Health Card Preparation'	Dr. N.K. Lenka, Dr. B. L. Lakaria and Dr. B.P Meena	14-18 March, 2017	Department of Farmers Welfare and Agriculture Development, M.P.
Kisan Sangosthi under MGMG	Dr. A. B. Singh	15 March, 2017	Khamkheda village, Bhopal
ICAR Short Course on "Advances in Assessment of Soil Pollution and its Remediation"	Dr. J.K. Saha, Dr. M. Vassanda Coumar and Dr. M.L. Dotaniya	16-25 March, 2017	ICAR-IISS, Bhopal
Kisan Sangosthi under MGMG	Dr. A. B. Singh	24 March, 2017	Bhairopura village, Bhopal
One day farmers training under Farmer FIRST Project	Dr. A. B. Singh, Dr. A. K. Patra, Dr A. K. Vishwakarma and Dr. R.K. Singh	24 March, 20 17	ICAR-IISS, Bhopal
Workshop on Utility of Soil health card for soil health management	Dr. A. K. Biswas	27-28 March, 2017	KVKs of RVSKVV, Gwalior and ICAR-IISS, Bhopal.
Kisan Sangosthi on Climate Smart Agriculture at Karond Khurd and Parwalia Sadak village	NICRA team	29 & 30 March, 2017	ICAR-IISS, Bhopal

Visit to field demonstration of Potassium project and Kisan Sangoshthi

A Kisan Sangosthi on 'Response of Crops to Applied Potassium in Vertisols of India' was organised under 'Mera Gaon Mera Gaurav' Mission at Amoni village (Bhopal) on 8 March, 2017. Farmers from nearby villages participated in the meeting and interacted during the discussion. On this occasion, the visit to field demonstrations were organised and soil health cards (SHC) were distributed by Dr. A.K Patra, Director, Dr. Muneshwar Singh (PC, LTFE) and other dignitaries.

Visit to 'Field Demonstration' sites at Amoni   Soil health cards distribution   Address by Dr AK Patra, Director, ICAR-IISS, Bhopal

Krishi Unnati Mela

ICAR-IISS Bhopal participated in the Krishi Unnati Mela organized at Mela Gorund in ICAR-IARI New Delhi during 15-17th March 2017. On this occasion two technologies (i) 'Mridaparikshak: A Mini-lab for Soil Testing and Fertilizer Recommendation' and (ii) 'Rapo-composting Technology for Recycling of Biodegradable Waste' of the Institute in digital form were displayed in 'KRISHI UNNATI' Pavilion of NRM. The ICAR-IISS stall (A-62) got the Certificate of Consolation for the display of the Exhibits, and Mridaparikshak in particular in this Krishi Unnati Mela. A large number of farmers, students, officials, entrepreneurs and local residents have visited the exhibition.

Participation in Krishi Unnati Mela organized at ICAR-IARI New Delhi (15-17ᵗʰ March 2017)

**SAARC Regional training at
ICAR-IISS during 16-23 August 2016**

**Workshop on Safe Utilization of Fly
Ash in Agriculture on 31 August 2016**

**Training on "Secondary and Micronutrient Analysis in Soil
for Enhancing Crop Production" during 23-28 May, 2016**

**ICAR sponsored short course on Advances in Soil
Testing and STCR Based Fertilizer Management
23 August to 1 September 2016**

**ICAR Sponsored short course on
Advances in assessment of soil and its
remediation during 16-27 March, 2017**

**Kishan Sangosthi under MGMG at
Shahpur on 16 May 2016**

**Kishan Sangosthi under MGMG at Chiklod
khurd, Raisen on 23 June 2016**

International
Decade of Soils
2015-2024

ICAR-IISS

IntensiveTraining cum Awareness Programmes for the tribal farmers of Jhabua, Alirajpur and Dhar districts of Madhya Pradesh on "Sustainable Soil Management for Improving Crop Production" on 7-9 March, 2017 under TSP program

Training cum Awareness Programmes for the tribal farmers

Small equipments (Tubular Maize Sheller-300 Nos. and Serrated sickles-300 Nos.), guava seedlings (600 Nos.) and fertilizers such as urea (100 bags), NPK complex (12:32:16 grade- 200 bags) were distributed to 400 tribal farmers.

