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Preface



Soil, the skinny 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 our feet is truly fascinating and alien to our understanding in many aspects. The importance of soils has enhanced globally when the United Nations General Assembly has officially recognized 2015 as the International Year of Soils. This recognition imparts a greater responsibility to all the scientists working on soil science and its associated disciplines towards rigorous research on the management of soil resources and creating awareness among people on the roles and functions of soils in the sustenance of humanity. In India, the food production and the associated agricultural enterprises have to be carried out in the 141 million hectare of finite agricultural land which is diminishing at an alarming rate owing to land degradation and various anthropogenic pressures. Soil degradation is eroding crop yields and contributing to malnourishment in many corners of the globe including India. Hence, the improvement and maintenance of the health of the soils is indispensable for productivity of agricultural system. This warrants regular monitoring of our soils and providing suitable technological interventions for maintenance of soil health.

At present, ICAR-IISS, Bhopal is engaged in research with the mandate “to provide scientific basis for enhancing and sustaining productivity of soil resources with minimal degradation”. The institute has developed viable technologies with field level validation for improvement of soil health to address the emerging challenges / issues. The report vividly illustrates the multi-scale approach in the area of soil health and input use efficiency, conservation agriculture and carbon sequestration, soil microbial diversity and genomics, soil pollution, remediation and environmental security. The report 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 year reported, some new technologies and methodologies were developed and refined by the institute viz. A mini lab named Mridaparikshak which can estimate 10 soil parameters viz., pH, EC, organic carbon, available N, P, K, S, Fe, Zn, and B; development of prediction models for SOC using MIR spectroscopy; mixed biofertilizer consortium of actinomycetes isolates along with consortia of Rhizobia and PGPR for wheat and chickpea; a bio-reactor for accelerated decomposition of biodegradable wastes; preparation of standard reference soil material for heavy metal analysis. Besides, on the basic research



front, identification and delineation of simultaneous deficiencies of more than one micronutrient and bacterial and archaeal diversity has also been identified in bioenergy crop.

There has been a considerable progress in the studies on conservation agriculture, carbon sequestration, greenhouse gas emission, crop modeling and climate change, soil resilience, soil and water quality, bio-fortification with micronutrients and microbial characterization using genomics and meta-genomics. Further, this report presents a glimpse of all the important activities undertaken by the institute during the period reported upon. It is thus, a great pleasure for me to bring out the Annual Report 2015-16 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 Divisions for compiling the information at AICRP/divisional level. I also extend my gratitude to all the scientists and staff members of the institute for their painstaking efforts in carrying out the research and other developmental activities of institute and for providing the requisite material for of this report.

I place on record, my sincere appreciation to Dr. R. Elanchezhian, Dr. K. Ramesh, Dr. Pramod Jha, Dr. M Mohanty, Dr. Sangeeta Lenka, and Dr. J.K. Thakur for their dedicated efforts in compiling and editing the report.

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

Bhopal

(Ashok K. Patra)
Director





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विशिष्ट सारांश

प्रसंग - 1: मृदा स्वास्थ्य एवं इनपुट उपयोग क्षमता

मृदा उर्वरता मूल्यांकन

- मृदा परीक्षक का एक संसोधित संस्करण तैयार किया गया जो मृदा के 15 मानकों को माप सकता है। यह मृदा विश्लेषण के आधार पर उर्वरक अनुसंशाएं भी देता है।
- विभिन्न संसोधित यूरिया अर्वरकों में से नीम लेपित यूरिया द्वारा मक्का के दानों व डण्डल की उपज, मृदा में जैविक पदार्थ की मात्रा व पोषक तत्वों की उपयोग दक्षता अधिक दर्ज की गई। इसके उपरान्त बायोचार व पाइन-ओलियोरेजिन लेपित यूरिया रहे।
- मक्का की फसल में नत्रजन की भिन्न भिन्न मात्राओं को अलग-अलग समय पर देने से उन नवाचारों में ज्यादा दानों व डण्डल की उपज प्राप्त हुई जिनमें नत्रजन की पूरी मात्रा (60 कि. ग्रा./ है.) दो बराबर भागों में बुआई के 20 व 40 दिन के बाद डाली गई थी।
- एम.आई.आर. स्पेक्ट्रोस्कोपी विधि का उपयोग मृदा के गुणों को जानने के लिए किया जा रहा है। विशिष्ट स्पेक्ट्रा को ध्यान में रखते हुए निर्धारण के गुणांक के आधार पर मृदा में जैविक कार्बन के अनुमान के लिए विभिन्न पूर्वसूचना मॉडल तैयार किए गए।
- देश के 23 राज्यों के 435 जिलों के जी.पी.एस. आधारित 169290 मृदा नमूनों के हाल ही में किए गए विश्लेषण से इन मृदाओं में सूक्ष्म व गौण पोषक तत्वों की प्रबल कमी के संकेत मिले हैं।
- औसतन 40 प्रतिशत मृदाओं में जस्ता की, 33 प्रतिशत मृदाओं में, सल्फर की तथा 23 प्रतिशत मृदाओं में बोरॉन की कमी देखी गई। विभिन्न राज्यों की मृदाओं में लोहा (12.6 प्रतिशत), ताँबा (4.6 प्रतिशत) व मैंगनीज़ (6.0 प्रतिशत) की कमी भी उभर रही है जो टिकाऊ कृषि के लिए खतरा प्रस्तुत कर रही है। देश के एक तिहाई जिलों की लगभग 50 प्रतिशत मृदाओं में जस्ता की कमी है।
- विभिन्न राज्यों की मृदाओं के लिए डी.टी.पी.ए. निष्कर्षित जस्ता, लोहा, ताँबा, मैंगनीज तथा गर्म जल निष्कर्षित बोरॉन की कमी व पर्याप्तता की सीमाएं दोबारा तय की गई हैं।

इनपुट उपयो दक्षता बढ़ाने के लिए नैनो-तकनीकी

- पौधों को नैनो रूप (अति सूक्ष्म रूप, 54 माइक्रो मीटर) में लोहा की इष्टतम मात्रा देने पर उनके रूपात्मक विशेषताओं जैसे – पौधे की ऊँचाई, जैविक उपज (जड़ तथा तना व पत्ते) में वृद्धि हुई जबकि एंटी-ऑक्सीडेंट एंजाइम्स की गतिविधि में उन पौधों की अपेक्षा कम रही जिन्हें इष्टतम से कम मात्रा में सामान्य लोहा दिया गया, जबकि लोहा की आधी मात्रा ही नैनो रूप (27 माइक्रो मीटर) में देने से पत्तों के क्षेत्रफल व प्रोलीन की मात्रा पर अच्छा असर पड़ा।
- सिंचाई समय निर्धारण में सहायक वास्तविक समय आधारित "मृदा नमी सेंसर डेटा" के लिए एक दूरमापी नेटवर्क तैयार किया व उसे भाकृअप-केन्द्रीय कृषि अभियांत्रिकी संस्थान, भोपाल में संस्थापित किया गया है। यह दूरमापी नेटवर्क संतोषजनक कार्य कर रहा है।
- नैनो-रॉक फॉस्फेट को बढ़ते स्तर में डालने से वर्टीसोल व अल्फीसोल मृदाओं में उपलब्ध फॉस्फोरस की मात्रा में अर्थपूर्ण





बढ़ोत्तरी हुई ।

संतुलित एवंसमन्वित पोषक तत्व प्रबंधन

- मक्का की फसल में समन्वित पौध पोषण के विभिन्न मॉड्यूल्स में से एस.टी.सी.आर. (मृदा विश्लेषण आधारित अनुक्रिया) आधारित उर्वरकों की 75 प्रतिशत मात्रा देशी खाद के साथ डालने से दानों की उच्चतम उपज प्राप्त हुई ।
- एन.पी.के. के साथ देशी खाद डालने से पृष्ठीय व अपृष्ठीय मृदा में गर्म जल घुलनशील जैविक पदार्थ की मात्रा उच्चतम दर्ज हुई जबकि इसकी न्यूनतम मात्रा बिना किसी उर्वरक उपयोग से पृष्ठीय मृदा में तथा सिर्फ नत्रजन उर्वरक उपयोग से अपृष्ठीय मृदा में पाई गई ।
- फसलों को शत प्रतिशत जैविक पोषक तत्व प्रबंधन करने से मृदा में सबसे अधिक औसतन जैविक कार्बन की मात्रा (0.98 प्रतिशत) पाई गई तथा इसके बाद 75 प्रतिशत एन.पी.के. उर्वरक (0.97 प्रतिशत) रही । विभिन्न फसल चक्रों में सबसे अधिक जैविक कार्बन की मात्रा सोयाबीन-गेहूँ फसल चक्र द्वारा दर्ज की गई तथा इसके बाद सोयाबीन-सरसों, सोयाबीन-अलसी तथा सोयाबीन-चना फसल चक्र रहे ।

प्रसंग - 2: संरक्षित कृषि, कार्बन स्थिरीकरण एवं जलवायु परिवर्तन

- जबलपुर में किए गए संरक्षण कृषि प्रयोगों में शून्य जुताई और फसल अवशेष के साथ धान आधारित फसल प्रणाली में अधिकतम (0.87%) मृदा जैविक कार्बन का एकत्रीकरण पाया गया जो कि पारम्परिक जुताई के साथ अवशेष जलाये हुए या खेत में रखे हुए की तुलना में काफी अधिक था । मक्का आधारित फसल प्रणाली में भी इसी प्रकार के परिणाम प्राप्त हुए ।
- धान आधारित फसल प्रणाली में शून्य जुताई के साथ 519 मिली ग्रा. प्रति किलो (0-15 सेमी मिट्टी की गहराई) में काफी अधिक लेबाइल कार्बन पाया गया जो कि पारम्परिक जुताई के साथ 429 मिली ग्राम प्रति किलो फसल अवशेष की तुलना में काफी अधिक था । सोयाबीन तथा मक्का आधारित फसल प्रणाली में भी इसी प्रकार परिणाम प्राप्त हुए । साथ ही फसल अवशेष के साथ शून्य जुताई के अन्तर्गत लेबाइल कार्बन की अधिक मात्रा पाई गई जो कि बिना अवशेषों के साथ पारम्परिक जुताई की तुलना में अधिक था ।
- एक अन्य संरक्षण कृषि प्रयोग में गेहूँ की फसल में फसल अवशेषों द्वारा चार चौड़ी पत्ती वाले खरपतवार अल्टरनैन्थेरा सेसिलिस, ट्रिडॉक्स प्रोक्यूम्बेंस, सोनकस अरवेंसिस तथा पार्थिनियम हिस्टेरोफोरस की संख्या में प्रभावी कमी पाई गई ।
- 50 प्रतिशत फसल अवशेष द्वारा अल्टरनैन्थेरा सेसिलिस की संख्या में बिना अवशेषों की तुलना में काफी कमी आई है ।
- छह फसल चक्रों के पश्चात् भी जुताई के कारण सोयाबीन तुलनात्मक उपज अप्रभावित रही । जुताई प्रणालियों से प्रभावित हुए बिना मक्का-चना फसल प्रणाली में अधिकतम उपज प्राप्त हुई जो कि सोयाबीन+तुवर (2:1) तथा सोयाबीन+कपास (2:1) से काफी अधिक थी । सोयाबीन आधारित फसल प्रणालियों में कम उपज का मुख्य कारण प्रतिकूल मौसम था ।
- पारम्परिक जुताई की तुलना में मध्य वजन ब्यास (MWD) के रूप में मापा गया । मृदा एकत्रीकरण 0-5 सेमी में फसल अवशेषों के साथ शून्य जुताई तथा कम जुताई में काफी सुधार पाया गया । इसी प्रकार जल स्थिर एकत्रीकरण मृदा की 0-5 सेमी गहराई में शून्य जुताई के साथ अधिक पाया गया । इसी प्रकार फसल अवशेषों के साथ शून्य जुताई में मृदा जल संधारण में रबी मौसम के दौरान सुधार पाया गया ।
- संरक्षण कृषि के अन्तर्गत दो निंदाई (बुवाई के 20 एवं 40 दिन पश्चात्) सबसे कम खरपतवार जैव उत्पादन तथा चना उत्पादन पाया गया जो कि ऑक्सीफ्लोरफेन 200 ग्रा. सक्रिय तत्व प्रति है. के उगने से पूर्व प्रयोग के बराबर था ।



- गेहूँ की फसल में दो निंदाई (बुवाई के 20 एवं 40 दिन पश्चात्) में सबसे कम खरपतवार जैव उत्पादन एवं गेहूँ की उपज प्राप्त हुई जो कि अंकुरण उपरांत डाले गए मीजोसल्फ्यूरॉन+आइडोसल्फ्यूरॉन @400 ग्रा. प्रति है. के बराबर थी।
- मक्का-सरसों फसल चक्र में सरसों की फसल में अधिकतम उपज 14.18 किं. प्रति है. दो निंदाई के द्वारा प्राप्त हुई जो कि पेंडिमिथलिन के 750 ग्रा. सक्रिय तत्व प्रति है. अंकुरण पूर्व के बराबर था।
- मक्का-चना फसल चक्र के अन्तर्गत अंकुरण पूर्व डाले गए ऑक्सीफ्लूरोफन 200 ग्रा. सक्रिय तत्व प्रति है. द्वारा खरपतवार नियंत्रण से पाया गया जो कि दो निंदाई के बराबर पाया गया।
- सोयाबीन फसल में खरपतवार नियंत्रण प्रोपाक्विजाफाप 100 ग्रा. सक्रिय तत्व प्रति है. +क्लोरीम्यूरॉन इथाइल 1 ग्रा. प्रति है. द्वारा सबसे कम खरपतवार जैव उत्पादन तथा अधिकतम उपज प्राप्त हुई जो कि दो निंदाई के बराबर थी।
- मध्यप्रदेश में उपज अंतर विश्लेषण के तहत पाया गया कि मक्का की अधिकतम अनुमानित उपज 7.6 टन प्रति है. मंदसौर जिले में पाई गई तथा न्यूनतम 0.8 टन प्रति है. दमोह जिले में दर्ज की गई। मध्यप्रदेश राज्य में मक्के की उपज में 3.0 टन प्रति है. तक सुधार करने की संभावना है। पौधों को उपलब्ध जल की क्षमता (73-140 मि.मी.) में यह देखा गया कि 10 प्रतिशत वर्षा कमी होने से मक्का की उपज में बढ़ोत्तरी पायी गई।
- स्थूल घनत्व में 1.2 से 1.6 मेगा ग्राम प्रति क्यूबिक मीटर तक बढ़ने से गेहूँ की लम्बाई, नोड्स की संख्या, प्राथमिक अक्ष तथा जड़ों के कोष में कमी पाई गई। उर्वरक के अकेले अनुप्रयोग की तुलना में उर्वरक तथा खाद को लम्बी अवधि तक डालने से वृहद कुल अंशों के अनुपात में वृद्धि हुई। (>2 मिमी तथा 2-0.25 मिमी), 100 प्रतिशत उर्वरक+खाद डालने से मध्य वजन व्यास में काफी वृद्धि पाई गई।

प्रसंग - 3: सूक्ष्म जैविक विविधता एवं जैवप्रौद्योगिकी

- जैट्रोफा करकस के जड़ की सतह पर 15 बैक्टीरिया तथा 17 आर्किया के टी.आर.एफ. विद्यमान थे जिसमें एकटीनोबैक्टीरिया, फार्मीक्यूट, एसीडोबैक्टीरिया, वेरुमाइक्रोबियेसी एवं क्लोरोफ्लेक्सी शामिल थे। आर्किया के टी.आर.एफ. पर्यावरण नमूने के असंवर्धित आर्किया से संबंधित थे। प्रमुख अंतःपादीजीवाणु बैसिलस जाति के समान थे एवं इनके जीन अनुक्रम बैसिलस पूमिलस, राइजोबियम, पेनिबैसिलस इत्यादि के समान पाये गये। ये उपजातियाँ अधिकतम 15.44 माइक्रोग्राम प्रति मि.ली. तक इंडोल एसिटिक अम्ल उत्पादन में सक्षम थे तथा मक्के पर इनका बोजोपचार मक्के के विकास में बढ़ोत्तरी लाई।
- जैट्रोफा करकस के प्रमुख पर्णसतही जीवाणुओं के 16 rRNA जीन अनुक्रम अल्फा प्रोटियोबैक्टीरिया, बीटा प्रोटियोबैक्टीरिया, गामा प्रोटियोबैक्टीरिया, फार्मीक्यूट्स तथा एकटीनोबैक्टीरिया के बहुत ही समान थे। अधिकांश वियोजन गतिशील एवं ग्राम अभिरंजन के प्रति परिवर्तनशील थे। पर्णसतह पर राल्स्टोनिया, मिथाइलोबैक्टेरएवं एकटीनोमाइसिटीज के नजदीकी समान कई नवीन प्रजातियाँ भी पाई गई।
- दो ऊष्णकटिबंधीय मिट्टी (जलोढ़ तथा वर्टिसोल) में आयरन रेडाक्स चक्र एवं मिथेन ऑक्सीकरण के बीच सहलग्नता की स्पष्टीकरण की गई। वर्टिसोल में संभावित आयरन अवकरण दर (माइक्रोमोल Fe^{2+} उत्पादन प्रति ग्राम मिट्टी प्रतिदिन) 1.26 से 2.16 तक तथा जलोढ़ मिट्टी में 1.95 से 3.05 तक देखी गई। संभावित आयरन ऑक्सीकरण दर वर्टिसोल में (माइक्रोमोल Fe^{2+} ऑक्सीकृत प्रति ग्राम मिट्टी प्रतिदिन 2.33 से 5.77 एवं जलोढ़ मिट्टी में 2.43 से 9.58 तक पाया गया।
- एस्परजिलस टेरस तथा एस्परजिलस फ्लेवस द्वारा नैनो रॉकफॉस्फेट विलयन जैविक अम्ल उत्पादन के कारण होता देखा गया।





- चना के लिए मिसोराइजोबियम एवं मसूर तथा मटर के लिए राइजोबियम लेग्यूमिनोसेरम के आशाजनक उपभेदों का बिहार के तालभूमि से चयन किया गया। राइजोबियम लेग्यूमिनोसेरम तथा बैसिलस के सह उपचार से मसूर की अधिकतम उपज प्राप्त की गई। बिहार में देसरिया चावल के अंतःपादी जीवाणुओं एवं चावल-एस्काइनोमेन परिस्थितिकी तंत्र में एस्काइनोमेन के जड़/तना गांठ में उपस्थित जीवाणुओं का 16 rDNA अनुक्रम दोनों ही जगहों पर ब्राडीराइजोबियम के समान थे। चावल की जड़ों में 29 संघों के 2000 से ज्यादा जीवाणुओं की जाति पाई गई। इनमें प्रमुखतः प्रोटियोबैक्टीरिया (44 प्रतिशत), तत्पश्चात् फर्मीक्यूट(18 प्रतिशत) एवं एक्टीनोबैक्टीरिया (17 प्रतिशत) थे।
- मक्का के पौध विकास को प्रोत्साहित करने एवं पी.जी.पी.आर. गुणों यथा इंडोल एसिटिक अम्ल उत्पादन, सीडेरोफोर उत्पादन, फॉस्फोरस विलयन के आधार पर कुल 200 आर्थोबैक्टर वियोजनों का पृथक्करण किया गया। चयनित 13 प्रभावी उपभेदों ने सोयाबीन की गांठ संख्या, गांठ द्रव्यमान एवं दाने की उपज में, अनुपचारित सोयाबीन की तुलना में 6, 17 एवं 12 क्रमशः की बढ़ोत्तरी दिखाई। रबी में चना तथा गेहूँ की उपज में 21 एवं 24 प्रतिशत क्रमशः औसत बढ़ोत्तरी दर्ज की गई।
- जल संतृप्तता की स्थिति में मिट्टी जीवाणुओं द्वारा संचालित अवायवीय श्वसन रेडॉक्स प्रक्रिया से गुजरता है जिसमें वैकल्पिक इलेक्ट्रॉन स्वीकारक के अवकृत होने का क्रम NO_3^- , Fe^{3+} , SO_4^{2-} तथा CO_2 पया गया। अमोनिया ऑक्सीकारक बैक्टीरिया के प्रावरोध की स्थिति में अमोनिया ऑक्सीकरक आर्किया नाइट्रिकरण तथा टर्मिनल इलेक्ट्रान स्वीकारण प्रक्रिया को व्यवस्थित करता है।
- कोपियोट्राफिक जीवाणुओं (अल्फा, बीटा, डेल्टा प्रोटियोबैक्टीरिया एवं एक्टीनोबैक्टीरिया) को सापेक्ष अनुपात जैविक मिट्टी में ज्यादा पाया गया जबकि ओलिगोट्राफिक जीवाणुओं (गामा प्रोटियोबैक्टीरिया) का अनुपात रासायनिक खाद वाली मिट्टी में ज्यादा पाया गया। ट्रांसक्रिप्शन के साथ-साथ श्वसन, कोशिका विभाजन एवं ओसमोप्रोटेक्शन से संबंधित जीन भी जैविक मिट्टी में अधिक पाये गये।
- एक्टीनोमाइसिटीज के सबसे अच्छे वियोजनों (A10 एवं A17) का मिश्रित कंसोर्टियम राइजोबिया एवं पी.जी.पी.आर. के कन्सोर्टियम (राइजोबियम R40 एवं R56; पी.जी.पी.आर. P3, P10 एवं P25) के साथ-साथ उपयोग करने पर चना की उपज में 77 प्रतिशत वृद्धि पाई गई जबकि सबसे अच्छे एक्टीनोमाइसिटीज वियोजन (A6 एवं A10) सी.आर.पी. (राइजोबियम: R33 एवं R34; पी.जी.पी.आर: P3, P10 एवं P25) का संयुक्त उपयोग वर्टिसोल में 22 प्रतिशत अधिक सोयाबीन की उपज दिया।
- केरल में अदरक एवं काली मिर्च पर पेनीबैसिलस एवं माइक्रोबैक्टीरियम टेस्टासियम, नवीन पी.जी.पी.आर. का मूल्यांकन आशाजनक पाया गया।
- महाराष्ट्र में जिंक की कमी वाली वर्टिसोल में जिंक विलेयक जीवाणुओं के जांच में स्यूडोमोनस स्ट्रीआटा के उपयोग से सोयाबीन में 11 प्रतिशत अधिक उपज, बी.टी. कपास में ट्राइकोडर्मा विरिडी से 14 प्रतिशत एवं स्यूडोमोनास स्ट्रीआटाके उपयोग से नियंत्रण की तुलना में 12 प्रतिशत अधिक कपास प्राप्त हुए।
- उड़द में तरल बायोफर्टिलाइजर का बुवाई के उपरांत उपयोग बुवाई के समय चूक गये उपयोग की भरपाई में सक्षम है।
- महाराष्ट्र में सोयाबीन के तरल बायोफर्टिलाइजर ब्राडीराइजोबियम+पी.एस.बी. @50मि.ली. प्रत्येक प्रति 10 कि.ग्रा. बीज एवं गेहूँ में एजोटोबैक्टर+पी.एस.बी. @100 मि.ली. प्रत्येक प्रति 10 कि.ग्रा. बीज की अनुशंसा जारी की गई।



- आंध्र प्रदेश के लिए अनुसंधान जारी की गई। आंध्र प्रदेश में पोटेशियम विलयक जीवाणु तथा फसल अवशेष विघटित करने वाले जीवाणुओं का कंसोर्टियम जारी किया गया।
- मैक्रोएग्रीगेट के निर्माण में ग्लोमैलिन महत्वपूर्ण भूमिका अदा किया। अवशेष की सतत आपूर्ति, ग्लोमैलिन की मात्रा एवं मृदा एकत्रिकरण को बढ़ाने में सहायक पाई गई।

प्रसंग -4: मृदा प्रदूषण एवं निराकरण

- अनुपचारित सीवेज के पानी का फसल पर लम्बे समय तक इस्तेमाल से मिट्टी के जैविक कार्बन में बढ़ोत्तरी पाई गई। चूँकि सीवेज का पानी पौध पोषक तत्वों एवं जैविक पदार्थों का एक मूल्यावान् स्रोत है, इसका इस्तेमाल वर्टिसोल में कार्बन जब्तीकरण में भी सक्षम है। हालाँकि सीवेज के पानी में उपस्थित भारी धातुओं की मारण का अनुमान लगाने में सतर्कता की जरूरत है।
- गेहूँ समतुल्य उपज एवं मृदा नाइट्रेट ऑक्साइड उत्सर्जन के बीच सकारात्मक एवं काफी सहसंबद्ध रिश्ता है। दाने की उपज से N_2O उत्सर्जन में 69 प्रतिशत बदलाव की विवेचना की जा सकती है। इसके अलावा अन्य कारक जैसे उपलब्ध नत्रजन, नत्रजन उर्वरक का उपयोग, मध्य भारत के वर्टिसोल में सोयाबीन-गेहूँ फसल चक्र से N_2O उत्सर्जन में 59 से 61 प्रतिशत तक वार्षिक भिन्नता को समझा सका।
- भारी धातुओं के विश्लेषण के लिए भारतीय मृदा विज्ञान संस्थान के क्षेत्र से लिए गये मिट्टी के मिश्रित नमूने से संदर्भ मिट्टी मापदंड (स्टैंडर्ड रिसोर्स सोयल) सामग्री तैयार किया गया। समांगता जांच में पाया गया कि भारी धातुओं जैसे Cu, Pb, Cr, Ni, Z में 10 प्रतिशत से कम तथा Cd में 27.45 प्रतिशत गुणांक भिन्नता थी।
- सीहोर और विदिशा जिले के खेतों की मिट्टी में भारी धातुओं Cu, Cd, Pb, Ni एवं Zn की आधार रेखा सांद्रता 178.1, 0.7, 24.4, 116.9, 81.8 एवं 85.2 मि.ग्रा. प्रति कि.ग्रा. पाई गई।
- संवर्धन तकनीक द्वारा विमुक्त किये गये गंधक ऑक्सीकारण जीवाणु (3M एवं 4S+M), गंधक ऑक्सीकारक क्षमता तथा मुर्गी खाद से दुर्गंध कम करने में आशाजनक पाये गये।
- कीटनाशक क्षरण करने वाले जीवाणुओं के पहचान करने हेतु मृदा में कीटनाशक (क्लोरोपाइरीफॉस, इमिडाक्लोप्रिड) मिलाकर बढ़ाये हुये कार्बन डाईऑक्साइड एवं तापमान पर रखा गया। जीवाणु समूह इमिडाक्लोप्रिड की अपेक्षा क्लोरोपाइरीफॉस में अधिक थे। क्लोरोपाइरीफॉस में जीवाणुओं के जीन अनुक्रम माइक्रोबैक्टीरिया, बैसिलस आर्थ्रोबैक्टर के समान थे। इमिडाक्लोरोप्रिड में डी.एन.ए. अनुक्रम, बैसिलस मेगाटेरियम एवं माइक्रोकोकस जाति के समान थे।
- बी.टी. कपास (RCH-2) के पौध उद्भव कैडमियम के अलग-अलग स्तर (200 mg kg⁻¹ soil तक), Pb (1000 mg kg⁻¹ soil तक) एवं Cr (50 mg kg⁻¹ soil तक) अप्रभावित रहा। हालाँकि सीसा विषमपोषण को काफी हद तक कम की। भारी धातुओं को प्रक्षेत्र मृदा की डीहाइड्रोजिनेज क्रिया तथा पत्तियों के NR क्रिया में कमी लाई लेकिन प्रोलिन एस्कार्बेट, कुल मुक्त अमिनो अम्ल तथा इलेक्ट्रोलाइट रिसाव की मात्रा को बढ़ाया।



EXECUTIVE SUMMARY

Theme I: Soil Health and Input Use Efficiency

Soil Fertility Evaluation

- An improved version of mini lab for rapid soil testing "Mridaparikshak" has been developed which can estimate 15 physico-chemical parameters of soil. Through this mini setup soil test based nutrient recommendations can be obtained for selected crops and soils.
- Among different modified urea materials, neem coated urea (NCU) recorded higher maize grain, stover and total dry matter yield and NUE followed by biochar coated urea (BCU) and pine oleoresin coated urea (POR) over prilled urea.
- Among the varying N rate and time of application, grain and stover yield of maize crop were significantly higher where basal dose of N was skipped and applied in two equal splits (60 kg N ha^{-1}) at 20 and 40 days after sowing (DAS), respectively.
- MIR spectroscopy is being studied for prediction of soil properties in Vertisols. Different prediction models have been developed for estimation of soil organic carbon considering specific spectral parameters based on its coefficient of determination.
- A recent analyses of 1,69,290 soil samples collected from 435 districts of the 23 states of the country for delineation of micro and secondary nutrient deficiency using GPS indicated rampant micronutrient deficiency in the country.
- On an average, 40% soils are deficient in Zn, 33% in Sulphur and 23% in Boron. The deficiency of Fe (12.6%), Cu (4.6%) and Mn (6.0%) are also emerging in different states and posing threats to agricultural sustainability. About 50% soils of one third of total districts in India are deficient in Zn.
- The deficiency and sufficiency limits of DTPA extractable Zn, Cu, Fe and Mn and hot water extractable B has been revisited for the soils of different states.
- Agronomic bio-fortification is an inexpensive and simple approach which can be utilized to enrich genetically inefficient cultivars by application of micronutrient fertilizers at different rates, methods and at different crop growth stages.