Distribution of fertilizers, guava sapling, Tubular Maize Sheller and Serrated sickles to the farmers

National Seminar on Soil Health Assessment with Mridaparikshak during 4-5 November, 2016

Brainstorming on "Efficient utilization of soil test kits for the assessment of soil health" on 5 November, 2016

MTC on BMPs for Enhancing Input Use Efficiency and Soil Health during 30 August- 06 September, 2016

ICAR sponsored short course on Advances in microbial bio-fertilizers for sustainable agriculture in diverse soil and cropping systems during 10-19 January, 2017.

Healthy soils for a healthy life

Soil health assessment and management at ICAR-IISS, Bhopal during 2-6 Sept 2016

Soil health assessment and management at ICAR-IISS, Bhopal during 4-8 July 2016

Organized Launch meeting of India UK collaborative project

The launch meeting of international project "India-UK nitrogen fixation centre" was organized at IISS, Bhopal during 6-7 October,2016. This project opens the Virtual Joint Centres (VJC) on Agricultural Nitrogen funded by DBT- India and BBSRC-UK under the Newton- Bhabha Fund. There are three VJC's on Nitrogen Fixation in UK (University of Oxford, UK; John Innes Centre, Norwich; James Hutton Institute, Dundee) and seven in India (ICAR-IISS, Bhopal; M.S. University of Baroda; ICAR-NBAIM, Mau; University of Calcutta, University of Hyderabad; ICAR-I.ARI, New Delhi and TERI, New Delhi). All project investigators from UK and India participated in the meeting. The Secretary (DARE)& DG (ICAR), Dr. Trilochan Mohapatra, launched the India-UK Nitrogen Fixation Centre (IUNFC) project at ICAR-IISS, Bhopal on 6[th]October 2016.

Farmer FIRST Program

Organised Farmer first workshop on the occasion of National Productivity week on 14th February,2017. The programme was attended by 150 farmers from different villages. Besides awareness programmme on CA was conducted on 4th March, 2017 and 15th March,2017 at village Khamkheda and Bherupura, respectively. Farmers were taken to conservation agriculture demonstration plots to create awareness about conservation agriculture and to discuss on the implementation of the project in a participatory mode.

Healthy soils for a healthy life

International
Decade of Soils
2015-2024

14. DISTINGUISHED VISITORS

- Dr. Trilochan Mohapatra, Secretary (DARE) and Director General (ICAR) visited ICAR- Indian Institute of Soil Science (ICAR-IISS), Bhopal on 6 October, 2016.

- Dr. S.K. Chaudhari, ADG (S&WM)visited ICAR- Indian Institute of Soil Science, Bhopal on 6 October, 2016.

- Dr. V.N. Sharda, Hon'ble Member, Agricultural Scientists Recruitment Board (ASRB) visited ICAR-IISS, Bhopal on 1st Dec, 2016. Dr. Ashok K. Patra, Director, ICAR-IISS, Bhopal welcomed Dr. V.N. Sharda and briefed him about the institute activities and flagship programmes.

- Delegates from United Kingdom comprising Prof. Mark Swainson, University of Lincoln, Prof. Mark Rutter, The National Centre for Precision Farming, Harper Adams University and Prof. Ronald Corstanje, School of Energy, Environment and Agrifood Cranfield University and Ms. Swati Saxena, Senior Science and Innovation Advisor, British High Commission, New Delhi visited ICAR-IISS, Bhopal on November 9, 2016 to bring together UK and Indian Scientists to identify potential areas for joint collaboration in precision farming and natural resource management. They discussed the impacts of long-term fertilizer trials on soil management, soil quality and resilience; micro-and secondary nutrients on soil and plant health, microbial decomposition and rapid composting techniques for enhanced decomposition of waste materials.

- Prof. Philip. S. Poole, University of Oxford, UK and Professor Ray Dixon, FRS, John Innes Centre, Norwich visited ICAR-IISS, Bhopal.