Nano Technology for Improving Input Use Efficiency

- Plants fertilized with optimal recommended dose of Fe in nano form ($54 \mu\text{M}$) increased morphological features viz. plant height, biomass (shoot and root), while decreased antioxidant enzyme activity than the plants fertilized with the sub-optimal dose of Fe in macro form. However, half of the recommended dosage of Fe ($27 \mu\text{M}$) in nano form had positive influence on leaf area and proline content of plants.
- A telemetry network developed and installed in CIAE farm for real time soil moisture sensor data to assist irrigation scheduling in time is found to work satisfactorily. Data is collected in the field using soil moisture (MP406) sensors and transferred onto a server using radio telemetry and the mobile phone network. The data thus collected has been calibrated with oven method.
- Smart delivery of Zn and Mo, micronutrients could be done using nanoporous synthetic zeolites.
- Increasing the level of nano-rockphosphate application to Vertisol and Alfisol showed significant increase in available P content in soil.

Balanced and Integrated Nutrient Management

- Among the different IPNS modules, maize grain yield was found to significantly increased with the



application of 75% NPK of STCR based dose with 5t FYM.

- Hot Water Soluble Carbon (HWC) and Microbial Biomass Carbon (MBC) in both surface and sub-surface soil were found to be highest under NPK+FYM in both surface and sub-surface soils with lowest values under control in surface soil and under N alone in sub-surface soil.
- The mean soil organic carbon (SOC) was the highest under 100% organic nutrient management followed by 75% organic + inorganic practice. Among the cropping systems soybean-wheat recorded higher SOC followed by soybean-mustard, soybean-linseed and soybean-chickpea.

Theme II: Conservation Agriculture, Carbon Sequestration and Climate Change

- In a conservation agriculture (CA) experiment at Jabalpur, maximum buildup of SOC (0.87%) was recorded from rice and maize based cropping system under zero tillage with residue retention, which was significantly higher over conventional tillage with either residue burnt or retained.
- Labile C content (0-15 cm soil depth) was significantly higher under zero tillage with residue retained (519 mg kg⁻¹) in rice based cropping system in comparison to conventional tillage with residue retained (429 mg kg⁻¹). Similar trend was recorded in maize and soybean based cropping systems. Further zero tillage with residue retention maintained higher level of labile C as compared to conventional tillage with no residue.
- Results from LTFE Pantnagar indicated that a net loss of SOC under all other treatments except NPK+FYM. Though in NPK+FYM, net addition of carbon was very meager (50 kg ha⁻¹), the amount of carbon added through NPK + FYM was more or less equal to its loss suggesting external application of carbon through organic matter is essential to maintain initial SOC.
- Soybean grain equivalent yield remained unaffected due to tillage even after six crop cycles. Irrespective of tillage system, maize-gram recorded significantly higher yield followed by soybean +pigeon pea (2:1) and soybean + cotton (2:1). Lower crop yield under soybean based cropping system was due to aberrant weather conditions during kharif season.
- Soil aggregation as measured through mean weight diameter (MWD) significantly improved only in 0-5 cm under zero & reduced tillage coupled with residue retention than conventional tillage. Similarly, water stable aggregates recorded higher per cent in 0-5 cm depth under reduced tillage than conventional tillage. Reduced tillage coupled with residue retention improved soil moisture content (3-8% wt/wt) in the profile (0-30 cm) during *rabi* cropping period.
- Under CA experiment, two hand weeding at 20 and 40 DAS recorded the lowest weed biomass and the highest seed yield of chickpea and wheat (cv. C 306) which was at par with pre emergence application of Oxyfluorfen @ 200 g ai ha⁻¹ and post emergence application of Mesosulfuron + Idosulfuron @ 400 g ha⁻¹ treatment (33.07 q/ha), respectively.
- Similarly, in case of Maize-mustard and Maize-chickpea cropping system under CA, the highest seed yield which was at par with the application of pre emergence Pendimethalin @ 750 g ai ha⁻¹ and Oxyfluorfen @ 200 g ai ha⁻¹, respectively.
- In another CA experiment, four broad leaved weed species viz., *Alternanthera sessilis*, *Tridox procumbens*, *Sonchus arvensis* and *Parthenium hysterophorus* were suppressed through residue retention (50% maize residue) in wheat crop.
- In soybean cv. JS-335, post emergence application of Propaquizafop @100 g ai ha⁻¹ + Chlorimuron ethyl @ 9 g ai ha⁻¹ at 20 DAS has recorded lowest weed biomass and maximum seed yield which was at par with hand weeding (10.33 q ha⁻¹).
- In a yield gap analysis, study on maize in Madhya Pradesh, the highest simulated maize yield of 7.6 t ha⁻¹





was recorded in Mandsaur district while the minimum of 0.8 t ha^{-1} in Damoh district. There is a potential to improve maize yield to the tune of 3.0 t ha^{-1} for the state Madhya Pradesh.

- Based on plant available water capacity of soil (73-140 mm), the simulation has indicated that the maize grain yield increased with a decrease in rainfall by 10% and further decrease in rainfall led to decline in maize yield.
- With an increase in bulk density from 1.2 to 1.6 Mg m^{-3} , there was decrease in main axis length, number of nodes, number of primary axis and the root angles of wheat cv. Sujata by 58%, 47%, 54%, and 20%, respectively, whereas in cv. Malwa Shakti, it was 48%, 35%, 30% and 25%, respectively
- Long-term application of NPK + FYM, substantially increased the proportion of the macro-aggregate fractions ($>2 \text{ mm}$ and $2-0.25 \text{ mm}$), as compared to soils that received only fertilizer NPK.

Theme III: Microbial Diversity and Biotechnology

- Rhizoplane of *Jatropha curcas* was represented by 15 bacterial and 17 archaeal TRFs comprising *Actinobacteria*, *Firmicutes*, *Acidobacteria*, *Verrucomicrobiaceae* and *Chloroflexi*. The archaea, TRFs were affiliated to uncultured archaea of samples. The predominant endophytic bacteria were closely similar to *Bacillus* sp and the sequences were homologous to *Bacillus pumillus*, *Rhizobium*, *Paenibacillus* etc. Strains produced a maximum of $15.44 \mu\text{g IAA per ml}$ and upon seed inoculation, stimulated maize growth.
- The 16S rRNA gene sequences of phylloplane bacteria of *J. curcas* were closely similar to *Alphaproteobacteria*, *Betaproteobacteria*, *Gammaproteobacteria*, *Firmicutes* and *Actinobacteria*. Most of the isolates were motile and gram variable. Many species closely related to *Ralstonia*, *Methylobacter* and *Actinomycetes* were also found.
- Linkage between iron redox cycling and CH_4 oxidation in two tropical soils (alluvial and black soil) was elucidated. Potential iron reduction rate ($\mu\text{M Fe}^{2+}$ produced $\text{g}^{-1} \text{ soil d}^{-1}$) varied from 1.26 to 2.16 in Vertisol and 1.95 to 3.05 in alluvial soil. Potential iron oxidation ($\mu\text{M Fe}^{2+}$ oxidized $\text{g}^{-1} \text{ soil d}^{-1}$) varied from 2.33 to 5.70 in Vertisol and 2.43 to 9.58 in alluvial soil.
- Nano rock phosphate were solubilized by *Aspergillus terreus* and *A. flavus* through the production of organic acids.
- Promising strains of *Mesorhizobium* for chickpea and *Rhizobium leguminosarum* for lentil and pea were screened from Tal lands of Bihar. Co-inoculation of *R. leguminosarum* with *Bacillus* gave maximum yield of lentil.
- 16s rDNA sequencing of root endophytes of *Desariya* rice and bacteria of root/stem nodule of *Aeschynomene* in rice-*Aeschynomene* ecosystem in Bihar have shown that sequences were similar to *Bradyrhizobium* in both niches. Rice roots had >2000 bacterial species belonging to 29 phyla. Proteobacteria were dominant (44%) followed by Firmicutes (18%) and Actinobacteria (17%).
- Approximately 200 *Arthrobacter* isolates were screened for growth promotion of maize seedlings and PGPR characteristics like indole acetic acid production, siderophore production and phosphate solubilization. Thirteen effective strains were short-listed for field testing which exhibited higher nodule parameters and grain yield to the tune of 12%, over uninoculated soybean. During rabi, the average increase in grain yield was 21% and 24% in chickpea and wheat.
- Under flooded conditions, soil undergoes microbially mediated anaerobic respiratory redox processes with alternative electron acceptors being sequentially reduced in the order of NO_3^- , Fe^{3+} , SO_4^{2-} and CO_2 . Further if ammonia oxidizing bacteria (AOB) are inhibited then ammonia oxidizing archaea (AOA) would initiate the nitrification and modulate TEAPs in flooded soil ecosystem.
- The relative proportion of copiotrophic bacteria (α , β , δ Proteobacteria and Actinobacteria) and



oligotrophic bacteria (γ Proteobacteria) were found to be higher in organic and chemically fertilized soils, respectively. The genes involved in transcription as well as respiration, cell division, osmo-protection were found to be more in organic soil.

- Mixed consortium of the best actinomycetes isolates (A10 and A17) along with consortia of Rhizobia and PGPR (*Rhizobium* R40 and R56; PGPR P3, P10 and P25) gave 77% increased chickpea grain yield whereas the best actinomycetes isolates (A6 and A10) along with CRP (*Rhizobium*: R 33 and R 34; PGPR: P3, P10 and P25) gave 22% increased soybean grain yield in Vertisol.
- Novel PGPR *Paenibacillus* and *Microbacterium testaceum* evaluated on ginger and pepper in Kerala were found promising.
- Zinc solubilizing bacteria tested on zinc deficient Vertisol in Maharashtra indicated that *P. striata* increased soybean yield by 11%, Bt cotton yield by 14 % with inoculation of *Trichoderma viridae*; and 12% with *P. striata* as compared to control.
- Post-sowing application of Liquid BF in black gram compensated for missed application at sowing.
- Recommendation released in Maharashtra: Liquid biofertilizers *Bradyrhizobium* + PSB @ 50 ml each /10 kg seed to soybean and *Azotobacter* + PSB @ 100 ml each/10 kg seed to wheat.
- Recommendation released in A.P. Potassium solubilizing bacteria and consortia for decomposition of crop residues.
- Glomalin played an important role in macro-aggregate formation and continuous supply of fresh residue helped in improving soil glomalin content, which in turn, promoted soil aggregation.

Theme IV: Soil Pollution and Remediation

- Long-term use of untreated sewage water to crops was found to increase SOC since sewage water is a valuable source for plant nutrients and organic matter enabling carbon sequestration in Vertisol. However, caution may be taken to estimate heavy metal loading of the sewage water.
- Soil available N and N fertilizer application could explain 59 to 61% variation in annual N_2O emissions in soybean-wheat cropping cycle in Vertisols of central India.
- Standard reference soil material for heavy metals analysis was prepared from the composite sample of ICAR-Indian Institute of Soil Science farm. From the homogeneity test it was found that heavy metals like Cu, Pb, Cr, Ni, Zn had less than 10% co-efficient of variation (CV) and Cd had 27.45% CV.
- The baseline concentrations of heavy metals ($mg\ kg^{-1}$) were found to be 178.1, 0.7, 24.4, 116.9, 81.8 and 85.2 $mg\ kg^{-1}$ for Cu, Cd, Pb, Cr, Ni and Zn, respectively, in agricultural soils of Sehore and Vidisha districts.
- Sulphur oxidizing bacteria (3M and 4S+M) isolated through enrichment technique were found to be most promising in terms of time and S oxidation potential with minimum bad odour of poultry manure.
- To identify the pesticide degrading bacteria, soil was treated with pesticide (Chloropyrifos, Imidacloprid) and incubated at elevated CO_2 and temperature. Bacterial community was higher in chloropyrifos than imidacloprid. Sequences obtained were homologous to Microbacteria, *Bacillus*, *Arthrobacter sp* in case of chloropyrifos. In case of imidacloprid DNA sequences were homologous to *Bacillus megaterium* and *Microcococcus sp*.
- Seedling emergence of Bt Cotton (RCH-2) exposed to different levels of Cd (upto 200 $mg\ kg^{-1}$ soil), Pb (upto 1000 $mg\ kg^{-1}$ soil) and Cr (upto 50 $mg\ kg^{-1}$ soil) remained unaffected. However, Pb inhibited heterotrophs significantly in the soil. The application of heavy metals decreased dehydrogenase activity in the soil and nitrate reductase activity of the leaves, but increased the contents of proline, ascorbate, total free amino acids and electrolyte leakage.





1. INTRODUCTION

Food and nutritional security are inter-related and greatest global challenges of the 21st century, which depend upon the soil resources for successful eradication of hunger and malnutrition. Intensive agricultural interventions in the past have resulted in unprecedented exploitation of these scarce soil resources world wide. The stability of soil system is controlled by their inherent balance between inputs and output of all the nutrients. In spite of achieving self-sufficiency in food grain production in India, there is a need to produce more food from limited resources for more people. However, over the last four to five decades, the health of soil was declining at faster rate with higher rates of erosion, declining factor productivity and 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 tackle these issues ICAR-Indian institute of Soil Science was established on 16th April, 1988 with the mission of “Enhancing Soil Productivity with Minimum Environmental Degradation”. Since its inception, the institute has made every 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. These four institute based AICRPs act as a part of the “Network-Support Programmes” of the institute with their centres 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 programmes 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 nanotechnology, carbon sequestration and climate change, integrated nutrient supply system (IPNS), biofortification, nutrient transformation and dynamics in soil-plant systems, environmental impact on agricultural production, utilization of solid wastes and waste water, bio and phyto-remediation etc. The salient research findings, infrastructural development, technology transfer, human resource development, awards and recognitions etc are briefly highlighted in the present report.

1.1 Mandate

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

- a) To carry out basic and strategic research on soils especially physical, chemical and biological processes related to management of nutrients, water and energy.
- b) To develop advanced technologies for sustainable systems of input management in soils that is most efficient and least environmental polluting.
- c) To develop expertise and back-stop other organizations engaged in research on agriculture, forestry, fishery and various environmental concerns.



- d) To exchange information with scientists engaged in similar pursuits through group discussions, symposia, conferences and publications.
- e) To collaborate with State Agricultural Universities, National, International and other Research Organizations in the fulfillment of the above objectives, and
- f) To develop database repository of information on soils in relation to quality and productivity.

1.2 Priorities and Thrust Areas

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

Programme 1: Soil Health and Input Use Efficiency

- Integrated nutrient management: Indigenous mineral and by-product sources
- Nano-technology
- Precision agriculture
- Crop simulation modeling and remote sensing
- Fertilizer fortification
- Resilience of degraded soils.
- Developing a workable index of soil quality assessment imbibing influence of different physical, chemical and biological soil attributes

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

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

Programme 3: Microbial Diversity and Genomics

- Characterization and prospecting of large soil biodiversity
- 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

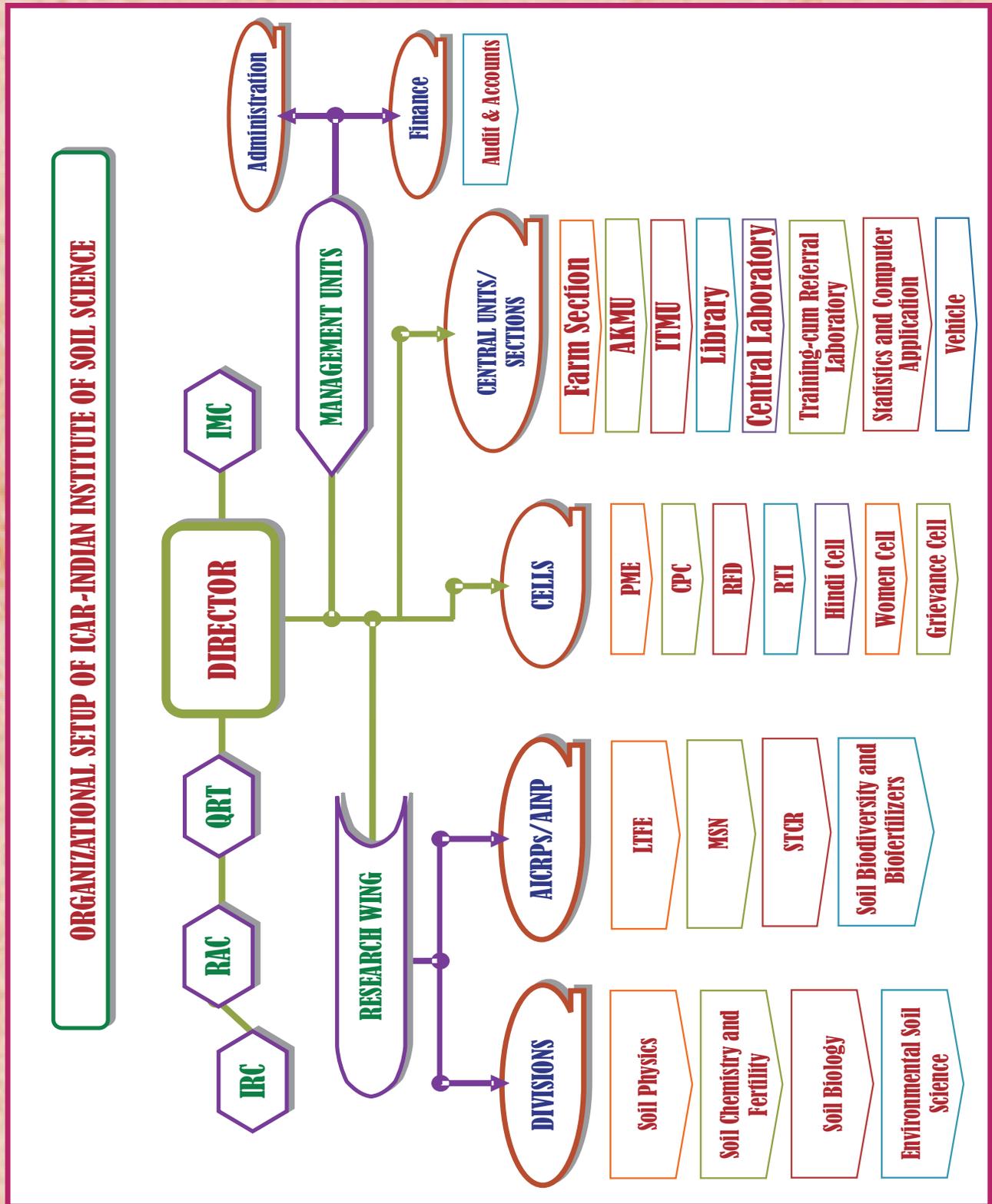
- (i) Statistics and Computer Application
- (ii) Farm Section
- (iii) Vehicle Section

Technical Units/Cells

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

- (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 (MSN)
- (iv) All India Network Project on Soil Biodiversity and Biofertilizers (BF)





1.4 Manpower

a) Scientific

S. No.	Discipline	Sanctioned				In Position			
		PS	SS	S	Total	PS	SS	S	Total
1	RMP	1	0	0	1	1	0	0	1
2	Agricultural Economics	0	1	1	2	0	0	0	0
3	Agricultural Extension	0	0	1	1	0	0	1	1
4	Agricultural Microbiology	1	1	2	4	1	1	1	3
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	8	8	14	30
	Total	13	16	28	57	11	13	22	46

a) Technical

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



c) Administrative

S. No.	Designation	Sanctioned	In Position
1	Sr. Administrative Officer	1	0
2	Finance & Accounts Officer	1	1
3	Asstt. Finance & Accounts Officer	1	1
4	Asstt. Administrative Officer	1	1
5	Private Secretary	2	2
6	Assistant	6	4
7	Personal Assistant	5	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

1.5 Finance: budget statement (Lakhs) for the financial year 2015-16 is as follows

Institute/AICRPs	Budget			Expenditure		
	Non-Plan	Plan	Total	Non-Plan	Plan	Total
Main IISS Institute	995.00	285.00	1280.00	1018.43	275.40	1293.83
AICRP- LTFE	0.00	560.00	560.00	0.00	559.96	559.96
AICRP- STCR	28.00	655.00	683.00	27.56	654.99	682.55
AICRP- MSN	52.00	720.00	772.00	51.68	719.99	771.67
AINP on Biofertilizer	0.00	309.60	309.60	0.00	309.60	309.60
CRP on CA Platform	0.00	320.00	320.00	0.00	311.64	311.64
Total	1075.00	2849.60	3924.60	1097.67	2831.58	3929.25





1.6 Resource Generation

S. No.	Head of Account	Amount (Rs)
1	Sale of Farms Produce	1047114.00
2	Sale of Fish	3780.00
3	Income from Royalty, Sale of Publication and Advertisement	34925.00
4	Licence Fee	519388.00
5	Interest earned on Loans and Advances	1001700.00
6	Analytical and Testing Fee	56000.00
7	Pre-shipment Fee	20.00
8	Application fee from candidates	2610.00
9	Diploma Charges	100.00
10	Interest earned on Short Term Deposits	4636990.00
11	Income generated from Internal Resource Generation	2453882.00
12	Recoveries of Loans & Advances	2011745.00
13	Miscellaneous Receipts	1021107.00
	Total	12789361.00



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 (IPNS) modules for sustainable productivity in a Vertisol

A long-term field experiment was initiated in 2012 and continued during 2015-16 to evaluate different IPNS modules in maize- chickpea cropping sequence for sustainable crop productivity in Vertisol (Table 2.1.1). In general grain, straw yield and nutrient uptake were significantly different in IPNS modules. Among the different modules, maize grain yield significantly increased with application of 75% NPK of STCR based dose with 5t FYM and followed by general recommended dose (GRD) and other FYM based IPNS modules (Fig 2.1.1). Maize productivity was 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 IPNS modules were statistically at par with GRD in terms of maize yield, whereas application of organic sources of nutrients alone produced significantly lower grain yield. Either soil-test crop response based fertilizer application or farmyard manure based different IPNS modules continued to perform better for maize productivity due to higher nutrient addition. The application of 5 t FYM in every season also improved the grain and straw yield of chickpea as compared to mulching by maize residues. The highest agronomic efficiency and partial factor productivity was found in FYM based IPNS module followed by GRD (Fig 2.1.2). The highest chickpea grain yield (Fig. 2.1.3) was recorded with the application of GRD, followed by STCR based dose and 100% P only with the residual fertility of maize crop.

Table.2.1.1 Treatment details of IPNS modules

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 ha ⁻¹ maize)	0-0-0 (1.5 t ha ⁻¹ chickpea)
T4	75% NPK of T3	100% P only
T5	75% NPK of T3 + 5 t FYM	100% P only
T6	75% NPK of T3+ 1 t PM	100% P only
T7	75%NPK of T3 + 5 t UC	100% P only
T8	75% NPK of T3 + MR	100% P only+ MR as Mulch
T9	MR +1 t PM + Gly 2 t ha ⁻¹	100% P only+ MR as Mulch
T10	MR + 5 t FYM + Gly 2 t ha ⁻¹	100% P only+ MR as Mulch
T11	20 t FYM ha ⁻¹ (every season)	5 t FYM ha ⁻¹ (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

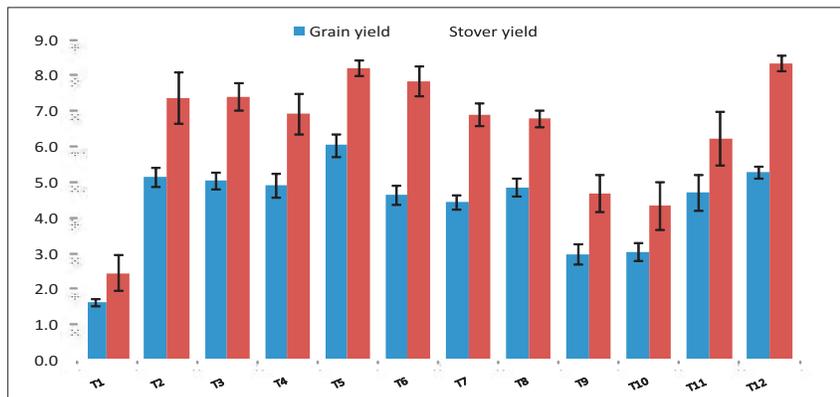


Fig. 2.1.1 Performance of maize yields under different IPNS modules (treatments as per Table 2.1.1)

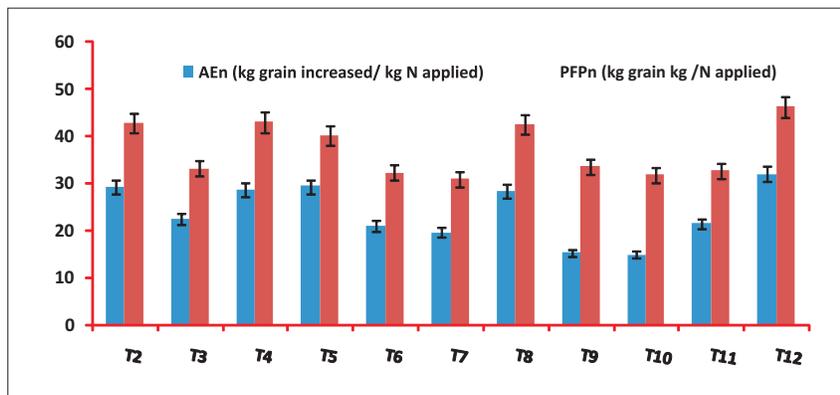


Fig. 2.1.2 AEn and PFPn in maize crop influenced by IPNS modules (treatments as per Table 2.1.1)

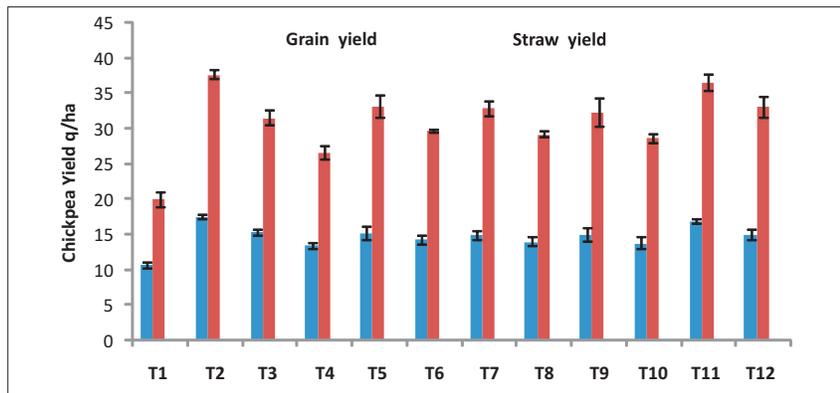


Fig. 2.1.3 Effects of residual fertility of IPNS modules on chickpea yields (treatments as per Table 2.1.1)

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

A field experiment was initiated from 2014 and continued during 2015-16 to evaluate different modified urea materials for enhancing nitrogen use efficiency and sustaining crop productivity. The results indicated maize yield and nitrogen use efficiency (NUE) significantly varied with the application of different modified urea

materials (Plate 2.1.1). Among different modified urea materials, neem coated urea (NCU) recorded higher maize grain, stover (Fig 2.1.4) and total dry matter yield and NUE followed by biochar coated urea (BCU) and pine oleoresin coated urea (POR). The increase is due to slow release of N. The agronomic use efficiency (AEn), partial factor productivity (PFPn) and recovery efficiency (REn) significantly differed with the application of different modified urea materials (Fig. 2.1.5).