- Dr. C.L. Acharya, Empowered Committee member of the NASF and Dr. P.N. Takkar, Former Director, ICAR-IISS visiting the OTC facility on 23rd March, 2017.

Dr. CL Acharya, Empowered Committee member of the NASF and Dr PN Takkar, Former Director, IISS visiting the OTC facility on 23rd March, 2017

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15. Infrastructure Development

Instrument/Equipment Purchased

Open top chambers (OTCs), Quick Heal Security, Microwave Oven, Hot Air Oven, CCTV Camera, Refrigerator GPS, Laptop, Colour Laser Jet Printer, Turbo Happy Seeder, Distillation Unit, DSC Soil Auger, UPS Batteries , pH-Meter, Compute Table, Office Table, Pocket Pentrometer, Furniture, ALC card, Kirloskar Pump Set, Flame Photometer, Water Storage Tank, UPS Batteries, CO_2 Gas, Maize Shellar, Table Top Incubator , Intercom Cable , UPS, Multi Socket, Bottle Top Acid Dispenser, Helium Gas Cylinder, Battery Operated Sprayer Vermi Bed, Computer and Printer Tractor Operated High Capacity, Furniture, Microplate Reader, Digital Cone Pentrometer, Photosynthesis Analysis System.

Hon'ble Secretary DARE & DG, ICAR, Dr. Trilochan Mohapatra, inaugurating OTC Facility

Foundation stone of Nanotechnology Laboratory was laid by Hon'ble Secretary DARE and DG ICAR, Dr. Trilochan Mahapatra

Training Hostel

Renovation of training hostel of ICAR-IISS, Bhopal was carried out during 2016-17 with facelift of existing rooms and corridor with granite and vitriefied tile flooring.

Library

The library is well maintained with facilities of document such as lending, reference service, reprographic services etc. The Library also exchanges the institute publications with other ICAR Institutes and SAUs. During the period of report, the Institute library has acquired total documents categorized as listed below:

Documents	Addition during 2016-17	Total
Books	Nil	2591
Bound Journals	Nil	2555
Annual Reports	120	2364
Foreign Journals	Nil	Nil
Indian Journals	Nil	Nil

Farm Activities

1. Revenue of Rs. 7.38 lakhs have been generated through sale of farm produce.
2. Resource conservation based farming activities were promoted in the research farm.
3. Two happy seeders were procured under CRP on CA.
4. Two inclined plate planter with herbicide application units were procured under CRP on CA.
5. Tractor operated spray has been procured under CRP on CA and Farmer first project.
6. Fish has been reared in water harvesting ponds.
7. Direct seeded Rice cultivation in low lying patches has been taken up.

International Decade of Soils 2015-2024

16. SCIENTIFIC, TECHNICAL, ADMINISTRATIVE PERSONNEL

DETAILS OF MANPOWER

Name	Designation	Discipline/ category	Date of Joining ICAR	Date of Joining IISS
DIRECTOR'S CELL				
Dr. A. K. Patra	Director	Soil Chemistry/Fertility/ Microbiology	05.10.1989	01.05.2014
Mr. Thomas Joseph	PS	Office Staff	18.09.1989	18.09.1989
Smt. Yojana Meshram	PA	Office Staff	12.05.1997	12.05.1997
Mr. Sukh Ram Sen	T-4	Sr. Tech. Asstt (Driver)	25.01.1991	25.01.1991
Mr. Bhoi Lal Uikey	Lab Attendant	Skilled Supporting Staff	13.11.1995	13.11.1995
Mr. Darashram	Lab attendant	Skilled Supporting Staff	15.03.1990	15.03.1990
DIVISION OF SOIL PHYSICS				
Dr. R.S. Chaudhary	Head & Pr. Scientist	Soil Physics/Soil & Water Conservation	10.11.1993	09.12.1999
Dr. K.M. Hati	Pr. Scientist	Soil Physics/Soil & Water Conservation	27.12.1996	27.12.1996
Dr. R.K. Singh	Pr. Scientist	Soil Physics/Soil & Water Conservation	25.01.1993	16.10.2002
Dr. J. Somasundaram	Pr. Scientist	Soil Physics/Soil & Water Conservation	12.11.2001	22.12.2008
Dr. A. K. Vishvakarma	Pr. Scientist	Agronomy	16.04.2003	01.08.2013
Dr. M. Mohanty	Sr. Scientist	Soil Physics/Soil & Water Conservation	10.11.1999	10.11.1999
Dr. N.K. Sinha	Scientist	Agriculture Physics	20.04.2010	27.08.2010
Mr. R.K. Mandloi	T-7-8	Asstt. Chief Technical Officer	19.06.1989	19.06.1989
Mr. Hukum Singh	T-3	Technical Assistant	30.12.1988	30.12.1988
Mr. Jagannath Gaur	Lab attendant	Skilled Supporting Staff	20.07.1992	20.07.1992
DIVISION OF SOIL CHEMISTRY AND FERTILITY				
Dr. A.K. Biswas	Head & Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	21.01.1992	11.01.1993
Dr. Sanjay Shrivastava	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	22.03.1996	02.09.1996
Dr. Brij Lal Lakaria	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	01.10.1997	15.01.2007
Dr. R. Elanchezhian	Pr. Scientist	Plant Physiology	09.11.1998	17.2.2012
Dr. N. K. Lenka	Pr. Scientist	Soil Physics/Soil & Water Conservation	30.11.2000	09.10.2009
Dr. K. Ramesh	Pr. Scientist	Agronomy	04.09.2008	04.09.2008
Dr. Pramod Jha	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	16.04.2003	17.07.2009
Dr. Shinogi, K.C.	Scientist	Agricultural Extension	27.04.2011	05.09.2011
Dr. B.P. Meena	Scientist	Agronomy	15.09.2011	22.12.2011
Dr. A.O. Shirale	Scientist	Soil Chemistry/Fertility	01.01.2015	10.04.2015
Dr. G.P. Pandurang	Scientist	Soil Chemistry/Fertility	01.01.2016	10.04.2016
Mr. Deepak Kaul	T-7-8	Asstt. Chief Technical Officer	29.12.1988	29.12.1988
Mr. K.S. Raghuvanshi	T-5	Technical Officer	29.12.1988	29.12.1988
Mr. B.S.Yadav	Messenger	Skilled Supporting Staff	01.09.1993	23.01.1999
DIVISION OF SOIL BIOLOGY				
Dr. M.C. Manna	Head & Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	21.01.1992	11.01.1993
Dr. A.B. Singh	Pr. Scientist	Biochemistry	22.03.1999	22.03.1999
Dr. A.K. Tripathi	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	05.08.1991	25.07.1992
Dr. S. Ramana	Pr. Scientist	Plant Physiology	06.02.1997	06.02.1997
Dr. S.R. Mohanty	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	18.06.2009	18.06.2009
Dr. Kollah Bharati	Pr. Scientist	Microbiology - Plant Science	29.10.2009	05.04.2011
Dr. Asit Mandal	Scientist	Soil Chemistry/Fertility	23.06.2009	30.10.2009