Plate 2.1.1 Maize evaluated with different modified urea materials

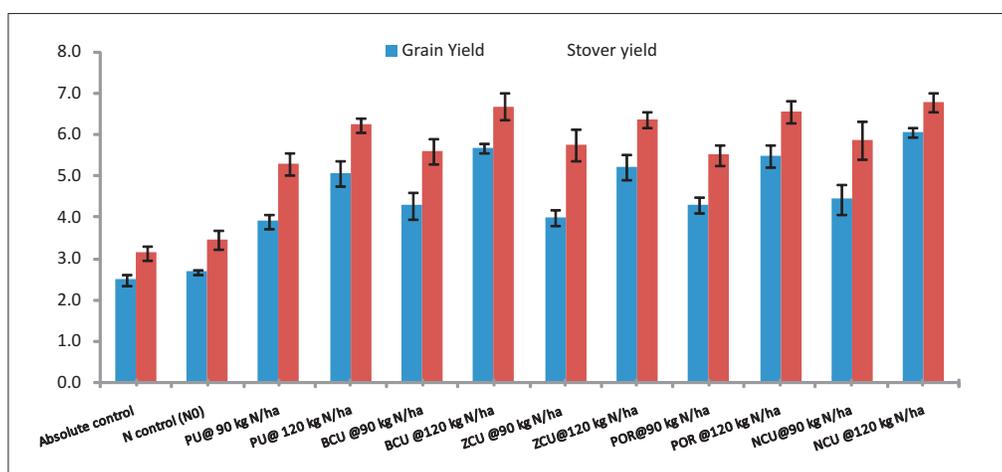


Fig. 2.1.4 Effect of different modified urea materials on maize yields

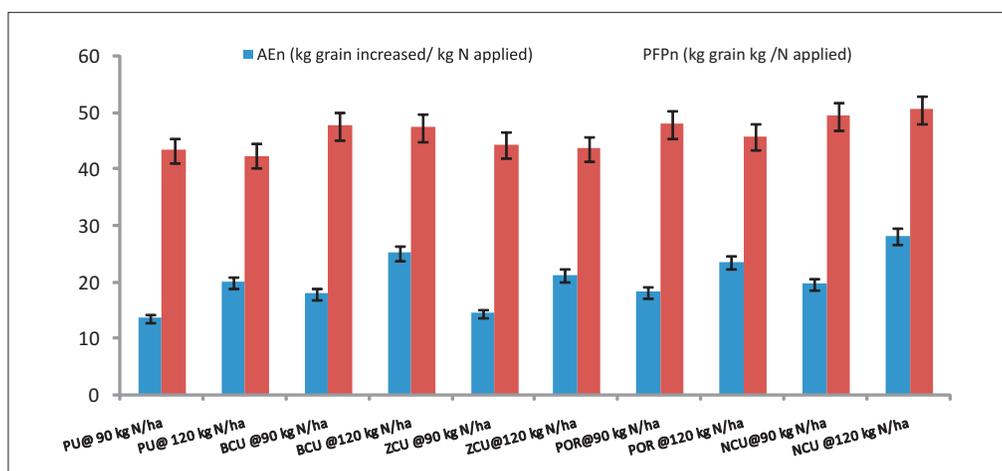


Fig.2.1.5 Nitrogen use efficiencies of maize as influenced by modified urea materials



Another field experiment was initiated from 2014 and continued during 2015-16 with the objective of evaluating best agronomic interventions for enhancing crop yield and nitrogen use efficiency through N application either with split doses at varying levels or time of application in maize. Results showed that total dry matter yield of maize crop was highest with soil test crop response equation based (STCR) fertilizer application probably due to higher amount of nutrient addition. While among the varying 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⁻¹) at 20 and 40 days after sowing (DAS), respectively (Fig 2.1.6). The total dry matter yield of maize crop was also improved in the treatments where biochar was applied as soil amendment. Agronomic N efficiency and partial factor productivity were also significantly different with varying N rate and time of application (Fig.2.1.7). The nutrient efficiencies were higher in the treatment where basal dose of nitrogen was skipped and total nitrogen was applied in two or three equal split dose at 20, 40 and 55 DAS, respectively.

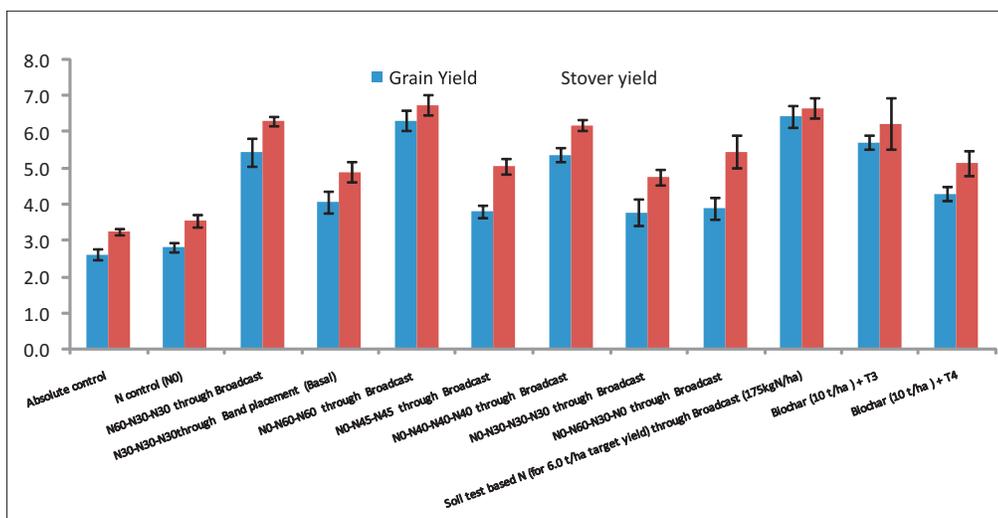


Fig. 2.1.6 Effect of different split doses of N on Maize yield

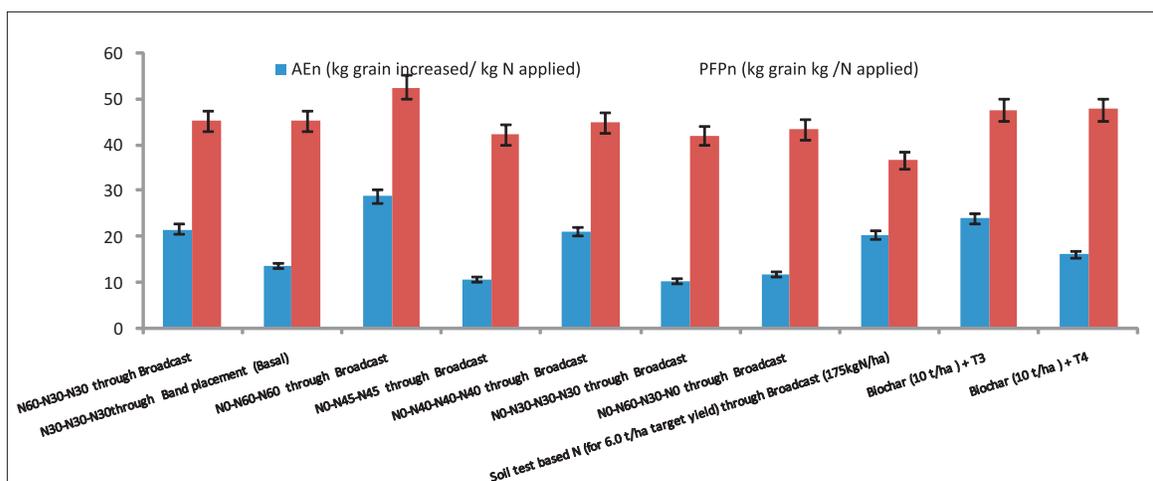


Fig. 2.1.7 Effect of time and application of nitrogen on N use efficiencies in maize crop



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

The impact of nano-micronutrient fertilization on growth and metabolism of plants *viz.* rice, soybean, chickpea and maize were studied under hydroponic (Plate 2.1.2) and sand culture (Plate 2.1.3) systems using ZnO, CuO and Fe₃O₄ nanoparticles (NPs). Most of the NPs analyzed in Transmission Electron Microscope (TEM) were within the size range of 30-100 nm. Plants fertilized with optimal recommended dose of Fe in nano form (54 μ M) registered an increased morphological features *viz.* plant height, biomass (shoot and root), and decreased antioxidant enzyme activity than the plants fertilized with the sub-optimal dose of Fe in macro form (salts). However, half of the recommended dosage of Fe (27 μ M) in nano form had positive influence on leaf area and proline content of plants. This indicated that there is a possibility of reducing the dose of Fe in its nano form to increase the nutrient use efficiency. The gas exchange analysis of sand cultured soybean and rice grown with Fe, Cu and Zn nanoparticles revealed that photosynthesis rate was higher with Fe NP treatments followed by Cu NP and

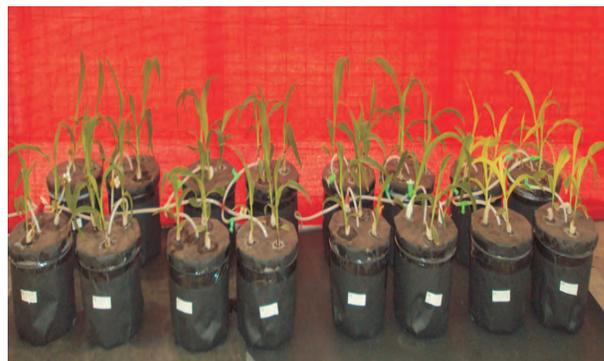


Plate 2.1.2 Maize grown with Normal Fe salt (54 μ M), Fe NP (54 μ M), Fe NP (27 μ M) and Fe salt (27 μ M)



Plate 2.1.3 Sand cultured soybean (left) and rice (right) grown with Fe, Cu and Zn NPs

2.1.4 Evaluation of plant nutrition products for nutrient use efficiency in cereal crops

Two pot culture trials comprising wheat cv. Malwa Shakti and maize cv. Rasi 4212 were undertaken during Rabi 2014-15 to study the effect of plant nutrition product (Suproneel) on the growth and yield attributes under three different soil types. The Suproneel product was found suitable for maize grown in alluvial and black soils in terms of grain yield which was found to be at par with GRD with two top dress of N (**Table 2.1.2**). However, the response of the crop to the product in red soil was not encouraging and not meeting the N requirement of crop. Hence the product can be used to grow maize in alluvial and black soils but not in red soil. However, Suproneel product was found suitable for wheat and was inferior to GRD with two top dressing of N under alluvial and red soils in terms of grain yield.



Table 2.1.2 Effect of Suproneel on grain yield (g)/plant of maize grown in different soils

Treatment	Alluvial	Black	Red
T1 - GRD100%	14.35	6.36	7.89
T2 - SU100%	27.07	12.99	11.60
T3 - SU75%	18.79	10.98	8.99
T4 - SU50%	14.11	8.22	3.31
T5 - NCU100%	24.34	11.10	10.18
T6 - GRD 100% with DAP	15.22	10.01	6.06
T7 - GRD with 75% basal + 25% top dress	19.71	11.22	8.15
T8 - GRD with 50% basal + 25% + 25% top dress	28.26	13.95	12.35
CD 5%	3.82	3.65	3.24

SU- Suproneel Urea; NCU- Neem Coated Urea; GRD- General Recommended Dose; SSP and MOP were given in all treatments as per GRD except T6 where DAP was given as per GRD

2.1.5 Evaluation of Nano-nutrients product (NUALGI) for improving nutrient use efficiency of crops

A field trial with chickpea cv. JG 315 and Wheat cv. Malwa Shakti was undertaken in *rabi* 2014-2015 to study the effect of nano-nutrient product (NUALGI) on growth, yield and nutrient use efficiency of crops (Plate 2.1.4). The effect of various combinations of NUALGI nano-nutrient product and conventional recommended dose of fertilizers on morpho-physiological parameters like growth and yield attributing traits of chickpea and wheat was analyzed. Grain yield of chickpea was found to be higher in recommended dose of fertilizer indicating no advantage of NUALGI product. In case of wheat, there were not much significant differences in yield attributing traits like grain number/plant, test weight, panicle length and panicle weight among various treatments



Plate 2.1.4 Field view of chickpea (left) and wheat (right) grown with NUALGI nano-nutrient product

2.1.6 Evaluation of polysulphate on soybean and mustard

Polysulphate or polyhalide contains both potassium and Sulphur. The first crop soybean failed due to late sowing. The effect of polysulphate was clearly visible on the subsequent mustard crop (Table 2.1.3). However, the seed potassium and sulphur content remained unaltered. In the consequent third crop in the same field (second crop of soybean), although the yield of the soybean crop was very poor to the tune of below one tonne due to weather aberrations leading to yellow mosaic virus attack, the response to polysulphate was visible through variations in seed yield and seed potassium and sulphur content. This suggests that polysulphate may release the nutrient to the succeeding crops in the sequence.



Table 2.1.3 Soybean and mustard yield as influenced by polysulphate (PS)

Treatment	Soybean Seed yield (q ha ⁻¹)	Mustard seed yield (q ha ⁻¹)
1. Control without S and K (100% NP through urea and DAP)	4.81c	13.48b
2. 100% NPK (Urea, DAP and MOP)	5.41b	16.45b
3. 100% NPK (urea, SSP, MOP)	5.99a	25.28a
4. 100% NP + 50% S through PS (Balanced K through MOP to make 100% K)	5.43b	23.46a
5. 100% NP + 75% S through PS (Balanced K through MOP to make 100% K)	5.72ab	24.59a
6. 100% NP + 100 % S through PS (Balanced K through MOP to make 100% K)	5.78ab	23.85a
7. 100% NPK (urea, DAP, MOP) + 100% S through Gypsum	5.83a	22.22a
cd (5%)	0.39	4.86

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 2.1.5). Morpho-physiological parameters were recorded in Soybean based inter cropping system involving crops viz. pigeon pea, maize, sesamum, sorghum and black gram in *kharif* 2015 (Table 2.1.4) and lentil in *rabi* 2015-16 under rainfed and supplemental irrigation.



Plate 2.1.5 Soybean based intercropping during kharif

Table 2.1.4: Plant biomass and leaf area of soybean and intercrops grown in BBF and flat bed system

	Intercrop	Dry Weight /plant (g)			Leaf Area cm ²		
		Main crop	Soy bean	Inter crop	Main crop	Soy bean	Inter crop
BBF	Pigeonpea		13.3	33.5	333.5		1262.0
	Urd bean		9.7	8.0	283.3		90.0
	Sorghum		11.1	22.7	377.8		836.5
	Til		12.5	8.8	435.1		108.1
	Maize		7.6	84.2	276.8		1760.3
	CD (5%)		1.8	16.2	26.4		62.3
	Flat bed	Pigeonpea		7.7	21.6	200.7	
Urd bean			10.2	0.8	374.7		15.9
Sorghum			12.1	36.2	371.8		792.8
Til			11.3	9.8	314.8		89.2
Maize			9.4	68.7	226.6		1380.6
CD (5%)			2.3	27.0	42.2		45.9



2.1.8 Suitability of biochar as a source of N delivery to crops

A field experiment was initiated to assess the suitability of biochar as a source of N delivery to crops in addition to its other beneficial effects. The biochar of pigeon pea stalks was prepared. The entire quantity of N and biochar to be applied to maize crop were split into two equal halves and supplied at 15 and 50 DAS. Before application, the required amount of urea was dissolved in water and mixed thoroughly with desired amount of biochar and kept for a couple of day. The N enriched biochar was then applied to maize rows on the surface and slightly mixed with the top soil. Application of 120 kg of N in two splits resulted in highest yield. The grain yield was significantly reduced with the supply of N after mixing with 2 t biochar ha⁻¹ in two splits (Fig. 2.1.8). Further decrease in the yield was recorded with application of same quantity of biochar through 5 and 10 t biochar ha⁻¹. Application of only 80 kg ha⁻¹ N also decreased the grain yield significantly over 120 kg ha⁻¹. Also addition of 80 kg N mixing with 2 t ha⁻¹ biochar decreased the grain yield significantly. Further increase in quantity of biochar led to a decreased grain yield though it was statistically at par with that of N mixing with 2 t ha⁻¹ biochar.

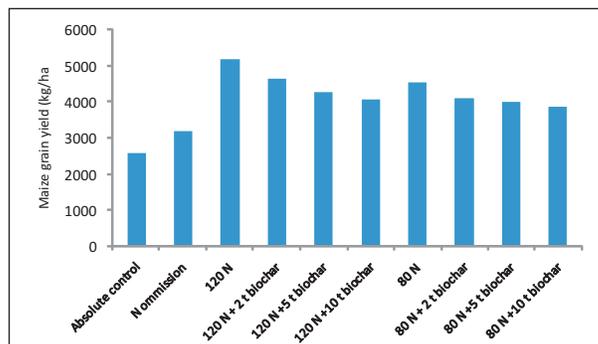


Fig. 2.1.8 Effect of method of N application through biochar on maize grain yield

2.1.9 Evaluation of urease inhibitor product for nutrient use efficiency in maize

Performance of urease inhibitor product (LIMUS Urea) was studied on maize cv Pro Agro 4212 during *kharif* season (Table 2.1.5). Basal application of P₂O₅ and K₂O @ 60 and 40 kg/ha was given through SSP and MOP, respectively.

Table 2.1.5 Details of treatments for maize crop

Treatment	Fertilizer	Symbol	N rate Kg/ha	Basal	1 st top dressing (V4)	2 nd top dressing (V8)	3 rd Top dressing (VT)
T1	Zero N	N ₀	0	0	0	0	0
T2	Urea 46%	N _{FP}	150	37.5	0	75	37.5
T3	Urea 46%	N _{GRD}	120	30	0	60	30
T4	Urea 46%	N _{opt}	80	16	20	24	20
T5	Urea + Limus	N _{opt} + L	80	16	20	24	20
T6	Urea 46%	N _{opt}	80	0	40	40	0
T7	Urea + Limus	N _{opt}	80	0	40	40	0
T8	Urea	N _{80% opt}	64	0	33	33	0
T9	Urea+Limus	N _{80% opt} + L	64	0	33	33	0
T10	Neem Coated Urea	N _{opt}	80	16	20	24	20

During second year application of 150 kg N ha⁻¹ recorded maximum grain yield (Fig. 2.1.9). Decreasing the dose of N to maize crop significantly affected the performance of the crop irrespective of time of N

application. Application of 80 and 120 kg ha⁻¹ N to maize in two or three splits did not affect the maize grain yield indicating that the N to maize crop may be supplied in two splits alone. Application of neem coated urea resulted in statistically higher grain yield over normal and LIMUS urea. The performance of LIMUS urea was slightly better but statistically at par with that of normal urea at different doses as well as time of application. The agronomic N use efficiency varied between 20.0 and 37.3 kg grain kg⁻¹ N.

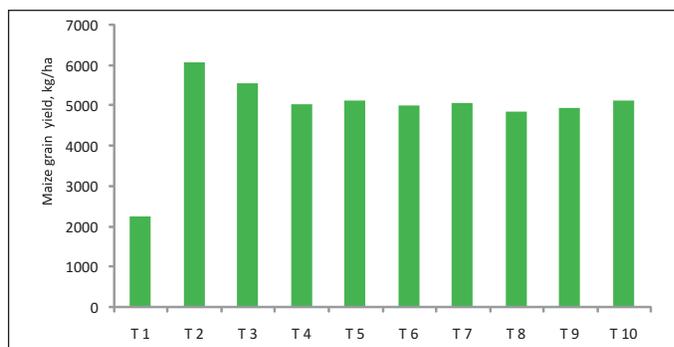


Fig. 2.1.9 Effect of fertilizer doses, sources and timings on maize grain yield (treatments as per table 2.1.5)

2.1.10 Use of nano sensors network for field detection of temperature and moisture stress in plant and soil

A telemetry network has been developed and installed in response to an increasing need for accurate, real time soil moisture sensor data to assist irrigation scheduling in time on CIAE farm. System would include the equipment to monitor field conditions, radios to transmit the information from the field, interpretation of soil water status in field. Data is collected in the field using 4 nos. of soil moisture (MP406) sensors which surface is modified by Poly-aniline (PANI) nanofibers as a sensing layer for maximum response to soil moisture and transferred into a server using radio telemetry and the mobile phone network (*Plate 2.1.6*) All soil moisture sensors are placed near plant roots which are crucial for optimizing the crop yield. Specially designed software presents summary data of the sensors. Anyone can access essential data relating to, soil and water conditions from desktop computers and take decision for necessary action.

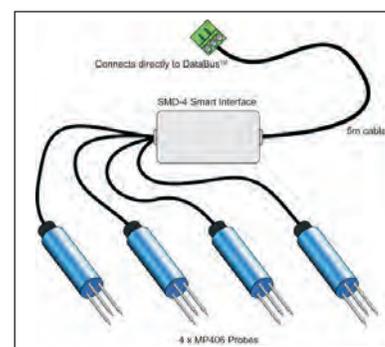


Plate 2.1.6 Soil moisture probes of which surface is modified by PANI nanofibers



Plate 2.1.7 Developed telemetry based WS network system with data logger

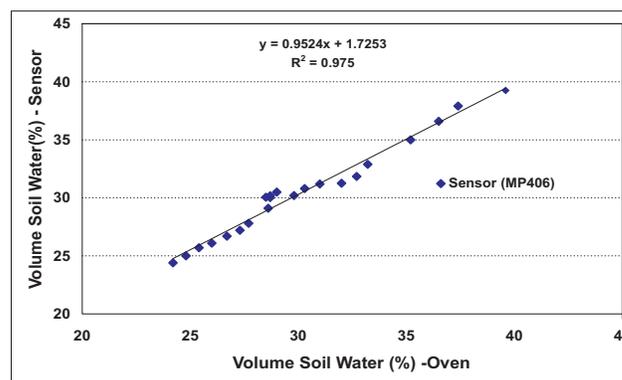


Fig. 2.1.10 Calibration of MP406 measurement of VSW% using soil samples as a standard

The soil moisture sensors (MP406) were installed at 15 and 30 cm depth in irrigated wheat crop field of Institute farm. The soil moisture sensor was calibrated by comparing measured field soil moisture and



recorded soil moisture through sensor. Soil moisture data collected through telemetry system has been calibrated with reference to oven method. The calibration curves for average values of measured soil moisture through telemetry and soil moisture data through oven method is shown in Fig 2.1.10. The results from the measurement of absolute volumetric soil water percent (VSW%) from field soil samples using telemetry (Plate 2.1.7) revealed that collected soil moisture data are as per oven method for a Vertisol.

All systems maintained the Soil Water Potential (SWP) close to the target of -20 kPa. Our developed system had the amplitude of oscillation of SWP around -20 kPa. Results of the study indicated that a telemetry network developed and installed in CIAE farm for real time soil moisture sensor data to assist irrigation scheduling in time is working satisfactorily. Data is collected in the field using soil moisture (MP406) sensors and transferred onto a server using radio telemetry and the mobile phone network. Soil moisture data collected through telemetry system has been calibrated with oven method. Specially designed software presents summary data of the sensors. The system is so designed that anyone can access essential data relating to, soil and water conditions from desktop computers and take preventive measures for irrigation.

2.1.11 Nutrient retention capacity of nano-porous synthetic zeolite

Smart delivery of plant nutrients through nano porous zeolite is one of the important means to increase Nutrient Use Efficiency and to prevent loss of nutrients from soil. A laboratory experiment was conducted with a Na- enriched synthetic zeolite to study its nutrient retention capacity. The said zeolite was neutralized with requisite amount of 0.2 N H₂SO₄, as a result of which exchangeable Na⁺ to the tune of 6 meq/100g was displaced from the exchange sites of zeolite. The moisture retention capacity was 55.4% and 6.3% at 0.33 and 15 bar respectively. The neutralized zeolite was treated with solutions of different nutrient containing salts (urea, (NH₄) H₂PO₄, NH₄ molybdate and ZnSO₄) and shaken for overnight, filtered and dried. The salt loaded dried zeolite was repeatedly washed with distilled water to leach out the excess salt and allowed to dry under shade. The results suggested (Table 2.1.6) that nano-porous synthetic zeolite could be used as carrier of two important micronutrients, namely, Zn and Mo, for their smart delivery in the field. Retention capacity of N, P and S appear to be considerable but cannot be used for their smart field delivery through nano-porous zeolite in view of their relatively higher crop demands. However, they can be used for potted agriculture and seedling raising.

Table 2.1.6 Nutrient retention capacity of neutralized synthetic zeolite

Name of the salt	Nutrient	Nutrient retention capacity (g kg ⁻¹)
Urea	N	73.4
(NH ₄) H ₂ PO ₄	N	90.4
	P	146.7
NH ₄ molybdate	N	24.4
	Mo	195.0
ZnSO ₄ 7H ₂ O	Zn	44.7
	S	22.0



2.1.12 Availability of P in soil treated with nano rock phosphate

Conversion of natural phosphate rocks to nano-form is considered to be an important green technology for utilization of indigenous rock-phosphate deposits for crop production at a relatively low cost without impairing the environment. A laboratory study was conducted to study the solubilization of P from nano-rockphosphate (Sagar Rockphosphate with 28% P₂O₅ and particle size 98.6 nm) following its application in two soils (Vertisol from Bhopal and Alfisol from Betul) after different time intervals. Increasing the level of nano-rockphosphate application showed significant increase in available P content in both the soils (Table 2.1.7 and Table 2.1.8). Initially (7 days) the available P of the soil is increased due to application of nano-rockphosphate and later it steadily decreased in all the treatments. The percent contribution to available pool was highest in 20 ppm applied P.

Table 2.1.7 Availability of P in Vertisol treated with nano rock phosphate at different time intervals

Rate of applied P as nano rock phosphate (ppm-P)	Available P (ppm) in soil after different time intervals (days)					
	0	7	14	21	28	35
0	10.10	9.15	8.66	7.31	6.77	6.24
10	12.60	13.20	9.68	8.48	7.93	7.47
	(25.00)*	(40.50)	(10.20)	(11.70)	(11.60)	(12.30)
20	16.12	19.60	11.46	10.67	9.75	8.81
	(30.10)	(52.25)	(14.00)	(16.80)	(14.90)	(12.80)
30	19.10	23.40	15.10	12.74	10.32	10.06
	(30.00)	(47.50)	(21.46)	(18.10)	(11.80)	(12.70)
CD (p=0.05)	1.41	1.56	1.23	1.11	0.98	0.89

* Data in the parenthesis indicate percent of the applied P in available pool in soil

Table 2.1.8 Availability of P in Alfisol treated with nano rock phosphate at different time intervals

Rate of applied P as nano rock phosphate (ppm-P)	Available P (ppm) in soil after different time intervals (days)					
	0	7	14	21	28	35
0	5.26	4.65	4.50	4.32	3.92	3.77
10	6.98	8.01	6.63	5.41	5.07	4.80
	(17.00)*	(33.60)	(21.30)	(10.90)	(11.50)	(10.30)
20	9.78	10.38	7.39	6.49	6.41	6.22
	(22.60)	(28.65)	(14.45)	(10.85)	(12.45)	(12.25)
30	11.96	14.25	10.48	8.29	7.12	7.01
	(22.30)	(32.0)	(19.90)	(13.20)	(10.70)	(10.80)
CD (p=0.05)	1.23	1.36	1.08	0.86	0.74	0.70

* Data in the parenthesis indicate percent of the applied P in available pool in soil



2.1.13 Effect of seed soaking pre-treatment with nano-anatase (TiO₂ nano particles) on some physiological attributes of maize

A pot culture experiment (with 7 kg soil) was conducted using Vertisol of IISS farm to study the effect of seed soaking pretreatment with different concentration of nano-TiO₂ (<25 nm, 99.7% metal basis) on some physiological attributes of maize. The water absorption rate of maize decreased gradually from 34.82% to 29.08% with the increase in concentration of nano-TiO₂ from zero to 200 ppm, indicating the possibility of clogging of pores on the seed coat by nano-TiO₂ particles at higher concentration of nano-TiO₂ particles. Based on the water absorption rate and concentration of nano-TiO₂, the content of Ti in seeds was computed and it ranged from 4.98 ppm (at 25 ppm level of nano-TiO₂) to 34.86 ppm (at 200 ppm level of nano-TiO₂). Total chlorophyll content in leaves showed an increasing trend with the increase in nano-TiO₂ concentration in the seed soaking solution, but such increase was significantly higher at concentration of nano-TiO₂ higher than 150 ppm level. Although chlorophyll content remained unaltered chlorophyll-b content increased significantly beyond 100 ppm nano-TiO₂. The ratio of chlorophyll a/b showed a decreasing trend with the increase in concentration of nano-TiO₂ but significant reduction was observed at levels beyond 100 ppm nano-TiO₂ concentration. The photosynthetic rate in 30 days old leaves showed significant increase at concentration higher than 100 ppm level, while, stomatal conductance showed significant decrease with the increase in concentration of nano-TiO₂ in the seed imbibed water. The result finally showed that soaking with nano-anatase had adverse effect on biomass yield of maize (Table 2.1.9)

Table 2.1.9 Effect of seed soaking with different concentration of nano-TiO₂ (< 25 nm) on some physiological attributes of 30 days old maize plant

Concentration of Nano TiO ₂ (ppm)	Biomass Yield (g/pot)	Root Biomass (g/pot)	Chlorophyll content (mg/gm)				Photosynthetic Rate (μmol/m ² /sec)	Stomatal conductance (mmol/m ² /sec)
			Ch-a	Ch-b	Total	a/b		
Control	15.12	1.68	1.58	1.16	2.74	1.36	6.95	110.25
25	12.80	2.02	1.59	1.21	2.80	1.31	7.25	93.50
50	12.37	1.77	1.61	1.22	2.83	1.32	7.85	88.25
100	10.66	1.61	1.61	1.24	2.85	1.30	8.22	84.25
150	10.66	1.53	1.64	1.26	2.90	1.30	8.97	71.50
200	9.54	1.59	1.62	1.25	2.87	1.29	9.65	65.25
CD(p=0.05)	1.86	n.s.	n.s.	0.06	0.12	0.05	0.96	8.33

2.1.14 Evaluating rock phosphates for their suitability for direct application

Incubation of the organic matter with RP increased the solubility of RP further. The other two treatments i.e. zeolites and acid clay increased the solubility of RP significantly when added in 1:1 ratio with RP, the maximum solubility was observed under incubation with acid clay in all the rock phosphates studied. Release of P in two soils (Alfisol and vertisol) was also studied under different treatments. Two soil series, Sarol, which is a vertisols from Indore and Thymagondalu which is an alfisol from Bangalore were used for incubation experiment. Untreated rock phosphate (Jhamarkotra 1) released more P in Alfisol than in Vertisol,



because of relatively lower pH in Alfisols than in Vertisols. Zeolite treatment led to a gradual release of P in the soil system. However, there was a decrease in slope with increase in the number of extractions in alfisol. However, zeolite-system's ability to release P decreased as the number of extractions increased in Alfisols possibly due to filling of exchange sites by Ca^{2+} in Alfisol as the total exchange sites (CEC of zeolite + CEC of soil) for Ca^{2+} was far less in Alfisol than Vertisol. Even though the Ca saturation in Vertisols and alfisol at the end of the extraction in zeolite system was nearly same, the RP continued to release P in Vertisols as the Vertisols on account of higher CEC is more buffered and continued to provide exchange sites for the adsorption of released Ca. The results showed that, in Alfisols, it should be possible to renew the system's ability to release P from rock phosphate in the soil by adding more zeolite. Acid clay-rock phosphate curves released more phosphate than zeolite system in both the soils. However, zeolite and acid clay system's ability to release P decreased as the number of extractions increased. The likely cause is a filling of exchange sites by Ca^{2+} as Ca saturation of the exchange site was higher in acid clay system than zeolite system. These results indicate that, it should be possible to renew the system's ability to release P from phosphate rock either by adding more NH_4 -zeolite or by adding acid clay.

2.1.15 Assessment of important soil properties of India using Mid-Infrared Spectroscopy

Diffuse reflectance spectroscopy recorded using the FT-MIR spectrometer in the middle infrared region provides a good alternative to enhance and support conventional methods of analysing soil properties and to overcome few limitations particularly where high spatial density is needed. MIR spectra however need calibration and validation with the laboratory analyzed data for development of prediction models for different soil properties which will be valid for a soil type. To develop a prediction model for Vertisols, geo-referenced soil samples collected from different land use systems to incorporate wide range of soil variability like, arable land under different cropping systems, fallow field, grassland, forest lands, and grazed lands were analyzed for their physical and chemical properties in the laboratory. The mid-infrared spectra between 400 to 4000 cm^{-1} wave number were used for development of mathematical models for prediction of soil properties. Different spectra pre-treatment techniques like, multiple scatter correction, standard normal variate, standard normal variate- detrending, first and second order derivative, were tested for processing the raw MIR spectra.

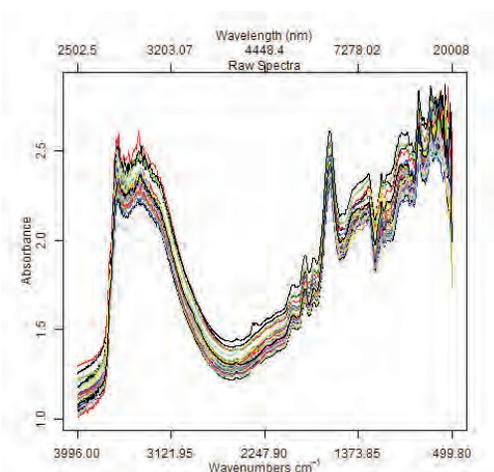


Fig 2.1.11. MIR spectra of soil samples

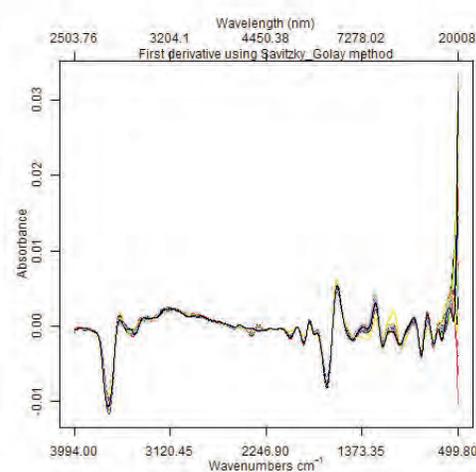


Fig. 2.1.12. Spectral signature after pre-treatment through first order derivative



It was observed that the first order derivative manipulation of the spectral data greatly enhances some of the spectral features (Fig. 2.1.11 and 2.1.12) and the second derivative enhances them even more. Different prediction models of soil properties were then developed using partial least square (PLS) regression and random forest regression technique with the pre-processed MIR spectra and laboratory generated soil properties data and then they were cross validated (Fig. 2.1.13). The results from this study indicated that the MIR spectroscopy could potentially be used for prediction of soil properties in Vertisols. However, the models need to be revalidated with more independent soil data from a larger soil sample.

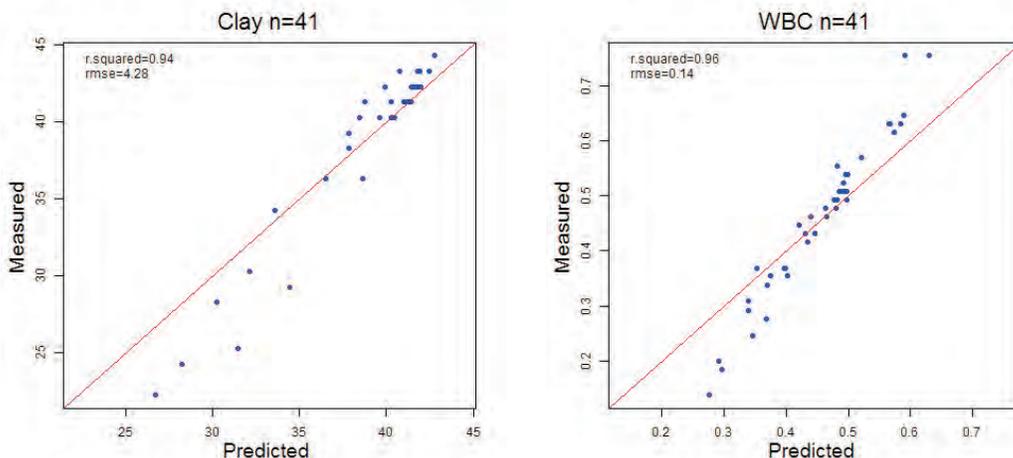


Fig. 2.1.13 Measured and predicted value based on model developed by random forest regression method for (a) clay content and (b) SOC

2.1.16 Development of Prediction Models for soil organic carbon using MIR spectroscopy

Different prediction models were developed for estimation of soil organic carbon considering specific spectral parameter based on its coefficient of determination. R^2 is a statistic that will give some information about the goodness of fit of a model. In regression, the R^2 is a statistical measure of how well the regression line approximates the real data points. The 1:1 graph of measured and predicted value based on regression model named random forest for estimation of soil organic carbon is presented in Fig. 2.1.14 and Fig 2.1.15.

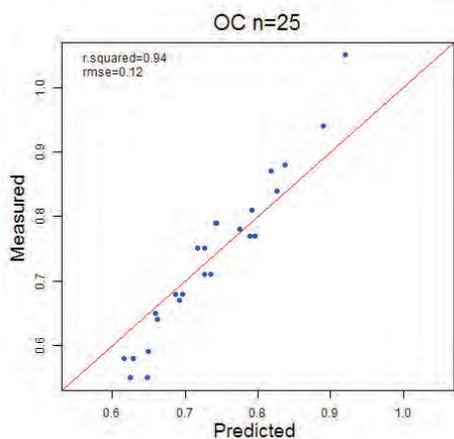


Fig. 2.1.14 Measured and predicted value of SOC based on random forest methodology

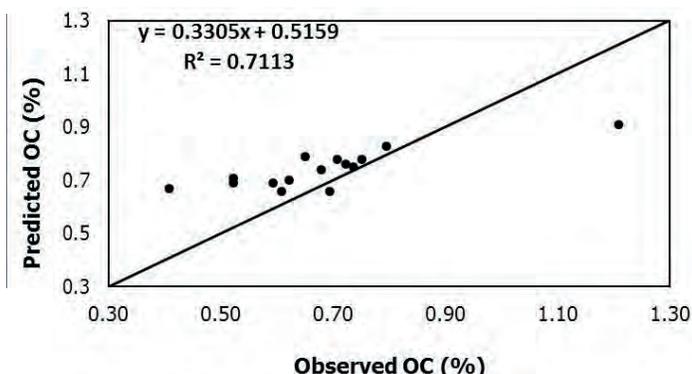


Fig 2.1.15 Relationship between measured and predicted values of SOC based on Random Forest Methodology



Soil organic C for model development was ranged from 0.55% to 1.05%. Higher coefficient of determination ($R^2 = 0.94$) and lower root mean square error ($RMSE=0.12$) indicated higher prediction efficiency of developed model. The model was further tested using one-third of independent datasets. Higher R^2 of 0.71 obtained from this study suggested good prediction efficiency of the developed model. Based on number of variables (i.e. bands) and best spectral parameter (reflectance or its derivatives), prediction model was developed for each soil parameter using partial least square and random forest regression model. Thus the random forest emerged out to be more robust when we compare the R^2 values and the whole model summary.

2.2 AICRP on LTFE

2.2.1 Effect of Long term application of fertilizers and manures on SOC and biological activity in an alluvial soil of North-western Indo-Gangetic plains

After 44 years of cultivation (1971-2015) soil samples were collected from selected treatments to study soil carbon pools, activity of enzymes, and glomalin content from different size classes of aggregate. Pearl millet-wheat-forage cowpea was the cropping system between 1971-72 and 1980-81, and thereafter pearl millet was replaced with maize. During 2001-02, forage cowpea was discontinued, and maize-wheat is the cropping system followed since then.

Long-term application of fertilizer alone or with manure resulted in differential amount of Hot Water Soluble Carbon (HWC) and Microbial Biomass Carbon (MBC) in both surface and sub-surface soil (Table 2.2.1 and Table 2.2.2). HWC was found to be highest under NPK+FYM in both surface and sub-surface soils with lowest values under control in surface soil and under N alone in sub-surface soil. HWC content also significantly decreased under control, N, NP and NPK treatments as compared to fallow situation. As compared to N alone, significant increase was found under NP, NPK and 150% NPK. Invariably under all the treatments HWC was lower in sub-surface soil. Application of P and K along with N promoted root growth and more rhizo-deposition along with it, resulting in more amount of soluble organic matter. Under NPK+FYM, there was a continuous supply of fresh and labile organic matter which helped to maintain a significantly higher HWC as compared to other treatments. MBC, followed the similar trend with highest values under NPK+FYM and lowest under N alone. Balanced fertilization of N, P, and K had a higher microbial biomass than P- and K-deficiency fertilizations and control. In both soil depths, dehydrogenase activity was found to be highest under NPK+FYM, whereas lowest values were registered under control in surface soil and N alone in sub-surface soil. NPK and 150% NPK plots with balanced fertilizer dose also had significantly higher dehydrogenase activities in both depths as compared to control and plots with imbalanced fertilizer dose. On the other hand, application of FYM along with NPK caused a significant increase in dehydrogenase activity as compared to NPK or 150% NPK (Table 2.2.1 and 2.2.2). Similar trend was found in case of alkaline and acid phosphatase activities. Conversion of fallow land to cultivation resulted in a decrease in total glomalin content in both the soil depths, as is evident from significantly lower total glomalin contents under control plots as compared to fallow in both soil depths. In treatments with nutrient additions (N, NP, NPK and 150% NPK), resulted in a significant increase in glomalin content as compared to unfertilised control, although, total glomalin content of these sole fertiliser treatments are comparable among them. Upon inclusion of organic manure along with inorganic fertiliser, under



NPK+FYM resulted in a significant increase in total glomalin content in both soil depths (Table 2.2.1 and 2.2.2).

Table 2.2.1 Effect of long term fertilization and manuring on SOC, glomalin and enzymatic activities in surface layer (0-15 cm) of a North-western IGP soil

Treatment	Hot water soluble C (mg kg ⁻¹)	Total glomalin (µg g ⁻¹)	Microbial biomass C (µg g ⁻¹)	Dehydrogenase activity (µg TPF g ⁻¹ day ⁻¹)	Fluorescein di acetate activity (µg fluroscein g ⁻¹ h ⁻¹)	Alkaline phosphatase activity (µg p-nitrophenol g ⁻¹)	Acid phosphatase activity (µg p-nitrophenol g ⁻¹)
Fallow	108.6	2141	544.3	83.68	4.70	190.1	15.4
Control	46.3	1828	587.2	63.04	5.09	206.9	21.7
N alone	40.4	1618	499.4	58.24	5.24	227.0	24.5
NP	67.2	3211	553.9	74.88	5.76	221.5	18.9
NPK	60.5	3290	624.8	75.68	5.37	235.4	21.3
150%NPK	84.2	3201	713.8	75.84	4.70	215.8	20.1
NPK+FYM	153.0	6531	769.9	92.24	6.71	242.8	24.9
M							
LSD (p=0.05)	11.71	395.2	44.56	4.15	0.58	15.3	4.5

Irrespective of soil depth and treatments, total glomalin content was found maximum in case of 2000-250 µm size fractions, followed by <53µm and 250-53 µm size fractions. Irrespective of the aggregate fractions aggregate associated glomalin content followed the similar trend as of bulk soil total glomalin content. Conversion of fallow land to cultivation resulted in a decrease in total glomalin content in both the soil depths, in treatments with nutrient additions (N, NP, NPK and 150%NPK), resulted in a significant increase in glomalin content associated with aggregates as compared to unfertilised control, although, total glomalin content associated with respective aggregate size class of these sole fertiliser treatments are comparable

Table 2.2.2 Effect of long term fertilization and manuring on SOC, glomalin and enzymatic activities in sub-surface layer (15-30 cm) of a North-western IGP soil

Treatment	Hot water soluble C (mg kg ⁻¹)	Total glomalin (µg g ⁻¹)	Microbial biomass C (µg g ⁻¹)	Dehydrogenase activity (µg TPF g ⁻¹ day ⁻¹)	Fluorescein di acetate activity (µg fluroscein g ⁻¹ h ⁻¹)	Alkaline phosphatase activity (µg p-nitrophenol g ⁻¹)	Acid phosphatase activity (µg p-nitrophenol g ⁻¹)
Fallow	34.1	1517	518.8	58.32	3.52	129.3	8.9
Control	25.9	1005	455.5	48.48	3.60	135.0	9.6
N alone	13.6	1761	387.3	65.68	3.65	132.2	12.0
NP	25.6	1446	463.5	60.96	3.95	133.9	11.1
NPK	25.0	1646	593.5	73.52	4.24	132.0	11.4
150%NPK	35.5	1623	514.1	69.76	4.22	126.6	10.9
NPK+FYM	48.3	2575	628.0	77.44	4.42	135.6	12.2
LSD (p=0.05)	5.0	231.9	38.9	3.49	0.82	NS	NS



among themselves. Upon inclusion of organic manure, under NPK+FYM resulted in a significant increase in total glomalin content in both soil depths (Fig 2.2.1 and Fig 2.2.2). Due to higher degree of stable macro-aggregates. In reality, Glomalin has a longer residence time in soil than hyphae, allowing for a long persistent contribution to soil aggregate stabilization. The results showed that the glomalin associated with macro-aggregates are in general greater than that associated with micro-aggregates.

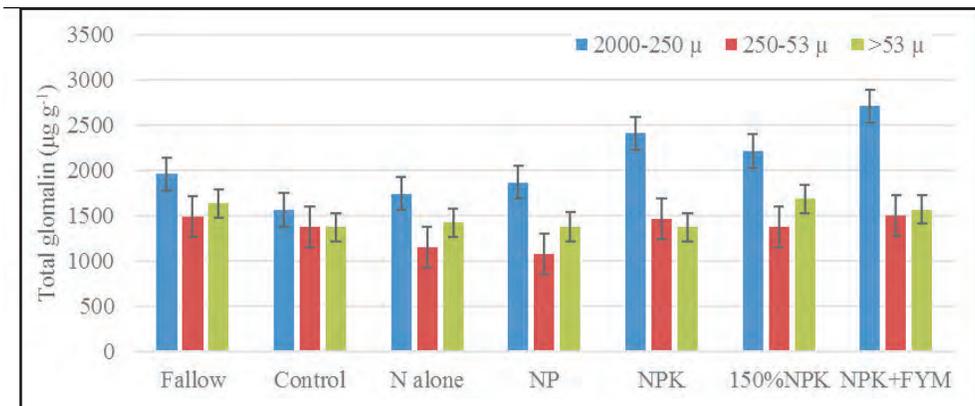


Fig. 2.2.1 Effect of long term fertilization and manuring on total glomalin content in different soil aggregate size classes of surface layer (0-15 cm)

After five years of forage cultivation C sequestration and potential and C-sequestration rate was studied (Table 2.2.3). The maximum carbon sequestration potential was found in Sorghum+Cowpea-Chickpea followed by Desmanthus, *Sesbania* cropping system. In case of resources conservation practices, the higher carbon sequestration potential was found in life saving irrigation followed by in-situ moisture conservation conditions.

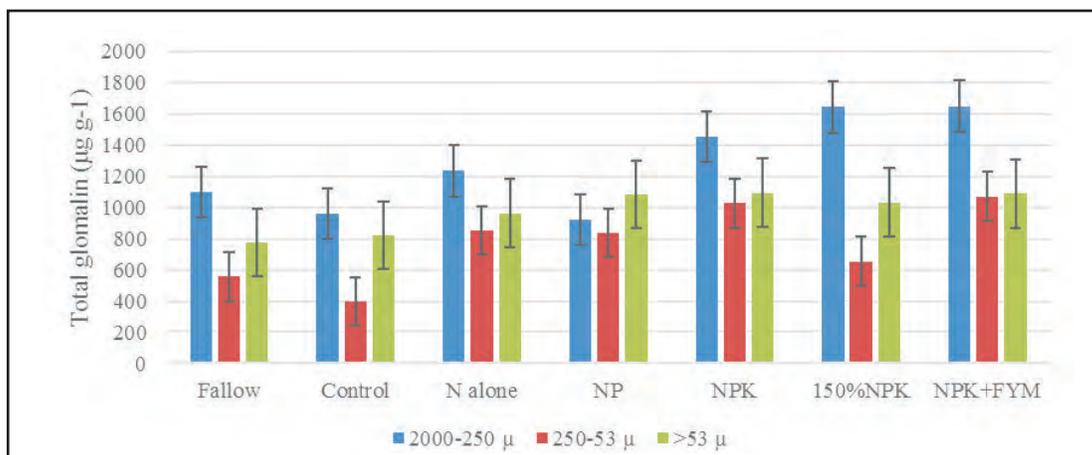


Fig. 2.2.2 Effect of long term fertilization and manuring on total glomalin content in different soil aggregate size classes of sub-surface layer (15-30 cm)



Table 2.2.3 Effect of cropping systems on carbon sequestration potential and carbon sequestration rate after five years at 15 cm soil depth

Cropping system	Initial SOC (Mg ha ⁻¹) (A)	Final SOC (Mg ha ⁻¹) (B)	C-sequestration potential (Mg ha ⁻¹)=B-A	C-sequestration rate (Mg ha ⁻¹ year ⁻¹) =B-A/No of year
CS1	7.77	9.98	2.21	0.442
CS2	7.77	11.43	3.66	0.732
CS3	7.77	10.78	3.01	0.602
CS4	7.77	12.29	4.52	0.904

Note : CS₁: Leucaena; CS₂: Desmanthus; CS₃: Sesbania; CS₄: (Sorghum + Cowpea)-(Chickpea)

2.2.3 Evaluation of organic, inorganic and integrated crop management practices on soybean yield and soil properties

During *kharif* season of 2015, the seed yield of soybean (Plate 2.2.1) was recorded highest in 100% organic treatment followed by 75 % organic + innovative practices and 75% organic + 25% inorganic treatment which were significantly higher than 100% inorganic treatment (Table 2.2.4) Among the cropping systems soybean-wheat recorded higher soybean equivalent yield followed by soybean-chickpea, soybean-mustard and soybean-linseed.

Mean soil organic carbon (SOC) content was significantly affected by different nutrient management practices. The mean SOC was the highest under 100% organic nutrient management (0.98%) followed by 75% organic + inorganic practice (0.97%). Among the cropping systems soybean-wheat recorded higher SOC followed by soybean-mustard, soybean-linseed and soybean-chickpea.

The soil available N content varied from 88 to 96.8 mg kg⁻¹ under different nutrient management and minimum soil available N was recorded under the treatments receiving either state recommendation of

Table 2.2.4 Yield of soybean (kg ha⁻¹) under different nutrient management practices

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
Kharif						
CS1	663	617	588	621	552	561
CS2	690	632	523	625	476	513
CS3	593	635	555	636	510	538
CS4	662	598	512	600	503	527
Source						
LSD (p=0.05)	Manure		72			
	Cropping System		NS			
	Manure X Cropping system		126			



fertilizer or inorganic fertilizer management system (Table 2.2.5). Mean soil available P varied from 17.2 to 23.8 mg kg⁻¹ and minimum being under inorganic management. However available potassium was significantly affected by different nutrient management practices. Among the cropping systems soybean-wheat recorded highest potassium followed by soybean-chickpea, soybean-mustard and soybean-linseed. Biological activity in terms of FDA (Fig 2.2.3) and dehydrogenase activity (Fig 2.2.4) indicated that these parameters were highest in organic treatment (100% organic and 75% organic + innovative treatment) followed by integrated management (75% organic and 25% inorganic and 50% organic and 50% inorganic treatment) and least in inorganic management.



Plate 2.2.1 Soybean crop in the organic farming experiment during kharif 2015

Table 2.2.5 Influence of organic, inorganic and integrated nutrient management practices on soil properties after 2014-15 crop cycle.

Management practice	Soil pH	Soil EC (dS m ⁻¹)	Soil WBC %	Available N (mg kg ⁻¹)	Available P (mg kg ⁻¹)	Available K (mg kg ⁻¹)
Practice 1	7.64	0.23	0.98	96.8	23.7	197
Practice 2	7.60	0.23	0.88	91.9	18.8	234
Practice 3	7.53	0.26	0.90	90.8	21.6	222
Practice 4	7.56	0.24	0.97	90.1	23.8	193
Practice 5	7.60	0.25	0.69	91.9	17.2	212
Practice 6	7.53	0.26	0.65	88.0	22.1	233
Practice 1	NS	NS	0.05	NS	3.7	15.2
Cropping systems						
CS1	7.58	0.24	0.89	92.7	24.3	219
CS2	7.57	0.24	0.86	93.2	19.8	215
CS3	7.56	0.24	0.81	91.2	21.8	217
CS4	7.60	0.25	0.82	89.3	18.7	209
CD(p=0.05)	NS	NS	0.03	NS	4.3	NS

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 blanket fertilizer recommendations

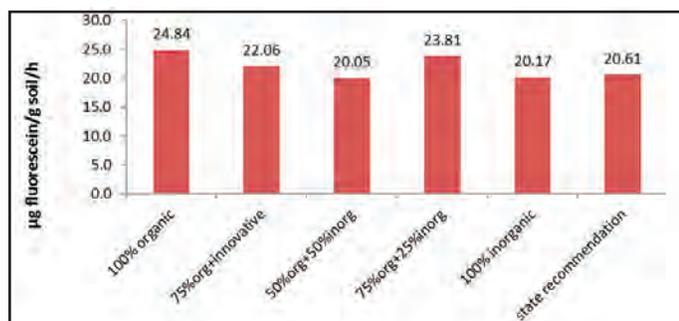


Fig. 2.2.3 FDA enzyme activity as influenced by nutrient management practices in soybean

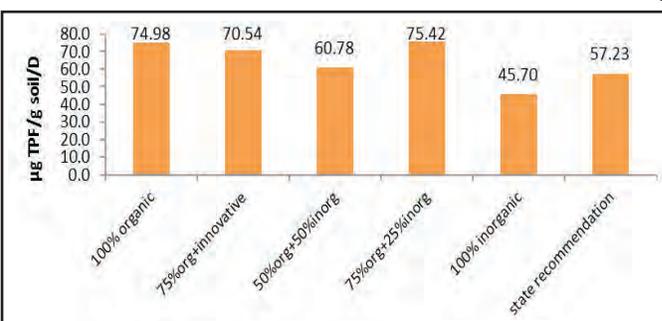


Fig. 2.2.4 Dehydrogenase activity as influenced by nutrient management practices in soybean

2.2.4 Evaluation of response of different varieties of major crops to organic farming

Performance of different varieties of soybean and maize (Plate 2.2.2) were evaluated for their yield response and to screen out promising varieties for organic management practices in central India (Table 2.2.6). Among the varieties of soybean grown under similar nutrient sources and doses, seed yield of cultivar RVS-2002-4 (821 kg ha⁻¹) out performed others. Among the maize varieties, yield of Kanchan variety was the highest (2308 kg ha⁻¹).

Analysis of nutritional quality constituents such as protein and oil content of the said varieties of soybean indicated that higher protein content in cv JS-93-05 variety followed by JS-20-29, NRC-37 and JS-335. However, higher oil content in RVS-2002-7 followed by RVS-2002-6, JS 20-29. In maize nutritional quality constituents such as protein, ash and tryptophan content were also determined. Although ash and tryptophan content in maize remained

Table 2.2.6 Performance evaluation of different varieties of major crops under organic farming practices during Kharif, 2015

Soybean				Maize				
Variety	Seed yield (kg ha ⁻¹)	Protein (%)	Oil (%)	Variety	Seed yield (kg ha ⁻¹)	Protein (%)	Ash (%)	Tryptophan (g/16 g N)
JS-335	631	36.37	19.39	Kanchan	2308	9.58	1.48	0.83
JS-93-05	517	37.55	19.19	Pratap 5	1573	9.40	1.39	0.82
JS-95-60	556	36.34	18.90	Arawali	1418	9.62	1.40	0.75
JS-20-41	808	36.20	19.31	Sona 222	1371	9.54	1.41	0.80
NRC-7	604	36.11	18.62	Pratap 6	1642	9.42	1.42	0.75
NRC-37	501	36.90	18.61	JM 216	1238	9.58	1.28	0.72
JS-20-29	521	37.53	19.66	Popcorn 1	673	8.97	1.29	0.66
RVS-2002-4	821	35.91	19.65	JM 8	1838	9.47	1.42	0.85
RVS-2002-6	517	35.85	19.90	JM 12	1500	9.13	1.43	0.79
RVS-2002-7	658	36.11	20.33	Proagro 4412	2181	9.93	1.49	0.89
JS-97-52	795	35.99	18.66	Sweet Corn	585	8.81	1.26	0.68
JS-20-34	563	35.90	18.19	CPBG 4202	1010	9.65	1.38	0.82
CD (0.05)	126	0.40	0.10		708	0.1	NS	NS

unchanged among the varieties of maize except protein content. The higher values of protein was recorded in cv Pro-agro-4212.