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Name	Designation	Discipline/ category	Date of Joining ICAR	Date of Joining IISS
Dr. J. K. Thakur	Scientist	Agricultural Microbiology	20.04.2010	27.08.2010
Dr. Asha Sahu	Scientist	Soil Chemistry/Fertility	03.05.2010	03.05.2010
Dr. S. Bhattacharjya	Scientist	Soil Chemistry/Fertility	01.01.2015	10.04.2015
Mr. Vinod Babu Pal	T-7-8	Asst. Chief Technical Officer	15.02.1993	15.02.1993
Mr. Vinod Choudhary	T-4	Tech. Assistant	14.06.1989	14.06.1989
Mrs. K.S. Rathore	PA	Office Staff	05.05.1997	18.02.2002
Mr. Ram Bharose	Lab attendant	Skilled Supporting Staff	20.03.1990	20.03.1990
DIVISION OF ENVIRONMENTAL SOIL SCIENCE				
Dr. J.K. Saha	Head & Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	21.01.1992	02.01.1993
Dr. S. Kundu	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	22.07.1986	03.07.2007
Dr. Ajay	Pr. Scientist	Plant Physiology	12.04.1993	31.08.1999
Dr. Tapan Adhikari	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	22.03.1996	07.11.1996
Dr. (Mrs) Sangeeta Lenka	Scientist	Soil Physics/Soil & Water Conservation	08.01.2007	18.05.2007
Dr. M.Vassanda Coumar	Scientist	Soil Chemistry/Fertility	04.11.2009	15.03.2010
Dr. M. L. Dotaniya	Scientist	Soil Chemistry/Fertility	20.04.2010	28.08.2010
Dr. Rajendiran S.	Scientist	Soil Science Soil Chemistry/Fertility	02.09.2010	10.01.2011
Shri. V.D. Meena**	Scientist	Agronomy	15.09.2011	23.12.2011
Dr. Sonalika Sahoo	Scientist	Soil Chemistry/Fertility	01.01.2016	10.04.2016
Smt. Seema Sahu	T-7-8	Asstt. Chief Technical Officer	14.04.1987	24.01.1989
Mr. Sant Kumar Rai	T-3	Technical Asstt.	15.06.1989	15.06.1989
Mr. Kalicharan	Lab attendant	Skilled Supporting Staff	01.09.1993	10.06.1999
AICRP-LTFE				
Dr. Muneswar Singh	Project Co-ordinator	Soil Chemistry/Fertility/ Microbiology	11.07.1989	11.07.1989
Dr. R.H. Wanjari	Sr. Scientist	Agronomy	07.01.1999	07.01.1999
Mr. Sunny Kumar	Steno Gr-III	Office Staff	21.12.2011	21.12.2011
Mr. A. K. Mishra	Lab attendant	Skilled Supporting Staff	01.09.1993	10.06.1999
AICRP-MSN				
Dr. A.K. Shukla	Project Co-ordinator	Soil Chemistry/Fertility/ Microbiology	05.07.1996	31.03.2011
Dr. P.K. Tiwari	Scientist	Soil Chemistry/Fertility/ Microbiology	01.01.2013	11.04.2013
Mr. Sahab Siddiqui	T-7-8	Asst. Chief Technical Officer	05.10.1992	05.10.1992
Mr. Jai Singh	T-6	Sr. Technical Officer	22.05.1999	22.05.1990
Mr. Venny joy	PA	Office Staff	14.02.1991	23.03.1998
Mr. Harish Kumar	Lab attendant	Skilled Supporting Staff	14.03.1990	14.03.1990
AICRP-STCR				
Dr. Pradip dey	Project Co-ordinator	Soil Chemistry/Fertility/ Microbiology	03.06.1993	01.02.2012
Dr. N.S. Bhogal	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	14.05.1999	26.05.2014
Dr. Abhishek Rathore*	Scientist	Agricultural Statistics	16.12.2002	16.12.2002
Shri Hironmay Das**	Scientist	Agriculture Statistics	15.09.2011	23.12.2011
Smt. Geeta Yadav	Private Secretary	Office Staff	26.12.1995	26.12.1995
Mr. Janak Singh Mehra	Khalasi	Skilled Supporting Staff	08.09.1997	08.09.1997

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International
Decade of Soils
2015-2024