Plate 2.2.2 Soybean and Maize under OPoPs (Kharif 2015)

2.3 AICRP on STCR

2.3.1 User friendly software for preparation of Soil Health Card

A user friendly software has been developed by AICRP (STCR) for the preparation of Soil Health Card as per Ministry of Agriculture & Farmers Welfare, Govt. of India guidelines. The application is a user friendly tool, very easy to handle and any user with desired information can handle the software. The user needs to fill the desired values at respective cells provided in the soil health card which is self-explanatory. After furnishing the information the user needs to click on generate soil health card button and the software will analyse the furnished information, interpret it and provide customized prescription for different crops (Fig. 2.3.1).

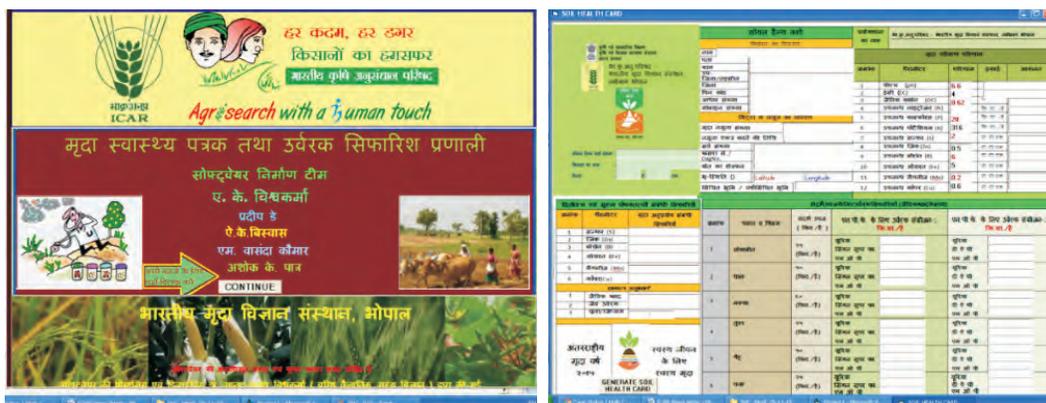


Fig. 2.3.1 Screen shot of software for soil health card

2.4 AICRP-Micronutrients

2.4.1 Available micronutrient status in soils

The current status of Zn, Fe, Mn, Cu and B deficiency have been estimated during 2010-2016. Status of micro- and secondary nutrients for different soil types, districts, regions as well as for the country has been estimated to know the nature and extent of their deficiencies/ toxicities and to formulate strategies for their



correction. A recent analyses of 1,69,290 soil samples collected from 435 districts of the 23 states of the country for delineation of micro-secondary nutrients deficiency using GPS indicates rampant micronutrients deficiency in the country, and is taking a toll on the food and economic security of the country in terms of the yield and economic losses due to unmatched yield goals. On an average, 40% soils are deficient in Zn, 33% in Sulphur and 23% in Boron. The deficiency of Fe (12.6%), Cu (4.6%), Mn (6.0%) are also emerging in different states and posing threats to agricultural sustainability. About 50% soils of one third of total districts in India are deficient in Zn. B deficiency are more common in sandy loam acid soils while Mn deficiency is emerging in rice-wheat cropping system grown in Indo-Gangetic Plains of India.

2.4.2 Revisiting critical limit of micronutrients

The deficiency of micronutrient in soil-plant system is quantitatively governed by its critical limits, the level below which the crops will respond to its application readily. The deficiency and sufficiency levels/limits of DTPA extractable Zn, Cu, Fe and Mn and hot water extractable B has been revisited for the soils of different states (Table 2.4.1).

Table 2.4.1 Revisiting critical limits of Zn, Cu and Mn for different soils and crops using DTPA extractant

State	Soil type	Crop (nutrients)	Critical limit (mg kg ⁻¹ soil)	
			Existing	Re-established
Madhya Pradesh	Mixed red and black soils	Wheat (Zn)	0.50	0.62
Bihar	Calcareous soil	Rice (Zn)	0.60	0.70
		Wheat (Zn)	0.70	0.78
Uttarakhand	Hill soils, loamy and acidic in nature	Lentil (Zn)	0.80	1.20
		Soybean (Zn)	0.60	0.75
Maharashtra	Black (swell-shrink) soils	Soybean (Zn)	0.50	0.65
Punjab	Sandy and sandy loam soils	Paddy (Cu)	0.20	0.30
		Wheat (Mn)	2.50	3.00
Tamil Nadu	Red loamy/laterite acid Soils	Onion (Cu)	1.20	0.65
		Maize (Zn)	1.20	0.85
Gujarat	Medium black soils	Wheat (Mn)	4.50	5.30

The critical limits have been shown to vary with micronutrient, crops, soil, and the extractants used. The critical limit of micronutrients increased in most of soils, except in red laterite soils of Tamilnadu. The critical limit of Cu (1.20 mg/kg) and Zn (1.20 mg/kg) in Onion and maize were reduced to 0.65 and 0.85 mg/kg soil, respectively. The critical limit of Zn in black, calcareous soils has increased in Madhya Pradesh, Maharashtra and Bihar. The critical limit of Cu and Mn has also shifted to positive side in sandy loam soils of Punjab. Almost all soil types and crops responded to B and S application at concentration much above the earlier fixed critical limits for these nutrients (Table 2.4.2). The change in critical limit may be ascribed to change in crop varieties and buffering capacity of soils due to continuous mining of micronutrients from soils.



Table 2.4.2 Revisiting critical limits of boron and sulphur for different soils and crops

State	Soil type	Crop (nutrients)	Critical limit (m g kg ⁻¹ soil)		
			Existing	Re-established	
Assam	Alluvium acid soils	Cabbage (HWS-B)	0.45	0.55	
		Cabbage (0.01M salicylic acid)	-	0.50	
		Rapeseed (HWS-B)	0.45	0.58	
		Rapeseed (0.01M salicylic acid)	-	0.62	
Uttarakhand	Hill soils, acidic in nature	Lentil (HWS-B)	0.5	0.70	
		Soybean (HWS-B)	0.5	0.55	
		Lentil (0.15M CaCl ₂ extractable S)	10.0	12.0	
		Maize (0.15M CaCl ₂ extractable S)	10.0	11.0	
Bihar	Old alluvium Calcareous soil	Rice (HWS-B)	0.50	0.55	
		Wheat (HWS-B)	0.50	0.58	
	Young alluvium non calcareous soil	-	Wheat (HWS-B)	0.50	0.65
	Old alluvium Calcareous soil	Rice ((0.15M CaCl ₂ extractable S)	10.00	13.00	
		Wheat (0.15M CaCl ₂ extractable S)	10.00	15.00	
	Haryana	Sandy, alkaline soils	Raya (HWS-B)	0.50	1.00
Jharkhand	Red and lateritic soils	Maize (HWS-B)	-	0.40	
		Maize (0.01M salicylic acid)	-	0.45	
Odisha	Red and lateritic soils	Potato (HWS-B)	0.50	0.58	
		Potato (0.15M CaCl ₂ extractable S)	10.0	12.0	
	Alluvial acidic soil	Potato (0.15M CaCl ₂ extractable S)	10.0	15.0	
		Inceptisols neutral	Ground nut (0.15M CaCl ₂ extractable S)	20.0	30.0

2.4.3 Biofortification of crops with micronutrients

In order to manage the problem of Zn and Fe deficiency in soil and in human, production of micronutrient-rich staple food grains, especially of rice and wheat, are required. In India, under the aegis of AICRP-Micronutrients, based on Yield Efficiency and Uptake Efficiency Index we have identified genetically efficient and inefficient cultivars for micronutrient enrichments (Table 2.4.3). Interestingly, the genetically inefficient cultivars are agronomically highly efficient, and should be used for agronomic biofortification to enrich the grains with desired micronutrients. The efficient cultivars could be utilized by breeders for QTL identification and developing high yielding micronutrient enriched cultivars (genetic biofortification). There





are different approaches to improve the micronutrient content of the edible part. One is to increase the efficiency of uptake and transport into edible tissue and second is to increase the amount of bioavailable micronutrient accumulation in the plant.

Agronomic Bio-fortification: Agronomic biofortification is an inexpensive and simple approach which can be utilized to enrich genetically inefficient cultivars by application of micronutrient fertilizers at different rates, methods and at different crop growth stages. Of the several strategies developed using permutation and combinations of nutrient management options, soil application with foliar feeding is best option for grain enrichment with Zn, in soils having low Zn status. In soils with adequate Zn, 2-3 foliar sprays are sufficient to increase grain Zn concentration in rice, wheat and pigeon pea. Foliar spray of K along with Zn has also been an effective strategy for enhancing grain Zn concentration pigeon pea. At Bhopal, application of Zn enhanced

Table 2.4.3 Genetically and agronomically Zn-efficient cultivars of different crops based on YEI and UEI

Genetically and Agronomically Zn Efficient Cultivars											
IISS, Bhopal				ANGRAU, Hyderabad				GBPUAT, Pantnagar			
Pigeon pea		Wheat		Rice		Maize		Rice		Wheat	
Genetically efficient	Agronomically efficient	Genetically efficient	Agronomically efficient	Genetically efficient	Agronomically efficient	Genetically efficient	Agronomically efficient	Genetically efficient	Agronomically efficient	Genetically efficient	Agronomically efficient
C11	Hisar H02-60	GW-322	C-306	JGL 11470	JGL 11727	Super 9681	Harsha	Pant Dhan 18	Jaya	UP2554	UP 262
ICPL 87119	Hisar-Manak	JW-3211	JW-17	MTU 7029	JGL 11118	30 Y 92	Laxmi 4950	Pant Sugandh 17	Pant Dhan 19	K9107	PBW590
GT- 101	Hisar Paaras	HW-147	HW-2004	Erramalle lu	MTU 1001	DHM 111	NK 6240	Kala Namak	Pant Sankar 1	UP2628	VL804
T 15-15	SKNP 05-05	HI-8627	AKW-4627	WGL 32100	SUREKHA	DHM 117	Ashwini	Pant Dhan 16	Basmati 370	PBW502	WH147
BSMR 853	GAUT 93-17			BPT 5204	NLR 33892			Pusa Sugandh 4	Type 3	UP2565	WH1021
Virsa Arhar-1	PKV Trombay									PBW 502	UP 2572
Fe Efficient/Inefficient Cultivars						Mn Efficient/Inefficient Cultivars					
AAU, Anand				RAU, Pusa				PAU, Ludhiana			
Pigeon pea		Chickpea		Rice		Maize		Rice		Wheat	
Genetically efficient	Agronomically efficient	Genetically efficient	Agronomically efficient	Genetically efficient	Agronomically efficient	Genetically efficient	Agronomically efficient	Genetically efficient	Agronomically efficient	Genetically efficient	Agronomically efficient
DT-23	BSMR-853	GJG- 506	ICCC- 4	Birsamati	Boro 3	Dewaki	Shaktiman -3	PAU 201	Pusa 44	BW 8989	PDW 291
AAUT-2007-4	BP-1-96	GG- 1	GAG- 839	RAU 759	Jeerabati	Hemant	Shaktiman -4	3047	3138	BW 9149	PDW 314
BDN-2	C-11	GAG- 838	GJG- 305	Sanwal Basmati	Rajendra Kasturi	Pop-64	Lakshmi	PR 116	3140	PBW 550	BW 9022
PKV- Trombay	AAUT200 7-10			Swarna Sub-1	Rajendra Subhashini	Rajendra H M 1	CM-400	3131	3141	PBW 636	BW 9178



37.2% and 30.9% Zn concentration in inefficient cultivars of pigeon pea and wheat. Fe concentration in efficient cultivars of pigeon pea and chickpea grown at Anand exhibited 10% and 6% increase while 14% and 20%, in inefficient cultivars. Inefficient cultivars of rice grown at Hyderabad showed 77.8% increase in Zn concentration. At Pantnagar, Zn concentration doubled in rice and tripled in wheat. While Fe loading in efficient cultivars of rice and maize enhanced by 37% and 46% when Fe was supplied as foliar application. In case of inefficient cultivars, Fe concentration in rice and maize increased by 76% and 53% (Table 2.4.4).

Studies have shown that Zn application beyond the optimum rate can help to increase wheat grain Zn concentration up to 60 mg kg⁻¹ without affecting the wheat yield, and considered to be adequate for better human nutrition. Fertilizer strategy could be a rapid solution to the problem and can be considered an important complementary approach to the on-going breeding programs. Fertilizer studies focusing specifically on increasing Zn concentration of grain (or other edible parts) are, however, very rare, although a large number of studies are available on the role of soil and foliar applied Zn fertilizers in correction of Zn deficiency and increasing plant growth and yield.

For enrichment of grains of chickpea and pigeon pea with Fe, only one spray of 0.5% FeSO₄ solution either at flowering or at pod filling stage, two sprays at tasselling and silk stage to maize, and two sprays at pre- and post-anthesis to rice proved most effective. No doubt that agronomic bio fortification of staple food grains with Fe and Zn has substantially increased their content, the same is true in the case of identified Fe and Zn efficient cultivars, yet their concentrations are far from the adequate amount required to enrich the diet to fully meet the requirement of Fe and Zn for better human nutrition.

Nipping (apical bud removal) and defoliation (25% leaf removal) are two important practices to change the physiology of legume crops for micronutrients enrichment. Plant releases greater amount of soluble organic acids, phytosiderophores, enzymes and reluctant or oxidants in order recoup from injury caused by nipping and defoliation.

Table 2.4.4 Effect of Zn and Fe application on grain Zn and Fe Concentration in efficient and inefficient cultivars of crops.

Crop and Place	Efficient cultivars				Inefficient cultivars			
	Grain Zn (mg kg ⁻¹)		Increase over no Zn		Grain Zn (mg kg ⁻¹)		Increase over no Zn	
	-Zn	+Zn	(mg kg ⁻¹)	percent	-Zn	+Zn	(mg kg ⁻¹)	percent
Pigeon pea (Bhopal)	32.6	43.8	11.2	34.4	35.1	48.2	13.1	37.3
Wheat (Bhopal)	41.0	47.8	6.8	16.6	43.0	56.3	13.3	30.9
Rice (Dehusked) Hyderabad	11.0	16.7	5.7	51.8	9.5	16.9	7.4	77.9
Maize (Hyderabad)	24.2	27.4	3.2	13.2	23.7	29.5	5.8	24.5
Rice (dehusked) Pantnagar	16.1	26.8	10.7	66.5	13.1	26.8	13.7	104.7
Wheat (Pantnagar)	20.3	43.1	22.8	112.3	25.1	43.8	18.7	74.5
Crop and Place	Efficient cultivars				Inefficient cultivars			
	Grain Fe (mg kg ⁻¹)		Increase over no Fe		Grain Fe (mg kg ⁻¹)		Increase over no Fe	
	-Fe	+Fe	(mg kg ⁻¹)	percent	-Fe	+Fe	(mg kg ⁻¹)	Percent
Pigeon pea (Anand)	34.1	36.0	1.9	5.6	33.7	38.5	4.8	14.2
Chickpea (Anand)	59.	62.8	3.8	6.4	56	67.5	11.5	20.5
Rice (dehusked) Pusa	21.4	31.7	10.3	47.5	13.8	24.3	10.5	76.1
Maize (Pusa)	46.8	66.2	19.4	41.5	41.3	63.2	21.9	53.0



AICRP-Micronutrients, Anand, (Gujarat) observed that nipping and defoliation practices could enhance Fe concentration both in efficient and inefficient cultivars of Chickpea and pigeon pea. In chickpea, nipping of apical buds at grand growth stage but before flower resulted in 11% increase in Fe concentration in grain of efficient cultivars (GG1 and GAG 735) while in inefficient cultivars (ICCC4 and GJG 305) this increase in grain Fe was only 5 per cent. Defoliation (25% of leaves) at pre-flowering stages could enhance the Fe concentration in grain by 7 and 4% respectively in efficient and inefficient cultivars. In case of pigeon pea, nipping and defoliation had greater response than chickpea. The grain Fe concentration had increased by 17 and 5% in efficient (BDN-2 and PKV Trombay) cultivars after nipping and defoliation, while in inefficient cultivars (C-11 and AAUT 2007-08) the increase was reckoned by 10 and 12 percent, respectively.

2.4.4 Bioassimilation of enriched cereal and pulses

Increased micronutrient concentration in seed does not qualify that it will be bioavailable to human and animals. Assessing amount of a trace element in a diet bio available to human population is extremely complex and difficult due to numerous interacting factors involved in it. Some trace elements are lost during processing and cooking; some are made unavailable for absorption from the gastrointestinal tract by binding to substances (ant nutrients) in the meal that prevent their absorption from the gut or interfere with their utilization in the body once absorbed, making them metabolically inactive. Quantitative assessment of intake of Fe and Zn from commonly consumed diet is much lower than the recommended dietary allowance of 10 mg day⁻¹ due to high phytates content. Micronutrient (Zn/Fe) bioavailability assessed under AICRP-micronutrients project using rat models showed that intake of Zn enriched pigeon pea/ wheat diet was more in Zn/Fe enriched diet than that of normal diet. The quantum of Zn/Fe supplied, through the bioavailability of Zn/Fe enriched grain was as good as Zn/Fe supplied through standard sources. Fe/Zn concentration in different body parts of rats, liver, kidney and femur were comparable in all treatments but total absorption was high from wheat based diet because of its greater intake by rats. When rats were fed with Zn/Fe deficient diet, it had effect on kidney, liver and haemoglobin content. The Fe intake by rat was similar under both diet system, i.e. Fe supplied through Fe enriched pigeon pea seed or standard sources (purified ferrous sulphate). However, Fe excretion through animal faeces were more in rat fed with Fe enriched pigeon pea diet. Zn/Fe absorption in liver, kidney, and femur bone of rats under both the sources was similar, showing at par Zn bioavailability in rat.

Theme II. Conservation Agriculture, Carbon Sequestration and Climate Change

2.5. Conservation Agriculture and Climate Change

2.5.1 Quantification of carbon sequestration, green house gas emissions (NO₂ and CO₂) and soil quality changes under the practice of conservation agriculture

Soil samples were collected from soybean, rice and maize based cropping systems under conservation agriculture (CA) at depths of 0-15 and 15-30 cm. Soil chemical (pH, EC, Organic Carbon, Labile C, and available N, P, and K) and biological parameters (Dehydrogenase activity, FDA and alkaline phosphatase activity) were analyzed after the completion of 3 years of experimentation. A perusal of data from CA experiments at Jabalpur indicated that maximum buildup of SOC (0.87%) was recorded from rice based



cropping system under zero tillage with residue retention, which was significantly higher over conventional tilled plot with residue burnt or retained (Fig 2.5.1). Similar observations were recorded in maize based cropping system. The effect of residue retention along with zero tillage was also noticed in 15-30 cm of soil depth. However, there was no significant difference between conventional and zero tillage on soil SOC content in soybean-wheat cropping system.

The $KMnO_4$ oxidisable C was estimated under different CA experiments of Jabalpur to measure management induced changes in soil quality parameters. It was observed that labile C content (0-15 cm soil depth) was significantly higher under zero tilled with residue retained (519 mg kg^{-1}) in rice based cropping system in comparison to conventionally tilled with residue retained (429 mg kg^{-1}) (Fig 2.5.2). Similar trend was recorded in maize and soybean based cropping systems. In both these experiments zero tilled plots with residue retention maintained higher level of labile C in comparison to conventional tilled plots with no residue. Similar effect was recorded in 15-30 cm of soil depth also.

Changes in available N and P remained unaffected amongst different tillage treatments in CA experiments. However, there was a buildup of P. Available K being relatively higher in zero tillage with residue retained in comparison to no residue retention in all the experiments (Fig. 2.5.3). However, the effect was only pronounced to 0-15 cm of soil depth. Available K content was found to be the maximum in zero tillage with either residue retained or burnt. It was significantly lower in plots which were conventionally tilled. Soil pH ranged from 6.6 to 7.1 and EC ranged from 0.3 to 0.6 dS m^{-1} in different experiments under CA at Jabalpur. Initial soil samples collected from newly initiated conservation agriculture experiment at ICAR-IISS Bhopal were characterized for pH, EC, organic C, available N, P and K content (Table 2.5.1).

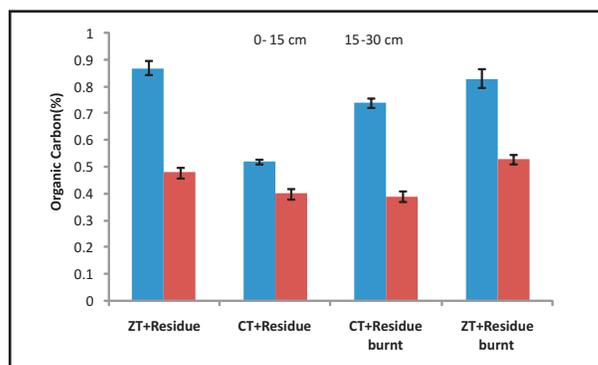


Fig. 2.5.1 Soil organic carbon content (%) in rice-wheat-green gram based CA experiment

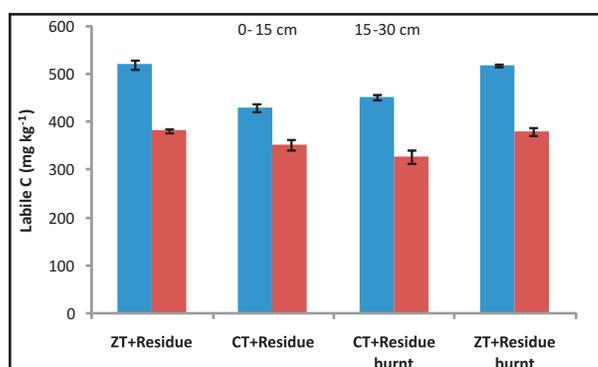


Fig. 2.5.2 Labile carbon content (mg kg^{-1}) in rice-wheat-green gram based CA experiment

Table 2.5.1 Initial soil characterization of conservation agriculture field of ICAR-IISS farm

Parameters/Soil depth	0-5 cm	5-15 cm	15-30 cm
pH	7.82 (0.03)	7.88 (0.02)	7.95 (0.01)
EC	0.44 (0.03)	0.39 (0.03)	0.34 (0.03)
OC (%)	0.57 (0.03)	0.46 (0.01)	0.39 (0.05)
Labile C (mg/kg)	418 (6.05)	362 (11.3)	327 (9.11)
N	209.5 (5.47)	173.1 (3.76)	156.8 (1.98)
P	22.4 (0.92)	11.5(1.44)	8.6 (1.66)
K	467.0 (17.4)	333.9 (21.6)	311 (22.7)



2.5.2 Effect of conservation tillage practices and residue cover on weed-wheat ecosystem

In a CA experiment, four weed species (broad leaved weed) viz., *Alternanthera sessilis*, *Tridox procumbens*, *Sonchus arvensis* and *Parthenium hysterophorus* were present in the wheat crop. No sedge and grassy weeds were seen. Only the density of *Alternanthera sessilis* was influenced by tillage practices and residue cover. Minimum density of *A. sessilis* was recorded under conventional tillage (CT) which was significantly lower than the No till (NT) and Reduced Tillage (RT). Among the crop residue levels, application of 50%, 75% and 100% residue recorded significantly less density of *A. sessilis* at 8 to 51 DAS than no residue. Conventional tilled wheat recorded significantly lower density of total weeds at all stages as compared to no till at 23 to 51 DAS which was at par with RT at 23 DAS. Conventional tilled wheat was most effective in minimizing total weed dry weight. Further 50% to 100% residue level significantly reduced weed dry weight at all the growth stages. Among the tillage practices highest relative density of *A. sessilis* was found at all the stages.

The weed control efficiency (WCE) worked out at 30, 37, 44 and 51 DAS revealed that CT wheat recorded higher WCE as compared to NT and RT at 30 DAS but at 37, 44 and 51 DAS reduced till had higher value as compared to NT and CT. Among weed management practices, application of 100% residue recorded higher WCE at 37 and 51 DAS while 75% residue cover recorded higher WCE at 30 and 44 DAS 100%, 75% and 50% ground cover with residue caused maximum reduction in density and dry weight of weed as compared to the no residue and 25% residue since soil surface shaded and cool, and reducing daily fluctuations in soil temperature, weeds couldn't able to germinate.

2.5.3 AICRP (LTFE)

2.5.3.1 Carbon threshold level and sequestration

Carbon is key constituent of soil and control several functions like nutrient transformation, physical condition of soil and growth of soil microorganism. Therefore, it is of prime importance to know about input and output of carbon from soil under different nutrient management systems. This would not only help in maintaining soil carbon but also improving soil health. Attempt has been made to workout minimum amount of carbon required to maintain the status quo and determined the amount of carbon added to soil under different nutrient management.

2.5.3.2 Carbon budgeting under long term fertilizer experiments in Mollisols of Pantnagar

In general, carbon is added to the soil through plant root stubble and rhizodeposition, leaf biomass especially in leguminous crops and to some extent through organic manure. Residual biomass is one of the most important sources of carbon addition to soil. Data (Table 2.5.2) revealed that addition of C to soil is dependent on primary productivity (grain and straw) of the crop which in turn depends on nutrient supply. Perusal of data further revealed that balanced application of nutrient added more amount of carbon through root biomass. This is due to more root stubble biomass and rhizodeposition of carbohydrate as a result of more primary productivity due to application of nutrients.

2.5.3.3 Carbon stock and sequestration

Carbon stock and sequestration rate (Table 2.5.3) revealed that balanced application of nutrient maintained more stock of carbon because of larger primary productivity. As far as carbon sequestration is concerned at Pantnagar, data indicated that except NPK+FYM, there is a net loss of carbon from soil under all treatments.



Although in NPK+FYM treatment net addition of carbon was very meager (50 kg ha⁻¹), the amount of carbon added in NPK + FYM more or less equal to its loss. Thus to maintain initial soil organic carbon (1.48 %), external application of carbon through organic matter is essential.

Table 2.5.2 Effect of nutrient management practices on addition of carbon through residual biomass in rice-wheat system at Pantnagar

Treatment	Carbon added (kg ha ⁻¹ year ⁻¹)			
	Rice	Wheat	Rhizodeposition	Total
Control +Zn	698	525	217	1441
100% N + Zn	1138	1322	478	2939
100% NP + Zn	1177	1393	501	3072
50% NPK + Zn	1150	1148	434	2732
100% NPK- Zn	1199	1391	503	3094
150% NPK + Zn	1283	1463	520	3268
100% NPK+ Zn	1319	1535	554	3409
100% NPK+FYM *	1390	1689	603	7523

* Carbon added through FYM is 3840 kg ha⁻¹

Table 2.5.3 Effect of nutrient management on carbon stock (0-20 cm) and carbon sequestration/depletion in rice-wheat system at Pant Nagar

Treatment	Organic carbon (g kg ⁻¹)	Bulk density (Mg m ⁻³)	Carbon stock (Mg ha ⁻¹)	Carbon sequestration /depletion (kg ha ⁻¹)
Control	5.90	1.41	21.15	-553.4
100% N+Zn	7.95	1.35	21.47	-432.7
100% NP+Zn	8.85	1.35	23.90	-372.0
50% NPK + Zn	8.20	1.37	22.47	-407.7
100% NPK -Zn	7.90	1.36	21.49	-432.2
150% NPK+Zn	8.30	1.33	22.08	-417.4
100% NPK+Zn	9.06	1.34	24.28	-362.3
100% NPK+FYM	15.45	1.32	40.79	50.3

Initial B.D.=1.31 Mg m⁻³, initial carbon stock 38.78 and initial carbon 14.8 g kg⁻¹

2.5.3.4 Threshold value of carbon

Relationship worked out between the amount of carbon added and the change in carbon revealed that the amount of carbon required to be added to soil annually is 7095 kg ha⁻¹ yr⁻¹ (Fig. 2.5.4). Threshold carbon is the amount of carbon required to maintain the initial status of carbon which means if the carbon added to soil through residual biomass and other sources is less than this value then there will be net loss of carbon from soil. Perusal of data presented in

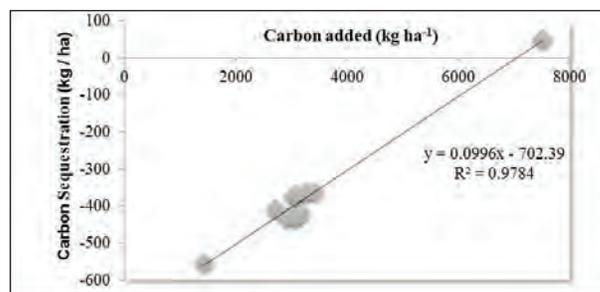


Fig. 2.5.4 Estimates of threshold carbon level in long term treatments under rice-wheat cropping system in Mollisols (Pantnagar, Uttarakhand)



Table 2.5.2 indicated that the amount of carbon added to soil is less than the threshold in Mollisols at Pantnagar and there is decline in carbon in all the treatments except NPK+ FYM. The amount of carbon added in NPK + FYM treatment is 7523 kg ha⁻¹ which is more or less similar to the amount of critical carbon of Pantnagar.