Name	Designation	Discipline/ category	Date of Joining ICAR	Date of Joining IISS
AINP-BIOFERTILIZERS				
Dr. D.L.N. Rao	Network Coordinator	Soil Chemistry/Fertility/ Microbiology	29.07.1978	25.06.1998
Mr. A.B. Mate	Lab Attendant	Skilled Supporting Staff	15.06.1999	15.06.1999
PME CELL				
Dr. R. Elanchezhian	Pr. Scientist	Officer In-Charge	09.11.1998	17.02.2012
Mr. Sanjay Kumar Kori	Steno Gr-III	Office Staff	03.01.2012	03.01.2012
ITMU				
Dr. S. Shrivastava	Pr. Scientist	Officer In-Charge	22.03.1996	02.09.1996
Dr. Shinogi, K.C.	Scientist	Agricultural Extension	27.04.2011	05.09.2011
AKMU				
Dr. J. Somasundaram	Pr. Scientist	Officer In-Charge	12.11.2001	22.12.2008
Remot Sensing & GIS Laboratory				
Dr. M. Mohanty	Sr. Scientist	Officer In-Charge	10.11.1999	10.11.1999
Mrs. Kavita Bai	Safaiwala	Skilled Supporting Staff	20.12.1988	20.12.1988
LIBRARY SECTION				
Smt. Nirmala Mahajan	T-7-8	Asst. Chief Technical Officer	15.03.1993	15.03.1993
Smt. Geesi Devi	Trainee	Supporting Staff	31.05.2014	31.05.2014
CENTRAL LAB				
Dr. S.R. Mohanty	Pr. Scientist	Officer In-Charge	18.06.2009	18.06.2009
Mr. Vinod Babu Pal	T-6	Sr. Technical officer	15.02.1993	15.02.1993
REFERRAL LAB				
Dr. Pradip Dey	Project Co-ordinator	Officer In-Charge	03.06.1993	01.02.2012
FARM SECTION				
Dr. A.K. Vishwakarma	Pr. Scientist	Officer In-Charge	16.04.2003	01.08.2013
Mr. O.P. Shukla	T-5	Technical Officer (Tractor Mechanic)	22.04.1989	22.04.1989
Mr. C.T. Wankhede	T-5	Technical Officer (Electrician)	03.08.1992	03.08.1992
Mr. D.R. Darwai	T-5	Technical Officer (Field Assistant)	23.01.1993	23.01.1993
Mr. P.K. Chouhan	T-5	Technical Officer	15.02.1993	15.02.1993
Mr. Bhagwat Prasad	Beldar	Skilled Supporting Staff	24.01.1992	24.01.1992
Mr. Lalaram Sahu	Beldar	Skilled Supporting Staff	24.07.1992	24.07.1992
Mr. R.K. Sen	Beldar	Skilled Supporting Staff	08.09.1997	08.09.1997
VEHICLE SECTION				
Dr. Asit Mandal	Scientist	Officer In-Charge	23.06.2009	30.10.2009
Mr. N.S. Yadav	T-5	Technical Officer (Driver)	23.09.1987	03.05.1999
ADMINISTRATION SECTION				
Shri R.K. Giri	AO	Administration	18.05.1976	03.06.2016
Mr. Neeraj Tahiliani	FAO	Audit & account	12.06.2012	22.07.2014
Mr. Rajesh Dubey	AF&AO	Audit & account	21.12.1988	26.11.1998
Mr. P. S. Sunil Kumar	AAO	Administration	30.01.1989	30.01.1989
Mr. A.S. Rajput	Assistant	Establishment section	14.03.1990	14.03.1990
Smt. Babita Tiwari	Assistant	Central store	30.05.1996	30.05.1996
Mr. Bansilal Sarsodia	Assistant	Purchase section	10.09.1997	10.09.1997

Name	Designation	Discipline/ category	Date of Joining ICAR	Date of Joining IISS
Mr. Hiralal Gupta	UDC	Bill section	23.12.1988	23.12.1988
Mr. O.P. Yadav	UDC	Audit & Account	19.12.1988	19.12.1988
Mr. Jineshwar Prasad	UDC	Administration	13.12.1988	13.12.1988
Mr. Sanjay Katinga	LDC	Cash Section	20.06.1989	20.06.1989
Smt. Raksha Parsai	LDC	Administration	24.05.2013	24.05.2013
Mr. Anurag	Security Supervisor	Security section	29.09.1997	29.09.1997
Mr. P.K. Raut	Beldar	Skilled Supporting Staff	21.07.1992	21.07.1992
Mr. Sanjay N. Gharde	Lab attendant	Skilled Supporting Staff	15.06.1999	15.06.1999
Mr. D.R. Singh	Messenger	Skilled Supporting Staff	10.09.1993	14.06.1999
Mr. L.N. Chouksey	Messenger	Skilled Supporting Staff	17.12.1988	17.12.1988
Mr. S.K. Batham	Messenger	Skilled Supporting Staff	19.12.1988	19.12.1988