2.5.4 Fine-tuning of conservation agricultural (CA) practices for Vertisols of central India

A field experiment was initiated during *kharif* 2015 with five tillage treatments namely T1: Conventional tillage, T2: RT-1 (sowing with residues + 1 duck foot, WC with herbicides), T3: RT-2 (Strip tillage - sowing with strip till- drill with residues, WC 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% RDF, N2:100% RDF, N3: Soil test based recommendation. The results revealed that regardless of tillage systems, higher nitrogen application namely N 100 and N application based on STCR recorded higher grain yield under soybean-wheat and maize-gram systems (Fig. 2.5.5 and Fig. 2.5.6).

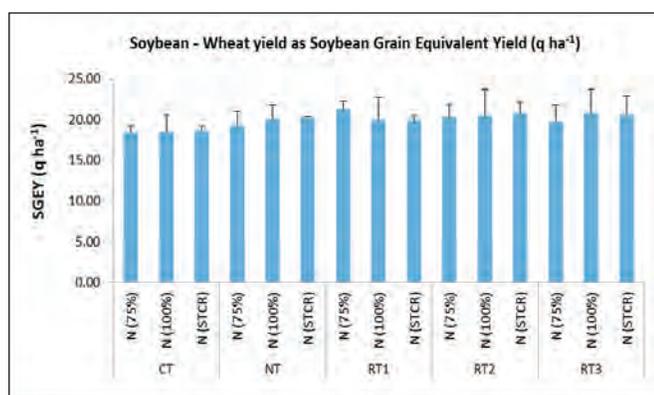


Fig 2.5.5 Crop yield of Soybean-Wheat system, as expressed in terms of Soybean Grain Equivalent Yield (q ha⁻¹)

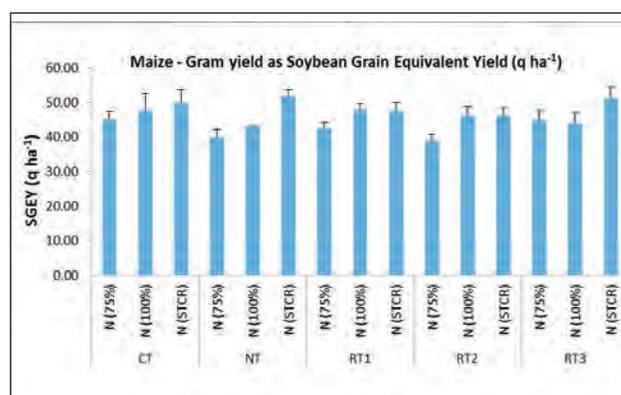


Fig 2.5.6 Crop yield of Maize-Gram system, as expressed in terms of Soybean Grain Equivalent Yield (q ha⁻¹)

2.5.5. Effect of conservation tillage practices on crop yield after 6 crop cycles

A study was conducted with two tillage treatments namely CT with residue removed and RT with residue retained along with six cropping systems namely i) Soybean-Fallow, ii) Maize- Gram, iii) Soybean- Fallow (R: rotated with maize-gram), iv) Soybean + Pigeon pea (2:1), v) Soybean+ Cotton (2:1) and vi) Soybean- Wheat. After completion of six crop cycles, crop yields were recorded and converted into soybean equivalent yield (SGEY, q ha⁻¹). Yield data indicated that tillage did not have significant effect on soybean grain equivalent yield after completion of six crop cycles (Fig 2.5.7). Irrespective of tillage system, maize-gram recorded significantly higher yield followed by soybean +pigeon pea (2:1) and soybean + cotton (2:1). The interactive effect of tillage x cropping system showed

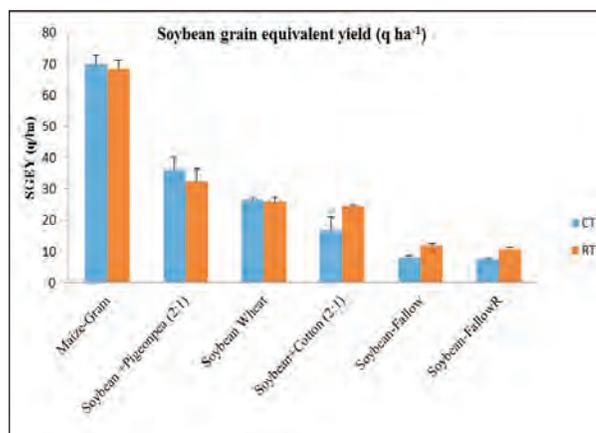


Fig. 2.5.7 Effect of conservation agricultural practices on soybean grain equivalent yield (q ha⁻¹) after five crop cycles



non – significant effect on SGEY. Lower crop yield under soybean based cropping system was due to aberrant weather conditions during kharif season.

Soil organic carbon (SOC) concentration (%) was relatively higher under RT with residue retention at 0-5 cm than CT and decreased with increasing depth (Fig 2.5.8). This has attributed to minimum soil disturbance coupled with incorporation of residue under RT. Soil aggregation as measured through mean weight diameter (MWD) significantly improved only in 0 -5 cm under NT and RT coupled with residue retention than CT (Fig. 2.5.9). Similarly, water stable aggregates recorded higher per cent in 0-5 cm depth under RT than CT (Fig 2.5.10). RT coupled with residue retention improved soil moisture content (3-8% wt/ wt) in the profile (0-30cm) during *rabi* cropping period.

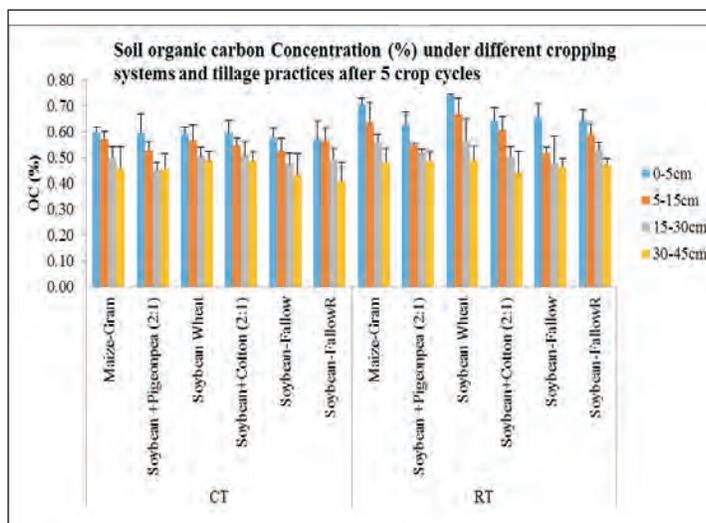


Fig. 2.5.8 Soil organic carbon under conservation agricultural practices after five crop cycles

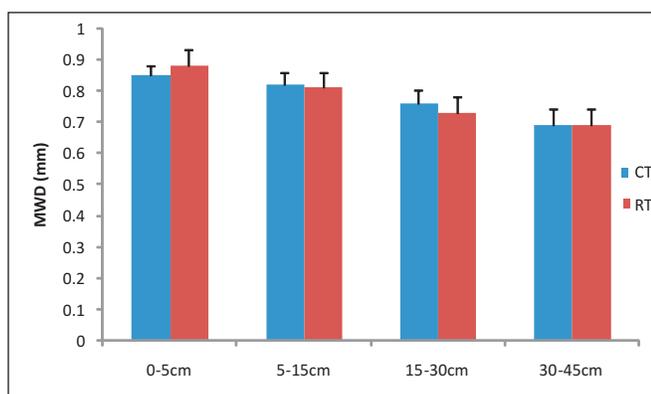


Fig 2.5.9 Soil aggregation (MWD) under different cropping systems and tillage practices after 5 crop cycles

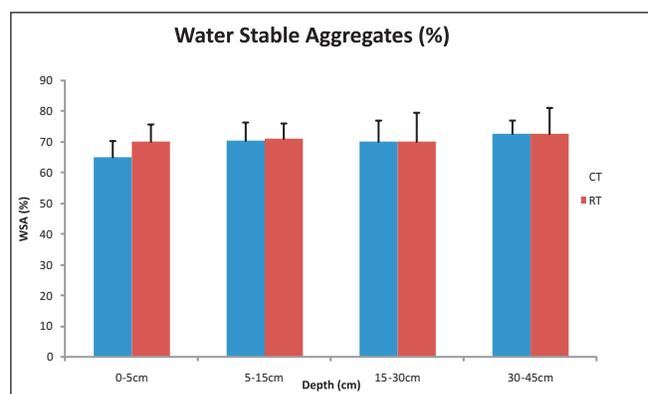


Fig 2.5.10 Water stable aggregate (>0.25mm) under different cropping systems and tillage practices after 5 crop cycles

2.5.6 Weed management for major cropping systems under conservation agriculture in vertisols

Rabi crops in soybean-chickpea, soybean-wheat, maize-mustard and maize-chickpea cropping system were sown in the experimental field under zero till conditions. Standard agronomic practices along with different weed control treatments were followed. The major weed flora comprised of *Anagallis arvensis*, *Convolvulus arvensis*, *Dichanthium annulatum*, *Euphorbia geniculata*, *Parthenium hysterophorus*, *Alternanthera sessilis*, *Abutilon indicum*, *Cardamine hirsute*, *Catharanthus pusillus* and *Sonchus asper* were seen in the experimental field. A uniform application of Glyphosate @ 1 kg ai ha⁻¹ in all the herbicide treated plots at the time of sowing.

2.5.6.1 Soybean-chickpea cropping system

Chickpea V.V. JG-16 was sown as the experimental crop under CA. Hand weeding at 20 and 40 DAS recorded



the lowest weed biomass and the highest seed yield (22.05 qha⁻¹) which was at par with pre emergence application of Oxyfluorfen @ 200 g ai ha⁻¹ (21.64 q ha⁻¹). Maximum weed index (82.54%) was recorded under absolute control conditions and minimum (1.81%) with the application of Oxyfluorfen @ 200 g ai ha⁻¹ (Table 2.5.4 & Plate 2.5.1).

Table 2.5.4 Effect of weed control treatment on yield of chickpea under Soybean-chickpea

Treatment	Biological Yield (q ha ⁻¹)	Grain Yield (q ha ⁻¹)	Straw Yield (q ha ⁻¹)	Weed Index (%)
Absolute control	10.34	3.85	6.49	82.54
Two hand weeding at 20 & 40 DAS (Conventional weed management).	60.71	22.05	38.67	0.00
Pre em. Pendimethalin 1000 g aiha ⁻¹ .	55.80	20.80	35.00	5.64
Pre em. Pendimethalin 1000 g ha ⁻¹ Fb PoE	53.61	18.94	34.67	14.08
Imazethpyr @ 30 g ai ha ⁻¹ at 30 DAS.				
PoE Imazethpyr @ 30 g ai ha ⁻¹ at 30 DAS.	33.15	11.49	21.67	47.89
PoE Imazethpyr @ 40 g ai ha ⁻¹ at 30 DAS.	36.32	12.98	23.33	41.12
PoEPropaquizafop @ 75 g ai ha ⁻¹ +Chlorimuron ethyl @4.5 g aiha ⁻¹ at 30 DAS.	28.05	10.08	17.97	54.26
Pre em. Pendimethalin 1000 g ha ⁻¹ FbPoE	35.42	12.42	23.00	43.65
Propaquizafop@60 g ai ha ⁻¹ at 30 DAS.				
Pre em. Oxyfluorfen @ 200g aiha ⁻¹	57.31	21.64	35.67	1.84
CD @ 5%	9.34	8.22	3.44	



Plate 2.5.1 Performance of chickpea under control and herbicide treated plots



2.5.7 Soybean- wheat cropping system

Wheat cv. C-306 was sown in the experimental field in the second week of October (Plate 2.5.2). Two hand weeding at 20 and 40 DAS recorded lowest weed biomass and maximum grain yield (34.75 q ha⁻¹) which was at par with post emergence application of Mesosulfuron + Idosulfuron @ 400 g ha⁻¹ treatment (33.07 q/ha), which was significantly higher as compared to weedy check (17.04 q ha⁻¹). Similarly, maximum weed index (50.97%) was recorded under weedy check and minimum (4.84%) with post emergence application of Mesosulfuron + Idosulfuron @ 400 g ai ha⁻¹ (Table 2.5.5).

Table 2.5.5 Effect of weed control treatment on yield of wheat under Soybean-wheat

Treatment	Biological Yield (q ha ⁻¹)	Grain Yield (q ha ⁻¹)	Straw Yield (q ha ⁻¹)	Weed Index (%)
Absolute control	56.83	17.04	39.79	50.97
Two hand weeding at 20&40 DAS (Conventional weed Management).	78.89	34.75	44.14	0.00
Pre em. Pendimethalin @1000 g ai ha ⁻¹	74.09	31.48	42.61	9.41
PoEmetsulfuron 4 g ai ha ⁻¹ + Clodinafoppropargyl 60 g ai ha ⁻¹ at 30DAS.	78.29	30.92	47.38	11.04
PoEMesosulfuron+ Idosulfuron 400g ai ha ⁻¹ at 20 DAS.	90.38	33.07	57.31	4.84
PoEIsoproturon @ 1000 g ai ha ⁻¹ at 20 DAS.	78.18	28.34	49.84	18.46
Pre em. Pendimethalin @750 g ai ha ⁻¹ Fb	85.98	31.10	54.88	10.51
PoEIsoproturon 1000 g ai ha ⁻¹ at 30 DAS.				
Pre em. Pendimethalin @750 g ai ha ⁻¹ Fb PoE	88.60	30.93	57.67	10.99
2 4 D amine salt 1000g ai ha ⁻¹ at 30DAS.				
Pre em. Pendimethalin @750 g ai ha ⁻¹ Fb	78.66	29.66	49.00	14.66
PoEMetsulfuron 4 g ai ha ⁻¹ at 30DAS.				
CD @ 5%	15.95	9.37	10.96	





Plate 2.5.2 Performance of Wheat under control and herbicide treated plots

2.5.8 Maize-mustard cropping system

In case of Maize-mustard cropping system two hand weeding recorded the lowest weed biomass and the highest seed yield (14.18 q ha^{-1}) which was at par with the application of pre emergence Pendimethalin @ 750 g ai ha^{-1} (14.07 q ha^{-1}) (Plate 2.5.3 & Table 2.5.6). Similarly, maximum weed index (59.73%) was recorded under absolute control treatment and minimum (0.82%) in Pendimethalin @ 750 g ai ha^{-1} .

Table 2.5.6 Effect of weed control treatment on yield of mustard under Maize-mustard

Treatment	Biological Yield (q ha^{-1})	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})	Weed Index (%)
Absolute control.	24.54	5.71	18.83	59.73
Two hand weeding at 20&40 DAS (Conventional weed management).	60.18	14.18	46.00	0.00
Pre em. Pendimethalin @ 750 g ai ha^{-1}	59.07	14.07	45.00	0.82
PoEClodinafoppropargyl @ 60 g ai ha^{-1} at 30DAS.	54.64	13.64	41.00	3.81
PoEIsoproturon 750 g ai ha^{-1} at 30DAS.	45.95	11.62	34.33	18.06
Pre em. Pendimethalin @ 500 g ai ha^{-1}	47.01	12.86	34.15	9.33
fbPoEIsoproturon 500 g ai ha^{-1} at 30DAS.	44.93	11.60	33.33	18.21
Pre em. Pendimethalin @ 750 g ai ha^{-1}	44.93	11.60	33.33	18.21
fbPoEIsoproturon 500 g ai ha^{-1} at 30DAS.	44.93	11.60	33.33	18.21
PoE. Isoproturon @ 500 g/ha + Propaquizafop 100 g ai at 30 DAS.	42.33	10.67	31.67	24.79
Pre em. Pendimethalin @ 500 g ai ha^{-1} Fb PoEIsoproturon 750 g ai ha^{-1} at 30 DAS.	44.33	11.67	32.67	17.74
CD @5%	5.89	4.75	3.13	

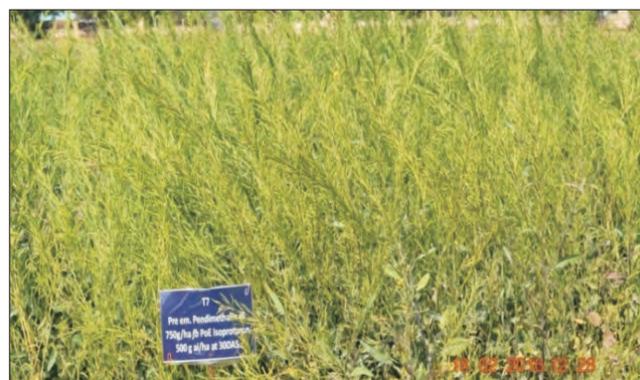


Plate 2.5.3 Performance of mustard in herbicide treated plots under zero tillage

2.5.9 Maize-chickpea cropping system

In case of Maize-chickpea cropping system, pre emergence application of Oxyfluorfen @ 200 g ai ha⁻¹ recorded maximum seed yield of 25.61 q ha⁻¹ which was at par with two hand weeding at 20 and 40 DAS (25.00 q ha⁻¹) which was significantly higher as compared to weedy check (6.38 q/ha). Treatment comprised of two hand weeding at 20 and 40 days after sowing has recorded lowest weed biomass. Similarly, maximum weed index (74.49%) was recorded under weedy check and minimum (-2.44%) with application of Oxyfluorfen @ 200 g ai ha⁻¹ (Table 2.5.7; Plate 2.5.4).



Plate 2.5.4 Performance of chickpea in herbicide treated plots under zero tillage


Table 2.5.7 Effect of weed control treatment on yield of chickpea under Maize-chickpea

Treatment	Biological Yield (q ha ⁻¹)	Seed Yield (q ha ⁻¹)	Straw Yield (q ha ⁻¹)	Weed Index (%)
Absolute control	16.71	6.38	10.33	74.49
Two hand weeding at 20&40 DAS (Conventional weed management).	58.63	25.00	33.63	0.00
Pre em. Pendimethalin @ 1000 g ai ha ⁻¹ .	49.85	18.00	27.00	8.60
Pre em. Pendimethalin @ 1000 g ai ha ⁻¹ FbPoE	39.74	16.74	23.00	33.05
Imazethpyr @ 30 g ai ha ⁻¹ at 30 DAS.	44.29	11.62	32.67	53.51
PoE Imazethpyr @ 40 g ai ha ⁻¹ at 30 DAS.	29.19	12.86	16.33	48.56
PoE Propaquizafop @ 75 g ai ha ⁻¹ + Chlorimuron ethyl @ 4.5 g ai ha ⁻¹ at 30 DAS.	31.93	11.93	20.00	52.27
Pre em. Pendimethalin @ 1000 g ai ha ⁻¹ FbPoE Propaquizafop @ 60 g ai ha ⁻¹ at 30 DAS.	43.75	14.75	29.00	41.02
Pre em. Oxyfluorfen @ 200g ai ha ⁻¹	60.28	25.61	34.67	-2.44
CD @ 5%	11.88	6.54	8.70	

Among various weed control treatments in soybean cv. JS-335, post emergence application of Propaquizafop @ 100 g ai ha⁻¹ + Chlorimuron ethyl @ 9 g ai ha⁻¹ at 20 DAS has recorded lowest weed biomass and maximum seed yield (10.60 q ha⁻¹) which was at par with hand weeding (10.33 q ha⁻¹) which was significantly higher as compared to weedy check (3.60 q ha⁻¹). Similarly, maximum weed index (65.13%) was recorded under weedy check and minimum (-2.58%) with application of post emergence Propaquizafop @ 100 g ai ha⁻¹ + Chlorimuron ethyl @ 9 g ai ha⁻¹ at 20 DAS (Table 2.5.8; Plate 2.5.5).

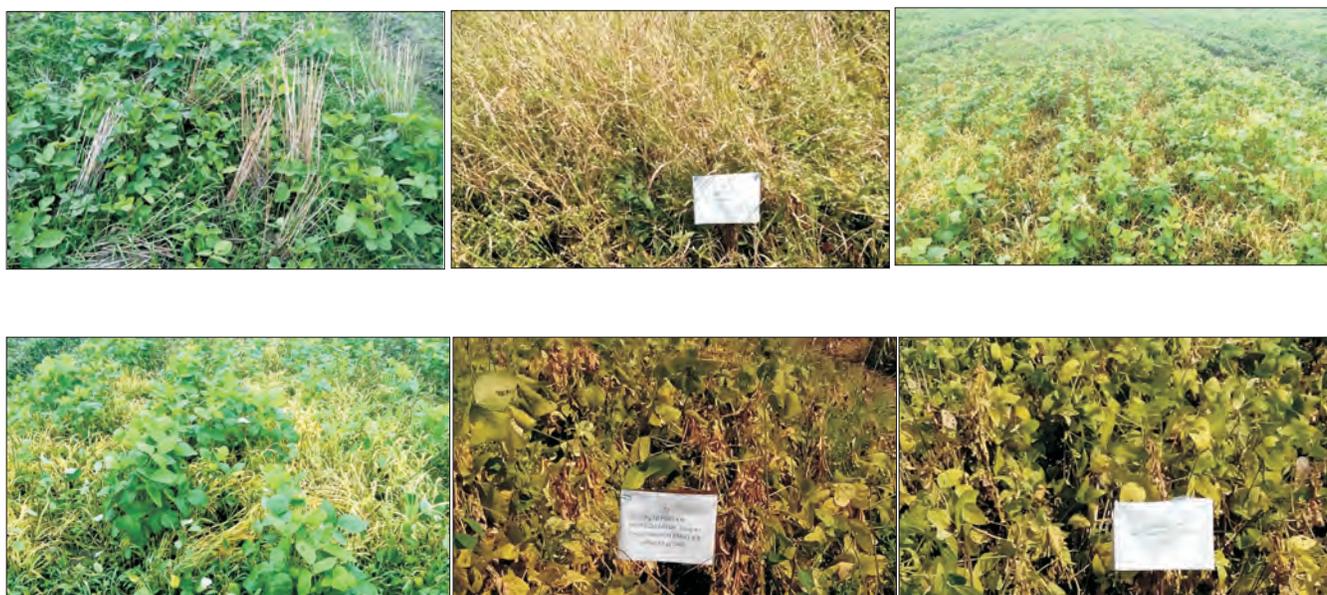

Plate 2.5.5 Performance of soybean in herbicide treated plots under zero tillage

Table 2.5.8 Effect of weed control treatment on yield of soybean

Treatment	Biologic al Yield (q ha ⁻¹)	Grain Yield (q ha ⁻¹)	Straw Yield (q ha ⁻¹)	Weed Index (%)	Weed density m ⁻²
Absolute control	11.40	3.60	7.80	65.13	268.00
Two hand weeding at 20 & 40 DAS	38.57	10.33	28.24	0.00	118.67
Pre em. Pendimethalin @1000 g ai ha ⁻¹	37.75	9.63	28.12	6.81	123.33
PoE Propaquizafop @ 100 g ai ha ⁻¹ + Chlorimuron ethyl @ 9 g ai ha ⁻¹ at 20 DAS.	31.39	8.06	23.33	22.00	129.63
PoE Imazethpyr @100 g ai ha ⁻¹ at 20 DAS.	38.03	10.03	28.00	2.90	98.67
Pre em. Pendimethalin @ 1000 g ai ha ⁻¹ Fb PoE Imazethpyr @ 100 g ai ha ⁻¹ at 30 DAS.	32.63	6.96	25.66	32.58	141.33
PoE Propaquizafop @100g ai ha ⁻¹ + Chlorimuron ethyl @ 9 g ai ha ⁻¹ at 20 DAS.	35.93	10.60	25.33	-2.58	116.00
CD @5%	5.98	3.98	3.24		



Plate 2.5.6 Performance of maize in herbicide treated plots under zero tillage



Table 2.5.9 Effect of weed control treatment on yield of maize

Treatment	Biological Yield (qha ⁻¹)	Grain Yield (qha ⁻¹)	Straw Yield (qha ⁻¹)	Weed Index (%)	Weed density m ⁻²
Absolute control	60.44	22.76	37.683	63.36	230.27
Two hand weeding at 20 & 40 DAS	146.30	62.12	84.186	0.00	70.16
Pre em. Atrazine @1500 g ai ha ⁻¹	135.82	54.99	80.830	11.47	86.00
Pre em. Pendimethalin @ 1000 g ai ha ⁻¹	102.22	37.56	64.680	39.54	157.33
PoE Atrazine @1250 g ai ha ⁻¹ at 20 DAS.	111.58	43.21	68.363	30.43	124.00
Pre em. Pendimethalin @ 1000 g ai ha ⁻¹ Fb PoEAtrazine @ 750 g ai ha ⁻¹ at 30DAS.	136.68	57.41	79.273	7.58	91.53
Pre em. Pendimethalin @ 750 g ai ha ⁻¹ Fb PoE Atrazine @1000 g ai ha ⁻¹ at 30DAS	141.06	61.24	79.823	1.41	63.33
CD @5%	11.26	7.09	5.09		

2.5.10 Climate change effects on maize productivity in Vertisols using APSIM crop growth simulation model

2.5.10.1 Yield gap analysis of maize

Yield gap analysis is a powerful method to reveal and understand the biophysical opportunities to meet the projected increase in demand for agricultural products, and to support decision making on research, policies, and development. Further potential yield and yield gap analysis may help in identifying the potential yield limiting factors and in developing suitable management strategies to improve the productivity of a crop or cropping system. The potential yield and yield gap analysis requires a thorough understanding of crop growth and development, which in turn depends on weather, soil, water, and crop management factors.

So it is important to consider all aspects of crop growth and soil management factors while using simulation models. In this study, a well calibrated and validated APSIM model was used to study yield gap analysis of Madhya Pradesh (Fig 2.5.11). Depending on the weather conditions over 30 years, APSIM observed considerable variation in maize simulated yield. The maximum simulated maize yield of 7.6 t ha⁻¹ was recorded in Mandsaur district while the minimum yield of 0.8 t ha⁻¹ was recorded in Damoh district. When averaged over the simulation period, the mean grain yield ranged from 3.3 to 5.2 t ha⁻¹ for the different soil series. The yield gap was minimum for Chhindwara and Damoh districts, while it was maximum in Indore and Mandsaur districts.

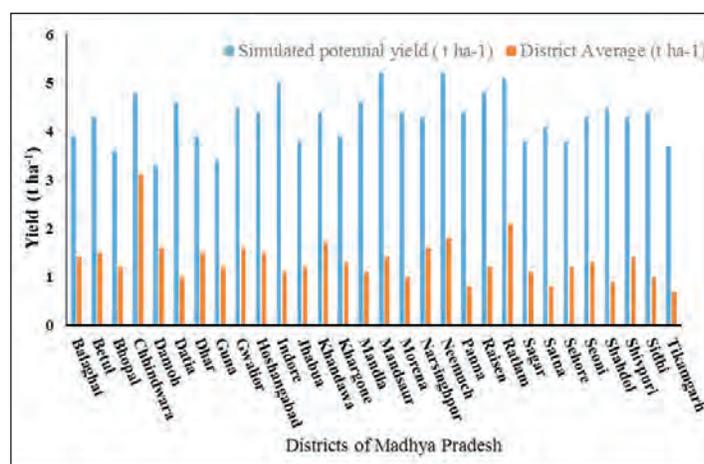


Fig. 2.5.11 Potential and average yield of different districts of Madhya Pradesh

So it is important to consider all aspects of crop growth and soil management factors while using simulation models. In this study, a well calibrated and validated APSIM model was used to study yield gap analysis of Madhya Pradesh (Fig 2.5.11). Depending on the weather conditions over 30 years, APSIM observed considerable variation in maize simulated yield. The maximum simulated maize yield of 7.6 t ha⁻¹ was recorded in Mandsaur district while the minimum yield of 0.8 t ha⁻¹ was recorded in Damoh district. When averaged over the simulation period, the mean grain yield ranged from 3.3 to 5.2 t ha⁻¹ for the different soil series. The yield gap was minimum for Chhindwara and Damoh districts, while it was maximum in Indore and Mandsaur districts.



2.5.10.2. Effect of plant available water capacity (PAWC) and change in temperature on maize grain and total biomass yield

The maize grain yield increased with increase in PAWC of soils as presented in Fig. 2.5.12. It was observed that maximum grain yield of 4.7 t ha⁻¹ was observed when the PAWC of soil varied between 73-140 mm while that of 3.7 t ha⁻¹ was observed when the PWAC was <72 mm. It was also observed that with increase in temperature the grain yield of maize decreased from 4.7 to 2.9 t ha⁻¹ in case of higher PAWC when the temperature increased from 0 to 5°C. Similarly, the maize yield decreased from 3.7 t ha⁻¹ to 2.4 t ha⁻¹ when the temperature increased from 0 to 5°C in case of

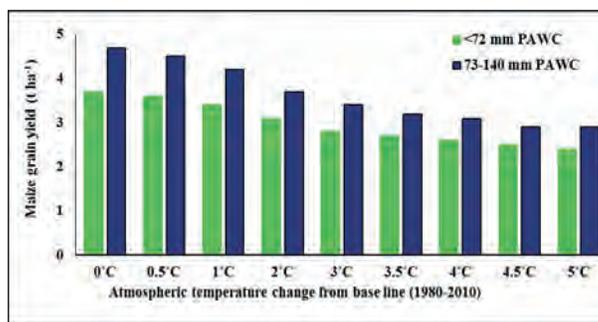


Fig. 2.5.12 Effect of PAWC and change in atmospheric temperature on maize grain yield

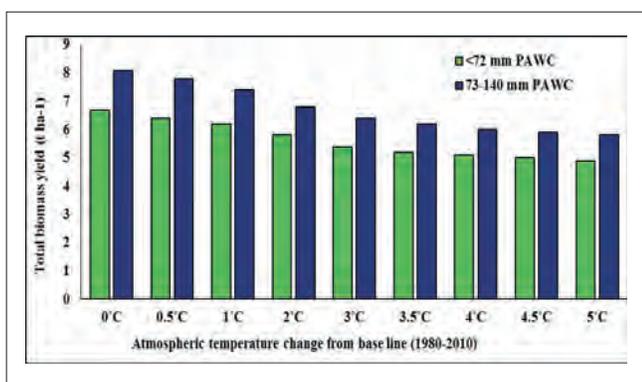


Fig. 2.5.13 Effect of temperature and profile water content on total biomass yield of maize

lower PAWC. There was 38.6% and 36% decrease in maize grain yield for PAWC of 72-140 mm and <72 mm in the soil profile, respectively. Similar trend in maize total biomass yield was also observed as presented in Fig. 2.5.13. A maximum total biomass yield of 8.1 t ha⁻¹ was observed when the PAWC of soil varied between 73-140 mm while that of 6.7 t ha⁻¹ was observed when the PWAC was <72 mm. There was 28% and 26% decrease in maize total biomass yield for PAWC of 72-140 mm and <72 mm in the soil profile, respectively.

2.5.10.3. Effect of plant available water capacity (PAWC) and change in rainfall on maize grain and total biomass yield

The maize yield and total biomass increased with increase in PAWC of soils as presented in Fig. 2.5.14 and Fig. 2.5.15. In case of PAWC of soil 73-140 mm, it was observed that the maize grain yield increased with

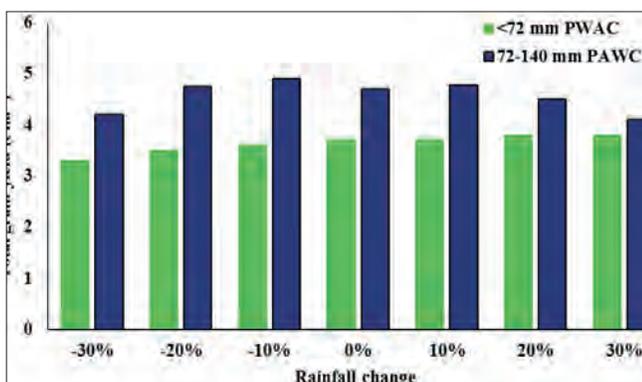


Fig. 2.5.14 Effect of PAWC and change in rainfall on maize grain yield

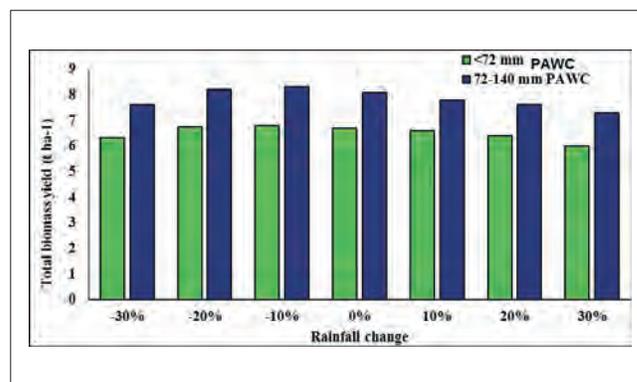


Fig. 2.5.15 Effect of PAWC and change in rainfall on maize total biomass yield



decrease in rainfall to 10% and 20%. Further decreasing the rainfall to 30%, the grain yield decreased by 9%. With increase in rainfall by 10% from the base there was slight increase in grain yield of maize but increasing the rainfall further decreased the grain yield. There was 10% decrease in grain yield by increasing the rainfall to 30%. While dealing the PWAC of <72 mm, it was observed from the simulated results that the grain yield decreased with decrease in rainfall amount while the grain yield of maize increased with increase in rainfall (Fig. 2.5.14). Similar results were also obtained from the maize total biomass yield (Fig. 2.5.15). In both the cases of PAWC, the biomass yield decreased with increase in rainfall amount while decreasing the rainfall decreased the total biomass yield of maize.

2.5.11 Characterization of wheat root architecture as influenced by soil compaction levels

Plant roots are strongly affected by soil mechanical impedance, either by natural processes or by the use of heavy machinery for soil cultivation. Therefore, a twenty-day laboratory investigation was conducted to quantify root system architecture (RSA) of two wheat cv. (sujata, malwa shakti) under different compaction levels (1.2, 1.4, 1.5 and 1.6 Mg m⁻³). After twenty days, root systems were separated out from soil and parameters of root system architectures were measured. Results indicated that different levels of bulk density have significant effect on root architectural parameters such as root main axis length, number of nodes, number of primary axis and the root angles. With an increase in bulk density from 1.2 to 1.6 Mg m⁻³, the decrease observed in root main axis length, number of nodes, number of primary axis and the root angles of cv. sujata were 58%, 47%, 54%, and 20%, respectively, whereas in cv. malwa shakti, it was 48%, 35%, 30% and 25%, respectively (Table 2.5.10).

Table 2.5.10 Effect different compaction levels on root traits of wheat cv sujata and malwa Shakti

	Root main axis length (cm)		Number of nodes		Number of primary axis		Root angle	
	Sujata	Malwa shakti	Sujata	Malwa shakti	Sujata	Malwa shakti	Sujata	Malwa shakti
BD 1	18.00 ±0.50	21.47 ±0.95	35.33 ±4.16	36.67 ±3.06	35.00 ±5.29	37.00 ±4.36	60 (40-70)	50 (30-70)
BD 2	16.23 ±0.42	15.30 ±0.70	33.33 ±2.08	34.67 ±1.53	34.00 ±2.65	34.67 ±2.08	60 (40-70)	50 (40-70)
BD 3	12.80 ±1.00	12.67 ±1.10	26.33 ±2.89	28.33 ±2.31	28.00 ±2.59	29.67 ±4.04	50 (40-60)	40 (40-70)
BD 4	11.34 ±0.91	11.13 ±0.55	24.00 ±2.00	23.67 ±3.06	22.7 ±3.79	25.67±3 .21	50 (40-70)	40 (30-50)
<i>LSD-value</i>								
Cultivar	NS		NS		NS		-	-
BD	0.98		3.36		4.46		-	-
Cultivar X BD	1.38		4.75		6.31		-	-



2.5.12 Long term fertilizer and manure management practices on soil organic carbon and aggregate stability of central Indian vertisols

2.5.12.1 Effects of long-term fertilization and manuring on different size aggregate fractions

Soil aggregates are the secondary particles (structural units) formed through the combination of mineral particles with organic and/or inorganic binding agents). An aggregate consists of grouping of a number of primary particles into a secondary unit. Four aggregates size fractions namely (i) large macroaggregates (> 2 mm) (ii) small aggregates (2-0.250 mm) (iii) microaggregates (0.250-0.053 mm) (iv) small aggregates (< 0.053 mm) are important in agricultural management point of view. So, the analysis was carried out from a 43 years old longterm fertilizer experiment comprising of various nutrient management practices from Jabalpur. The results of the study are as under.

2.5.12.2 Large macro-aggregate distribution

Highest amount of large macro aggregates (11.09 %) was found in T₂ (100 % NPK) treatment and the lowest amount (5.08 %) in T₆ (100 % NP). However, in control (no nutrient with crop), it was 4.28%. There were no significant difference among the treatments T₂, T₃, T₄, T₅, and T₈.

2.5.12.3 Small macro-aggregate distribution

Application of 100 % NPK + FYM (T₈) was shown to have the highest small macroaggregates distribution (78.16 %) and the lowest in T₄ (100 % NPK + hand weeding) treatment as compared to control (71.21 %). There were no significant difference among different treatments (Table 2.5.11). Long-term application of NPK + FYM, however, substantially increased the proportion of the macro-aggregate fractions (>2 mm and 2–0.25 mm), as compared with soils that received only NPK.

2.5.12.4 Micro-aggregates distribution

Data presented in Table 2.5.11 revealed that highest micro-aggregates distribution (18.02 %) was found under control (T₁₀) followed by treatment (T₇) and lowest small macro-aggregates was under T₄ (100 % NPK + hand weeding). Statistically, there was no significant difference among T₁, T₄, T₆, T₇, T₉ and T₁₀ treatments.

2.5.12.5 Silt + clay distribution

Application of 50 % NPK (T₁) resulted in the highest while the lowest (2.52 %) silt and clay distribution was observed in T₆ (100 % NP) treatment. There were no significant differences among other treatments.

2.5.12.6 Mean weight diameter (MWD)

Mean weight diameter is the index of aggregate stability. It is important for determination of soil structure which is directly related to the productivity of a crop. Application of 100 % NPK + FYM increased MWD significantly (Fig. 2.5.16) by approximately 35.77, 21.88 and 14.81 %, as compared to control (T₁₀), NPK + Zn (T₃), and 100 % NPK (T₂).



Table 2.5.11 Effect of long term fertilization and manure on soil aggregate distribution

	Aggregate distribution (%)			
	Large macroaggregate (>2000 μm)	Small macroaggregate (2000 – 250 μm)	Microaggregate (250 – 53 μm)	Silt + Clay (< 53 μm)
T1	5.72 ± 2.5cde	74.24 ± 1.6a	16.01 ± 2.4abc	4.03 ± 1.2a
T2	11.09 ± 1.1a	73.70 ± 1.2a	12.01 ± 0.7bcd	3.20 ± 0.5a
T3	9.90 ± 1.5a	77.38 ± 1.8a	9.80 ± 0.9d	2.92 ± 0.5a
T4	8.90 ± 0.7abcd	71.83 ± 2.4a	16.24 ± 2.6abc	3.03 ± 0.4a
T5	9.68 ± 3.4ab	77.03 ± 3.9a	10.77 ± 0.9cd	2.52 ± 0.3a
T6	5.08 ± 1.3e	76.50 ± 6.9a	15.22 ± 4.9abcd	3.20 ± 1.1a
T7	6.00 ± 3.4bcde	72.82 ± 9.0a	18.02 ± 6.0a	3.15 ± 0.5a
T8	9.29 ± 1.9abc	78.16 ± 1.4a	9.67 ± 0.8d	2.88 ± 0.7a
T9	5.19 ± 2.8de	74.27 ± 3.0a	16.81 ± 4.4ab	3.73 ± 1.9a
T10	4.28 ± 0.9e	71.21 ± 3.1a	20.58 ± 3.7a	3.94 ± 1.4a
LSD _{P<0.05}	3.723	7.17	5.58	1.68

Similarly, it was found that aggregate stability increased with increase in SOC concentration and there was a close correlation between the SOC concentration and MWD, with a coefficient of determination of 0.48 (Fig. 2.5.17).

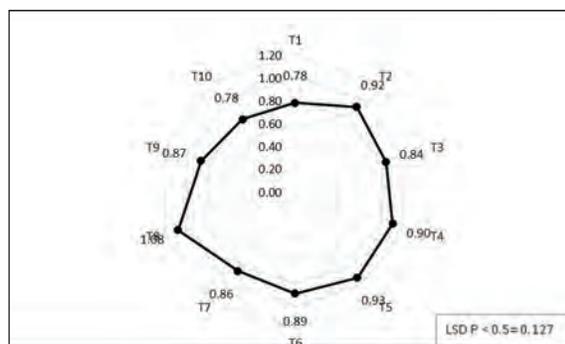


Fig. 2.5.16 Effect of long term fertilization and manure on mean weight diameter (MWD)

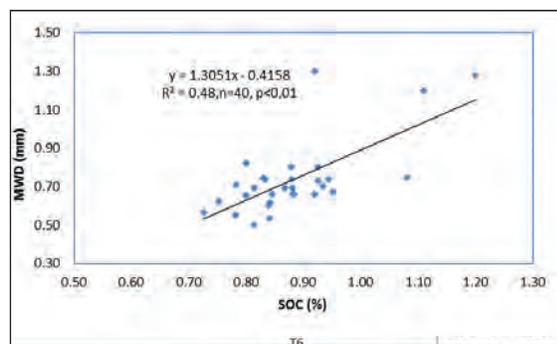


Fig. 2.5.17 The relationship between SOC concentration and mean weight diameter (MWD)

Theme -III: Microbial Diversity and Genomics

2.6 Microbial Diversity and Soil Genomics

2.6.1 Bacterial and archaeal diversity in the rhizosphere of bioenergy crop *Jatropha curcas*

Microbial diversity of bioenergy crop *Jatropha curcas* (*J. curcas*) is unclear and it is important for sustainable bioenergy production. The plant possesses complex microbial diversity comprising of both bacteria and archaea colonising different plant parts. Root samples were collected from three locations varying widely in the soil physico-chemical properties. Microbial diversity at rhizoplane estimated by

terminal restriction fragment length polymorphism (TRFLP) targeting 16S rRNA gene. There were 15 bacterial and 17 archaeal TRFs present in soil samples (Fig 2.6.1). Bacterial indicative TRFs represented Actinobacteria, Firmicutes, Acidobacteria, Verrucomicrobiaceae and Chlorflexi. In case of archaea, TRFs were affiliated to uncultured archaea of environmental samples. TRFs affiliating to crenarchaeota and euryarchaeota were also retrieved from the soil samples. Relative fluorescence of bacterial TRF160 was the lowest (0.94%) and was the highest for TRF51 and TRF 420. Relative fluorescence of Archaeal TRF 218, and TRF 282 was the lowest. Abundance of the TRF 278,

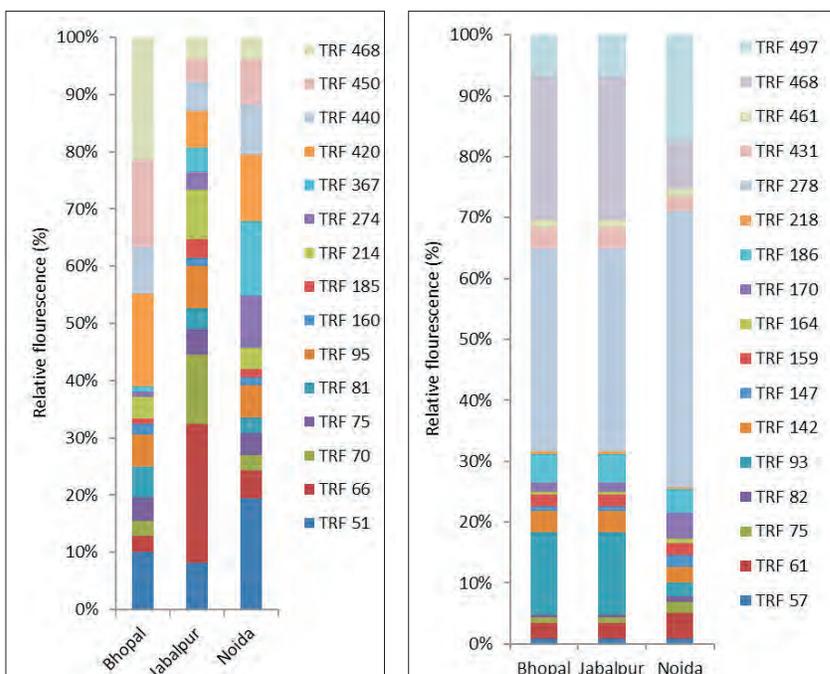


Fig 2.6.1. Relative fluorescence of bacterial (left) and archaeal (right) ribotypes in rhizosphere of *Jatropha curcas* collected from different locations

TRF 468 and TRF 93 were high in all the samples. Principal component analysis (PCA) of bacterial TRFs designated PC 1 with 46.83% of variation and PC2 with 31.07% variation. Similarly, the archaeal TRFs designated 90.94 % of variation by PC1 and 9.055 by PC2. For bacteria, the Simpson index varied from 0.53 to 0.88 and Shannon index from 1.462 to 3.139. In case of archaea, the Simpson index varied from 0.855 to 0.897 and Shannon index was in the range of 3.027 to 3.155. Study concluded that *J. curcas* rhizosphere constituted of diverse set of bacterial and archaeal species.

2.6.2 Endophytes of bioenergy crop *Jatropha curcas* and their plant growth promoting activities

Endophytic bacteria from *J. curcas* were isolated and characterized to reveal their identity and plant growth promoting activities. *Jatropha curcas* plant samples were collected from a site located at village Gunga, Bhopal district, Madhya Pradesh, India. Bacteria were isolated by enrichment techniques. Fifteen cultures were selected based on cultural characteristics. DNA was extracted from these isolates and 16S rRNA gene amplified and sequenced. The most predominant isolates were closely similar to *Bacillus* sp. Sequences were homologous to *Bacillus pumillus*, *Rhizobium*, *Paenibacillus* (Fig 2.6.2). Various plant growth promoting attributes were evaluated such as IAA, P solubilization, siderophore production, K solubilization, and ACC deaminase activity. Strains produced maximum of 15.44 µg IAA per ml. Maize seeds coated with these endophytes stimulated growth compared to un-inoculated control plants.

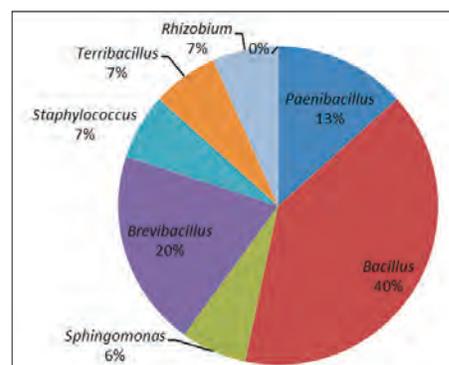


Fig 2.6.2. 16 S rRNA gene sequence of endophytic bacteria retrieved from *Jatropha curcas*



2.6.3 Genomic and cultural variability of phylloplane bacteria of bioenergy crop *Jatropha curcas*

The complex interaction between plant and phylloplane microorganisms is less understood in lieu of their pivotal role in plant's sustainability. Study conducted to elucidate the dominant phylloplane bacteria and their plant growth promoting activities. The plant *J. curcas* was taken as model plant because it possesses novel metabolic strategies to sustain under extreme environment. Secondly, this plant is the source of renewable energy like biodiesel. Heterotrophic bacteria were isolated from the phylloplane of *J. curcas*. The 16S rRNA gene sequences of these bacteria were closely similar to Alphaproteobacteria, Betaproteobacteria, Gammaproteobacteria, Firmicutes and Actinobacteria. Most of the isolates were motile and gram variable. Many novel species closely related to *Ralstonia*,

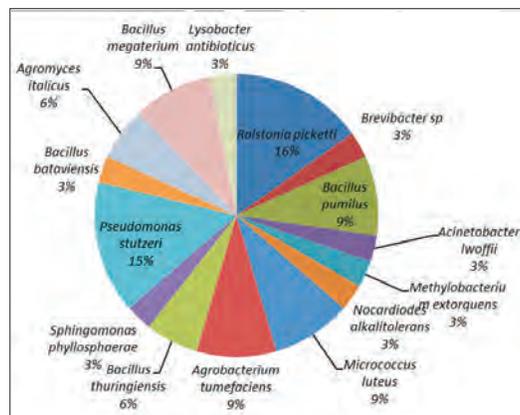


Fig 2.6.3. Bacterial 16S rRNA gene diversity of the phyllosphere of *J. curcas*

Methylobacter and *Actinomycetes* were found (Fig. 2.6.3). These phylloplane organisms preferably grew on alcohol than monosaccharides, and polysaccharides. PCA of the carbohydrate metabolism pattern highlighted that PC1 contributed 38.29% variation while PC2 contributed 17.69% only. The isolates exhibited ACC deaminase, phosphatase, K solubilisation and indole acetic acid (IAA) production activity. The phosphate solubilising ability (mg of PO_4 solubilized by 10^8 cells) of the isolates was in the range of 0.04 to 0.21. The IAA production potential (μg IAA produced by 10^8 cells in 48 hrs) varied from 0.41 to 9.29. The isolates significantly increased the shoot and root length of the maize seedlings. Linear regression model of the PGPR activities significantly correlated ($p < 0.01$) with growth parameters. Correspondence analysis categorized ACC deaminase and IAA production as the major factors contributing 41% and 13.8% variation to the maize growth.

2.6.4 Bacterial 16S rRNA gene diversity in phyllosphere and rhizosphere of bioenergy crop *J. curcas*

To understand the variation in above and below ground microbial diversity associated with plant, an experiment was carried out to define diversity of bacteria prevalent in phylloplane and rhizosphere of bioenergy crop *J. curcas*. Diversity of 16S rRNA gene was estimated by terminal restriction fragment length polymorphism (T-RFLP). Twenty two unique TRFs or ribotypes were observed from phylloplane and 17 TRFs were retrieved from rhizosphere soil (Fig 2.6.4). These TRFs were affiliated to Firmicutes, Actinobacteria, *Bacillus*, *Chloroflexi*, Acidobacteria, Verrucomicrobia, and Methylobacteria. Fluorescence intensity of TRFs were high in the phylloplane DNA samples than the rhizospheric soil. PCA confirmed that PC1 contributed 66.17% variation while PC2 only 33.82% variation. The TRF56, TRF65, TRF95, and TRF423 were the main variables in soil. Whereas, the TRF466, TRF475 and TRF483 were major TRFs in the phylloplane of *J. curcas*. Clustering analysis indicated deep branching of the TRFs those originated from the phylloplane. Shannon (H) and simpson (1-D) and evenness (H/S) were high in soil than phylloplane. Study concluded that both belowground and above ground part harbor selective bacterial groups those differ in their diversity and abundance. Further research is required to understand the complexity of the niche partition and plant microbial interaction.

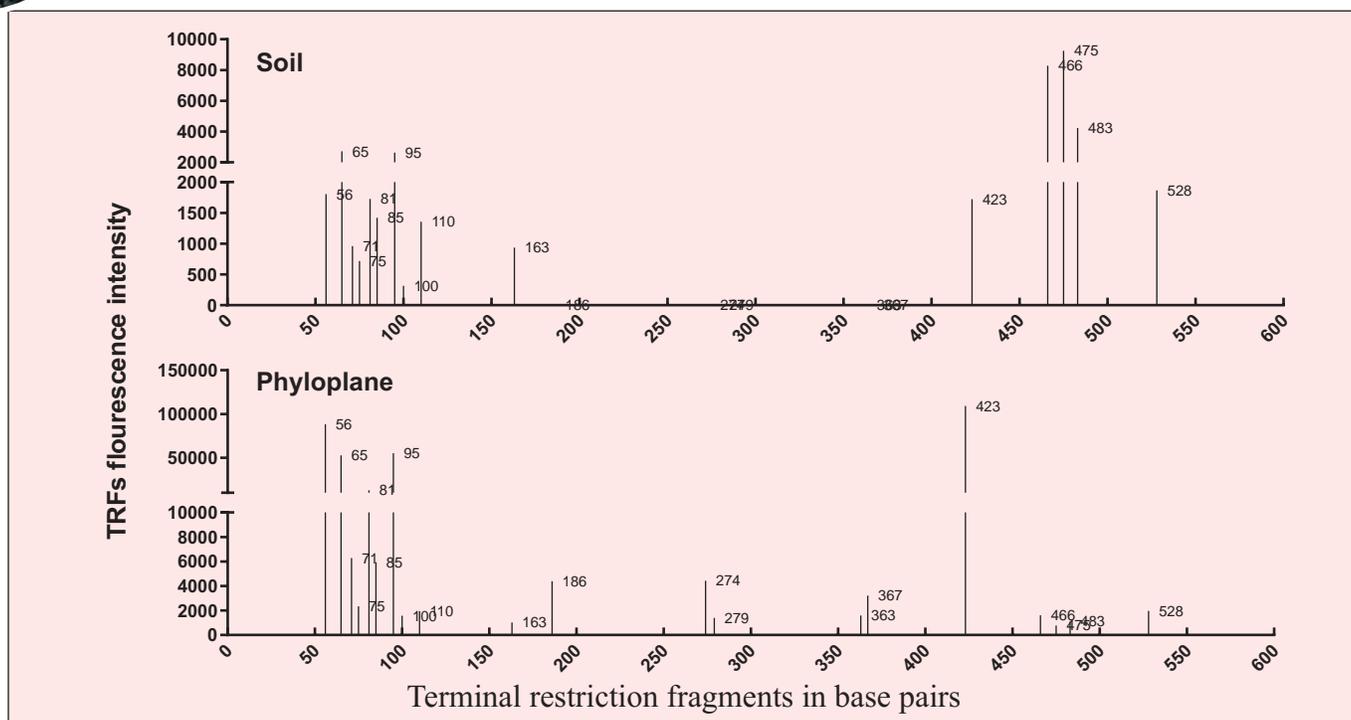


Fig 2.6.4. TRFLP of the bacterial 16S rRNA gene retrieved from soil and phyloplane of *J curcas*

2.6.5 Microbial iron redox metabolism holds key to regulate climate change

Mitigation of greenhouse gas (CH_4) has been prioritized in the recent global climate summit to regulate global climate change. A microbial process identified which holds key to mitigate CH_4 and can be explored to control global change. Experiments were carried out defining linkage between iron redox cycling (IRC) and CH_4 oxidation in two tropical soils (alluvial and vertisol). Soil samples were induced to undergo microbial Fe reduction and aerobic oxidation consecutively for three cycles simulating natural wetting-drying soil cycle. After each IRC, soil subsamples were explored to determine CH_4

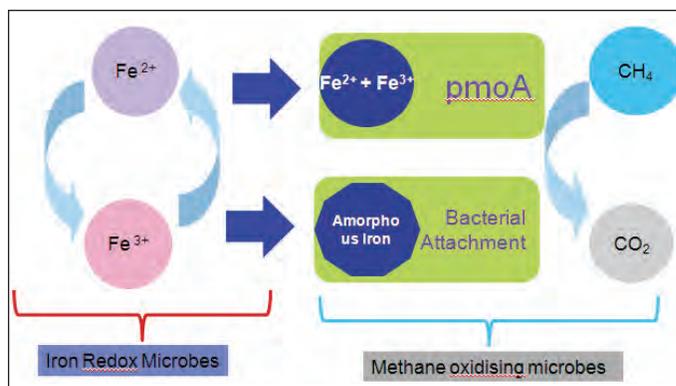


Fig 2.6.5. Iron redox coupled CH_4 consumption in flooded soil ecosystem

oxidation rate k , mineralogical changes and methanotroph abundance. Potential iron reduction rate ($\mu\text{M Fe}^{2+}$ produced g^{-1} soil d^{-1}) varied from 1.26 to 2.16 in vertisol and 1.95 to 3.05 in alluvial soil. Potential iron oxidation ($\mu\text{M Fe}^{2+}$ oxidized g^{-1} soil d^{-1}) varied from 2.33 to 5.70 in vertisol and 2.43 to 9.58 in alluvial soil. IRC stimulated CH_4 oxidation rate k . High affinity CH_4 oxidation rate increased from 0.030 to 0.186. Similarly, low affinity CH_4 oxidation rate increased from 0.047 to 0.472 in vertisol. Similar effect of iron redox cycle on k was observed in alluvial soil. X ray diffraction revealed that diffraction intensity of magnetite and goethite decreased over iron redox cycle. Real time PCR quantification of methanotrophs



(*pmoA* gene) confirmed that iron redox cycle stimulated methanotrophs abundance. A conceptual microbial process developed to exhibit how Fe redox cycle is coupled with CH₄ oxidation in soil. Based on the data it was hypothesized that decreased crystalline nature of Fe minerals promoted CH₄ oxidation by (1) activating *pMOA* gene abundance and (2) attachment of methanotrophs to less crystalline Fe minerals (Fig. 2.6.5). This provided exclusive information on the prospect of exploring Fe bacteria to mitigate greenhouse gas emission from the agricultural fields.