*on deputation; ** on study leave

Joining

Dr. Sonalika Sahoo, Scientist and Dr. Gurav Priya Pandurang, Scientist joined on 10 April, 2016 at ICAR-IISS, Bhopal

Promotion

Dr. D.L.N. Rao, joined as Emeritus Scientist at ICAR-IISS Bhopal w.e.f. 13 January, 2017
Dr. K. Ramesh, Senior Scientist promoted to Principal Scientist w.e.f. 4 September, 2014
Dr. R.K. Singh, Senior Scientist promoted to Principal Scientist w.e.f. 7 September, 2014.
Dr. J. Somasundaram, Senior Scientist promoted to Principal Scientist w.e.f. 22 December, 2014
Dr. A.K. Vishwakarma, Senior Scientist promoted to Principal Scientist w.e.f. 2 July, 2015
Dr. Pramod Jha, Senior Scientist promoted to Principal Scientist w.e.f. 15 July, 2015
Dr. S.R. Mohanty, Senior Scientist promoted to Principal Scientist w.e.f. 18 June, 2015
Dr. K. Bharati, Senior Scientist promoted to Principal Scientist w.e.f. 29 October, 2015
Dr. Sangeeta Lenka, Scientist promoted from RGP Rs 7000 to 8000 w.e.f.8 January, 2016
Dr. N.K. Sinha, Scientist promoted from Scientist RGP Rs 6000 to 7000 w.e.f.20 April 2014
Dr. Monoranjan Mohanty, Scientist promoted to Sr. Scientist RGP Rs8000 to 9000 w.e.f.10 November 2013
Dr. S. Rajendiran, Scientist have been promoted from RGP Rs 6000 to Rs 7000w.e.f.2 September, 2014
Dr. M L Dotaniya, Scientist have been promoted from RGP Rs 6000 to Rs 7000 w.e.f. 20 April, 2014
Dr. Asha Sahu, Scientist have been promoted from RGP Rs 6000 to Rs 7000 w.e.f. 3 May 2014
Dr. J.K. Thakur, Scientist have been promoted from RGP Rs 6000 to Rs 7000 w.e.f. 20 April 2014
Dr. B.P. Meena, Scientist have been promoted from RGP Rs 6000 to Rs 7000 w.e.f. 15 September 2014
Dr. Shinogi K.C., Scientist have been promoted from RGP Rs 6000 to Rs 7000 w.e.f. 27 April 2015
Mr. V.B. Pal, Sr. Technical Officer promoted to Asst. Chief Technical Officer w.e.f. 10 February, 2015
Mr. Jai Singh Technical Officer promoted to Senior Technical Officer w.e.f. 22 May, 2016
Mrs. Nirmala Mahajan Senior Technical Officer promoted to Assistant Chief Technical Officer w.ef. 15 March, 2013.
Mr. Sukhram Sen Technical Assistant promoted to Senior Technical Assistant w.e.f. 29 June, 2016
Mr. Hukum Singh Technical Assistant promoted to Senior Technical Assistant w.e.f. 30 October, 2015
Mr. Vinod Chaudhari Technical Assistant promoted to Senior Technical Assistant w.e.f. 30 November, 2015
Mr. N.S. Yadav Senior Technical Assistant promoted to Technical Officer w.e.f. 29 June, 2016
Mr. Sahab Siddiqui Senior Technical Assistant promoted to Assistant Chief Technical Officer w.e.f. 12 December, 2014
Mr. O.P. Shukla Senior Technical Assistant promoted to Technical Officer w.e.f. 1 January, 2014

Superannuation

Dr. D.L.N. Rao, Pr. Scientist & Network Coordinator of AINP on Soil Biodiversity and Biofertilizer superannuated on 30 November, 2016.

International
Decade of Soils
2015-2024

ICAR-IISS AT A GLANCE

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Decade of Soils
2015 - 2024

स्वस्थ मृदा ● स्वस्थ फसल ● स्वस्थ जीवन
Healthy soils for a healthy life