2.6.6 Developing technique for acceleration of decomposition process using thermophilic organisms

Genomic DNA of isolated Bacteria and Actinomycetes were extracted, 16s rRNA gene was amplified using eubacterial primer followed by sequencing of the amplified 16s rRNA gene. Taxonomic identity was ascertained by comparing the sequence from NCBI database. Most of the bacteria showed similarity with *Bacillus* sp. The sequence has been submitted to NCBI Gene bank, USA. Identification of Fungal cultures has been done from Indian Type Culture Collection (ITCC), IARI, New Delhi. The consortium of these cultures has been made and used for accelerated decomposition of biodegradable wastes.

2.6.7 Microbial solubilization of phosphorus from nano rock phosphate

To find out the extent of benefit of P solubilization due to the interaction of microbes and nano-size particles, phosphate solubilization study in laboratory was carried out. Initial qualitative estimation of the P solubilizing activity of the fungal isolate (*Aspergillus terreus* and *A. flavus*) was carried out on Pikovskaya agar with bromophenol blue dye Ca₃PO₄ in Pikovskaya agar medium was replaced with 0.1% and 0.5% nano rock phosphate. The petri plates were incubated at 30 °C. Plates showed halo and zone of decolorization around the fungal colonies due to solubilization of P by production of organic acid. (Plate 2.6.1 & Plate 2.6.2).

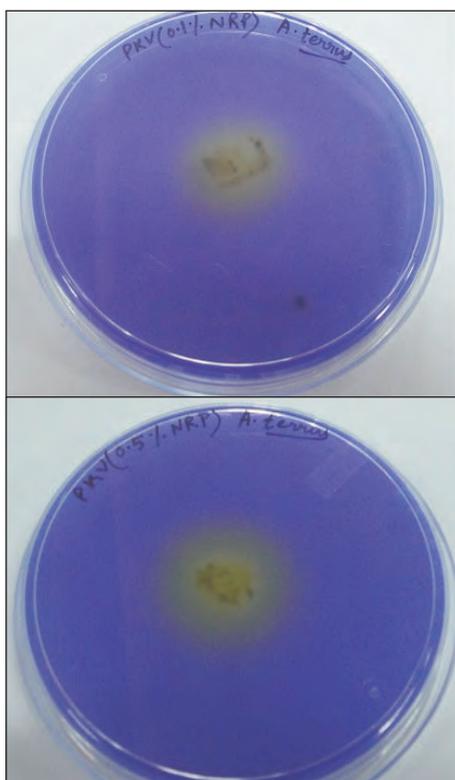


Plate 2.6.1. Growth and zone of phosphate solubilization by *Aspergillus terreus* after 48 h of incubation on 0.1% and 0.5% nano rock phosphate

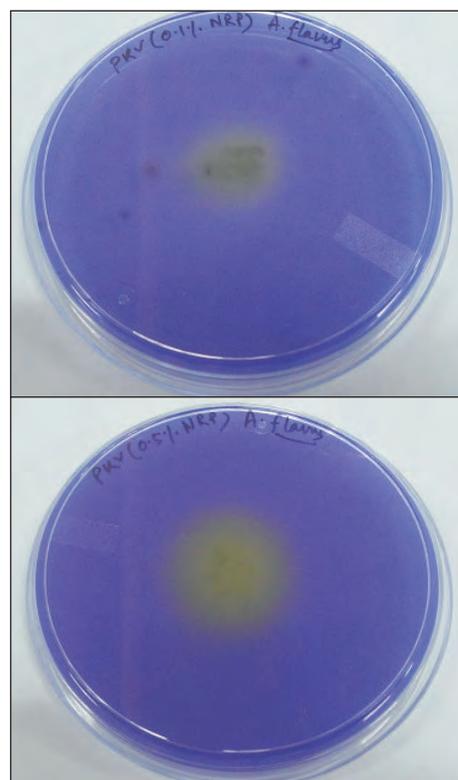


Plate 2.6.2. Growth and zone of phosphate solubilization by *Aspergillus flavus* after 48 h of incubation on 0.1% and 0.5% nano rock phosphate.



2.6.8 Utilization of amorphous nano carbon by soil bacteria

A study has been initiated to find out the nano carbon (amorphous) by soil heterotrophs. Rhizospheric soil sample of chickpea was collected from an organic farming field. Serially diluted soil sample was pour plated on modified nutrient agar medium from 10^{-6} , 10^{-7} and 10^{-8} dilution to see whether the soil heterotrophic bacteria can utilize the amorphous nanocarbon (C nano powder, <50 nm, 99%; Sigma-Aldrich) as their carbon and energy sources. Composition of modified Nutrient Agar is as follows.

1. Nutrient Agar: (Agar, peptone, NaCl, beef extract, yeast extract)
2. Modified Nutrient Agar I: (Agar, peptone, NaCl, beef extract, C nano powder)
3. Modified Nutrient Agar II: (Agar, peptone, NaCl, yeast extract, C nano powder)
4. Modified Nutrient Agar III (Agar, peptone, NaCl, C nano powder)

The plates in triplicate for each dilution were incubated at 28 °C for 48 hrs. After 48 hrs colonies were picked from different plates and streaked on modified nutrient agar amended with C nano powder as carbon and energy source (Agar, peptone, NaCl, C nano powder). The bacterial colonies which showed vigorous growth within 24 hrs are displayed below (Plate 2.6.3).

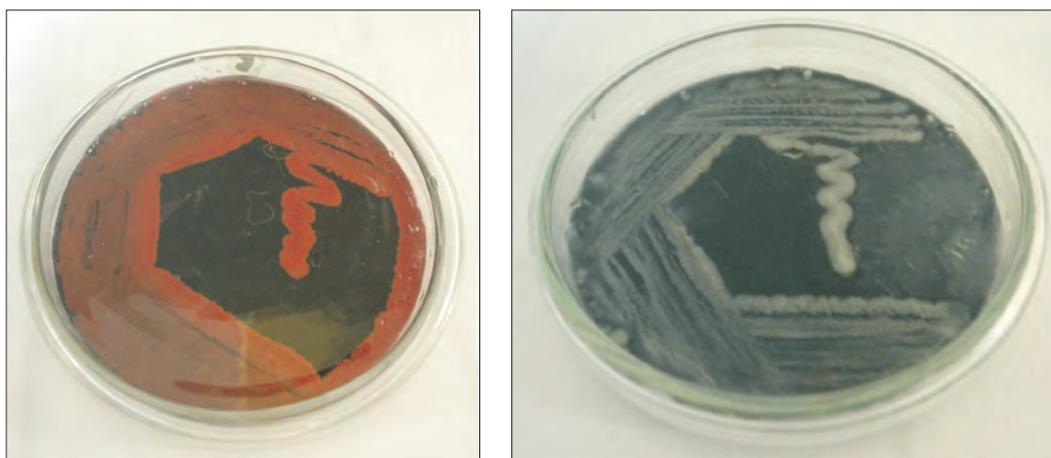


Plate 2.6.3 Growth of selected isolates on C nano supplemented media after 24 hrs of incubation

AINP on SBB

2.6.9 Microbial diversity

Several hundred rhizobial isolates of legumes in arid regions of Haryana and hyper-arid zone of Rajasthan were isolated and characterized for nodulation, plant growth promoting activity, drought and temperature tolerance. Promising strains were identified for cluster bean, pigeonpea and mung bean in field screenings. 16S rRNA diversity studies of rhizobia of different legumes is in progress. Besides rhizobia, *Enterobacter*, *Pantoea* and *Ochrobactrum* were found to be nodulating groundnut in Gujarat. Promising strains of *Mesorhizobium* for chickpea and *Rhizobium leguminosarum* for lentil and pea were selected in Tal lands of Bihar. Co-inoculation of *R. leguminosarum* in combination with *Bacillus* gave maximum yield of lentil. Proteomics of rhizobial isolates of legume pigeonpea from acid soils of Jharkhand and soybean and chickpea rhizobia from Vertisols of Madhya Pradesh by 2-D electrophoresis and MALDI-TOF was done to characterize the differences in expression of genes involved in a wide range of functions which are implicated





in adaptation to varied soil environments and regimes. Root endophytes of *Desariya* rice and bacteria of root/stem nodule of *Aeschynomene* in rice-*Aeschynomene* ecosystem in Bihar was characterized through 16S rDNA sequencing. Sequences similar to *Bradyrhizobium* detected in both niches. Rice roots had >2000 bacterial species belonging to 29 phyla. Proteobacteria were dominant (44%) followed by Firmicutes (18%) and Actinobacteria (17%). Both methanogens and methylotrophs found in abundance and may form consortia. *Frankia* were isolated from *Alnus* spp. and *Casuarina* spp. on different media in H.P. Maximum growth was obtained in DPM (Defined Propionate Minimal) Medium. Potassium solubilizing bacteria were isolated from crop rhizosphere in Assam soils and identified as *Bacillus cereus* and *Klebsiella* sp. Several *Arthrobacter* strains with PGPR activity were isolated from Vertisols of M.P. Ten promising strains were short-listed for molecular analysis.

2.6.10 Actinobacteria in Vertisols

Arthrobacter sp. is as major representatives of the cultural fraction of actinobacteria. A total of 200 *Arthrobacter* isolates were screened for growth promotion of maize seedlings and PGPR characteristics like indole acetic acid production, siderophore production and phosphate solubilization. Thirteen effective strains were short-listed for field testing for inoculation effect on growth of soybean, maize and rice in kharif and chickpea and wheat in rabi seasons. During kharif 2015, significant improvement in grain and straw yields, total uptake of NPK by rice crop was obtained with isolates AR₆, AR₈ and AR₁₀, AR₅. Average increase in grain yield was 16%. *Arthrobacter* isolates AR₁₀, AR₃ and AR₁₂ best improved maize yields (18%) and NPK uptake. In soybean, AR₂ performed the best followed by AR₄ and AR₇. Nodule number, nodule mass and grain yield were 6, 17 and 12%, higher over uninoculated soybean. During rabi, the average increase of grain yield was 21% and 24% higher in chickpea and wheat.

2.6.11 Differential role of ammonia oxidizing bacteria and archaea in redox metabolism

Most of the microbial species inhabiting soils are interdependent. For example, nitrifying bacteria often are co-existing with denitrifiers and sulfate reducers in biofilms in soil ecosystems. Similarly, ammonia oxidizing bacteria (AOB) have been found to coexist even with methanogenic microbes in flooded soil ecosystem. However, it is unclear if ammonia oxidizing archaea (AOA) also have similar co-existence and function in flooded soil ecosystem. Experiments were conducted to entail the differential role of AOB and AOA on terminal electron accepting processes (TEAPs) in flooded soil ecosystem. Under flooded condition soil undergoes microbially mediated anaerobic respiratory redox processes with alternative electron acceptors being sequentially reduced in the order of NO₃⁻, Fe³⁺, SO₄²⁻ and CO₂. Terminal electron accepting process in both the rice (Fig 2.6.6) and chickpea (data not shown) soils followed this classical sequential reduction pathway. Sulfadiazine was added to soil to differentiate the role of AOB and AOA in redox metabolism. Potential NO₃ reduction rate (mM NO₃ reduced g⁻¹ soil d⁻¹) was 4.10 in chickpea and 1.80 in rice soil. Addition of sulfadiazine inhibited PNR significantly at P < 0.05. Potential iron reduction rate (PIR) estimated as mM Fe³⁺ reduced g⁻¹ soil d⁻¹ was more in rice soil than chickpea. Potential sulfate reduction (mM SO₄²⁻ reduced g⁻¹ soil d⁻¹) ranged from 0.306 in chickpea and 0.029 in rice soil treated with sulfadiazine. Copy number of bacterial 16S rRNA gene was estimated from soil samples before, after each TEAPs (Table 2.6.1). Rhizospheric soil of chickpea had higher bacterial population than rice soil irrespective of treatments. Real time PCR of bacterial gene also indicated that sulfadiazine decreased abundance of total bacterial number. It

was also observed that bacterial population decreased over reductive phases. It could be due to niche specificity of bacteria during the later stage of soil reduction. Our experiment indicated that if AOB are inhibited then AOA would initiate the nitrification and modulate TEAPs in flooded soil ecosystem.

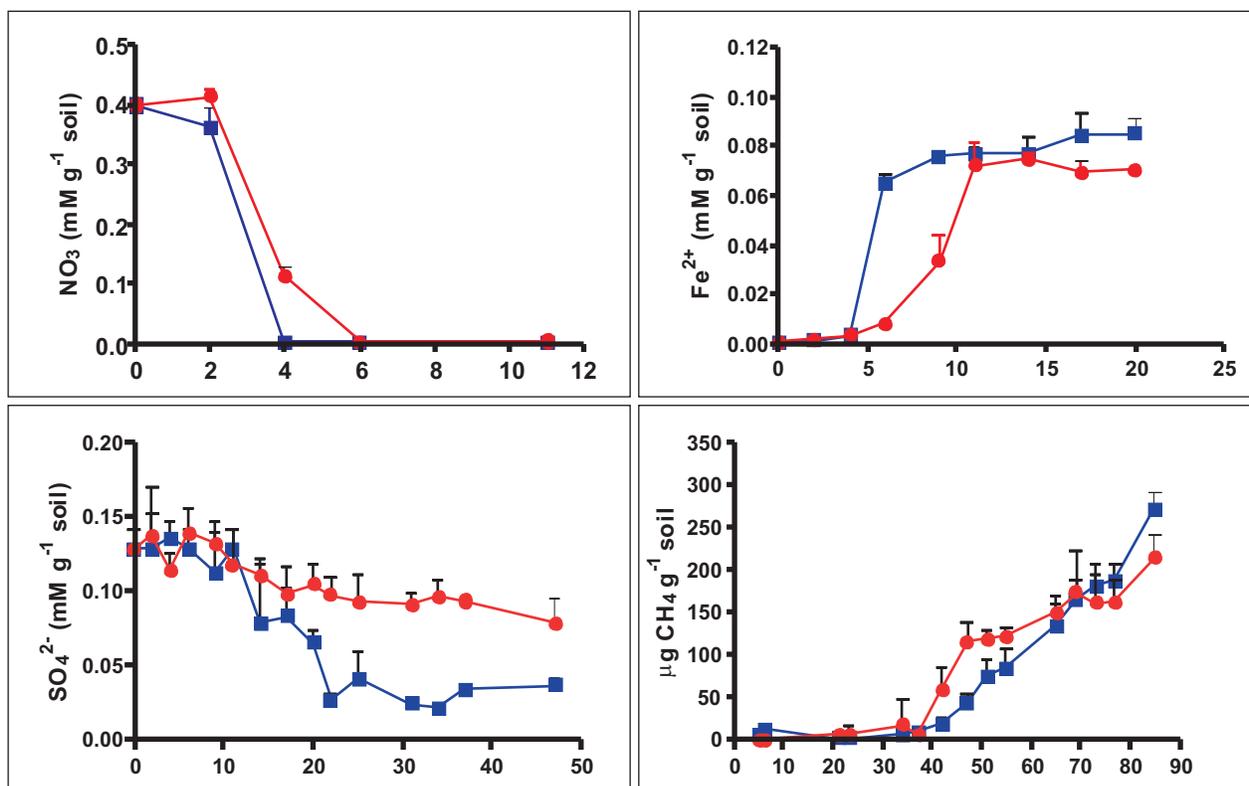


Fig 2.6.6. Redox metabolism of rice rhizospheric soils incubated under flooded condition with CH_3COO^- as electron donor and methanogenesis. Treatments represent soils with (sphere) or without sulfadiazine. X axis depicts incubation period in days and Y axis concentration of analytes.

Table 2.6.1. Real time PCR quantification of bacteria in soil samples during different TEAPs.

Crop	Sulfadiazine	16S rRNA gene copies $\times 10^8 \text{ g}^{-1} \text{ soil}$				
		Un-incubated control	NO_3^- reduction	Fe^{3+} reduction	SO_4^{2-} reduction	CH_4 production
Rice	-	6.39 \pm 0.67b	5.26 \pm 0.46c	3.05 \pm 0.35b	1.83 \pm 0.22b	1.21 \pm 0.13b
	+		4.29 \pm 0.18d	2.67 \pm 0.42d	1.15 \pm 0.11c	1.06 \pm 0.15c
Chickpea	-	8.62 \pm 0.52a	7.82 \pm 0.52a	5.26 \pm 0.36a	3.98 \pm 0.22a	3.28 \pm 0.18a
	+		5.72 \pm 0.41b	4.23 \pm 0.19c	1.66 \pm 0.13b	1.28 \pm 0.22b
Tukey's HSD (α 0.05, error df 11)		1.08	0.83	0.53	0.45	0.16

2.6.12 Soil genomics

The relative proportion of copiotrophic bacteria like Alphaproteobacteria, Betaproteobacteria, Deltaproteobacteria and Actinobacteria were higher in organic soil, whereas the proportion of oligotrophic bacteria like Gammaproteobacteria were more in chemically fertilized soils. The key species like *Arthrobacter*, *Rhizobium*, *Pseudomonas* and *Bacillus* were more in organic farm soils in Vertisols of Dharwad. The genes involved in transcription as well as respiration, cell



division, osmo-protection were more in organic farm soil showing better soil health. Rhizosphere soil samples from healthy arecanut palms in Kerala and from palms exhibiting symptoms of yellow leaf disease are under analysis by conventional cultural method and metagenomics for soil microbial communities.

2.6.13 Biofertilizer formulations

Seventeen actinomycetes isolates (liquid formulation) of IISS, Bhopal were evaluated on wheat in Vertisol and average of 16% higher yield was obtained. Mixed consortium of best actinomycetes isolates (A10 and A17) along with consortia of Rhizobia and PGPR (*Rhizobium* R40 and R56; PGPR P3, P10 and P25) gave 77% increased chickpea grain yield in Vertisol. Mixed consortium of best actinomycetes isolates (A6 and A10) along with CRP (*Rhizobium*: R 33 and R 34; PGPR: P3, P10 and P25) gave 22% increased soybean grain yield in Vertisol. Zinc solubilizing bacteria (*Pseudomonas striata*, *Bacillus megaterium* and *Trichoderma viridae*) tested on zinc deficient Vertisol in Maharashtra. *P. striata* increased soybean yield by 11%. Bt cotton yield increased by 14 % with inoculation of *Trichoderma viridae* and 12% with *P. striata* as compared to control.

Two rhizobial isolates showing anti-fungal activity, P solubilization and IAA production, A13 and CR24 gave best performance on chickpea in Inceptisols of Delhi. To make soils naturally suppressive to soil-borne fungal pathogens like *Sclerotium rolfsii* causing stem rot in groundnut, application of DAPG-producing fluorescent pseudomonads to susceptible cultivar GG20 suppressed the seedling mortality of groundnut from 73% in pathogen control to 21-38% with inoculation which increased the yield from 13-22% in Gujarat. Inoculation of DAPG-producing fluorescent pseudomonads - *P. putida* DAPG1, DAPG4, DAPG6, and *P. fluorescens* FP 98 enhanced the pod yield by 15% with cultivar TG37A during summer.

Novel PGPR *Paenibacillus* and *Microbacterium testaceum* were evaluated on ginger and pepper in Kerala and found promising. Three field trials on application of consortium of Biofertilizers (PGPR Mix I) under progress in Attappady on Banana and Chilli and on arecanut nursery at Puthoor.

Multi-functional PGPR strains from wheat rhizosphere were characterized; two promising strains B1 and B2 improved wheat yield in field by 5 and 14% in Himachal Pradesh. PGPR strains from seabuck thorn rhizosphere in Lahaul and Spiti soils were characterized. Of several plant growth promoting *Bacillus* strains of different crop rhizosphere, isolate S21 identified as most potent yield enhancer for tomato in the field and improving available NPK by 15, 35 and 8%, respectively.

In long term INM in acid Alfisols of Odisha on application of biofertilizers to millets and vegetables, integration of liming (paper mill sludge) over FYM or Vermicompost improved the yield response to 12-45% (5-20% response with FYM or VC alone). Over a 4 year period, organic package (enriched compost EC 10 t ha⁻¹) gave highest fresh yield of hot chilli (2.2 t ha⁻¹) as compared to normal compost @10 t ha⁻¹ and biofertilizers application (1.6 t ha⁻¹) in Assam. Over a 3 year period INM- 50% NP and 100% K with biofertilizers (*Azospirillum*, *Azotobacter* and PSB) gave significantly higher fibre yield (3.0 t ha⁻¹) of jute as compared to control (2.5 t ha⁻¹). The treatment received full doses of NPK (30:25:25 kg ha⁻¹) gave comparable fibre yield (3.3 t ha⁻¹) with INM.

Post-sowing application of liquid biofertilizers within 15 days in black gram compensated for yield in case application of solid carrier based biofertilizers is missed at the time of sowing.



Theme - IV: Soil Pollution, Remediation and Environmental Pollution

2.7 Greenhouse Gas Emission and Mitigation

2.7.1 Relationship between soil N₂O emission and wheat equivalent yield, total N application and soil available N

In conservation tillage manure interactive study in soybean-wheat cropping system the wheat equivalent yield ranged from 6.68 to 9.81 t ha⁻¹. Integrated nitrogen application through FYM plus inorganic fertilizer significantly increased wheat equivalent yield. The annual N₂O emission (y) was correlated with grain yield (x) by the relationship $y = 0.386x - 0.528$ ($R^2 = 0.688$, $p < 0.001$) (Fig. 2.7.1a). Thus, grain yield can be a sensitive predictor for N₂O emissions from soil under soybean and wheat crops when different management practices are considered. Grain yield significantly explained 69 % of the variation in N₂O emission. Further annual N₂O emissions (y) increased linearly with increased application of fertilizer and organic N (x) to soil according to the relationship $y = 0.069x - 6.919$ ($R^2 = 0.61$, $p < 0.001$) (Fig. 2.7.1b). Increase in availability of soil N (x) also linearly increased annual N₂O emission (y); $y = 0.019x - 2.387$ ($R^2 = 0.59$, $p < 0.001$) (Fig. 2.7.1c). This indicates that soil available N and N fertilizer application could explain 59 to 61% variation in annual N₂O emissions in soybean-wheat cropping cycle in Vertisols of central India. However, grain yield explains greater variation in N₂O emission.

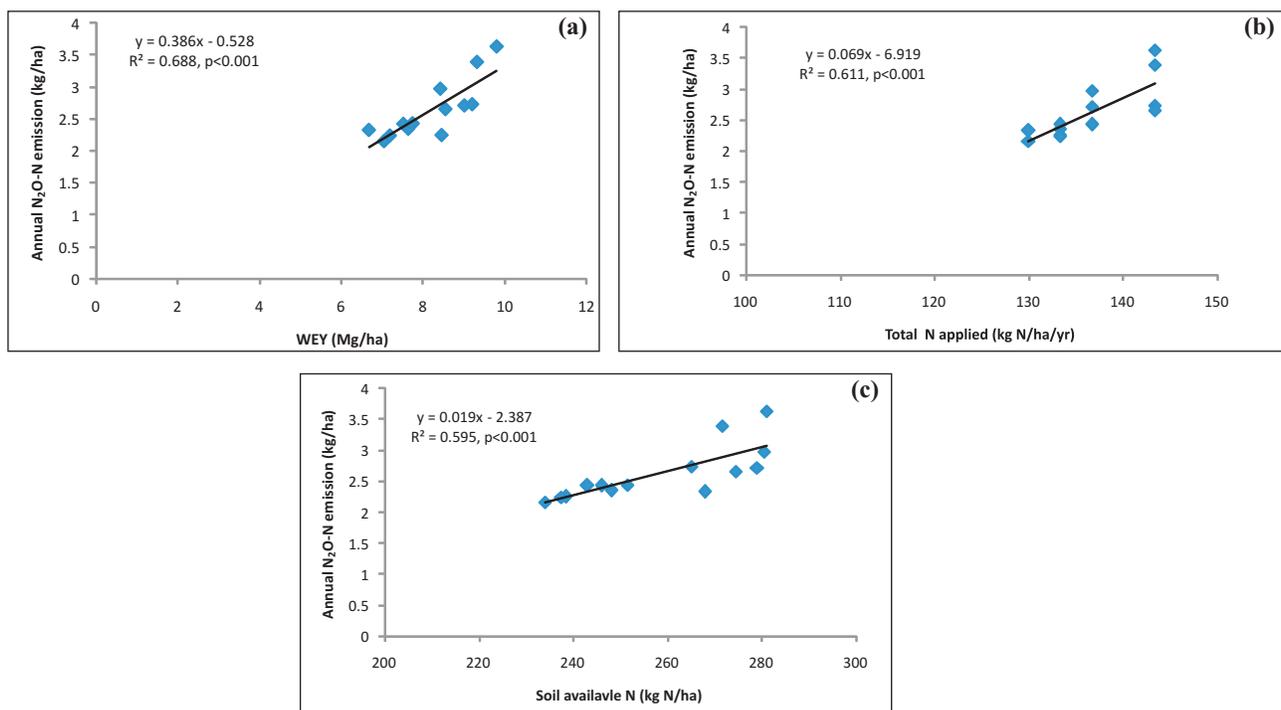


Fig.2.7.1 Correlation of annual N₂O emission to wheat equivalent yield (a), total N applied (b) and soil available N (c)

2.7.2 Carbon sequestration through use of sewage water for crop production

Farmers in the peri-urban areas are using sewage water for crop production especially vegetable production. It contains huge amount of organic carbon, plant nutrients and also trace amount of heavy metals. Long-term





use of untreated sewage water to crops results in significant increase in SOC than soils irrigated with groundwater. Sewage water is a valuable source for plant nutrients and organic matter which help in maintaining fertility and productivity of soils. Geo-referenced soil sample were collected from different sewage water irrigated farmers fields along with drainage channel at a distance of 1-2 km. Long-term untreated sewage water irrigation has been found to sequester carbon in the upper 60 cm of soil profile in farmers' fields of peri-urban areas around Bhopal city (Fig. 2.7.2). Addition of large amount of organic matter from sewage water irrigation led to anaerobic conditions which reduced organic carbon mineralization and build-up of SOC. Hence, long term sewage water irrigation could be a good means of carbon sequestration in Vertisol and referred as a soil quality sustaining practice. However, cautions may be taken to estimate heavy metal loading of the sewage water.

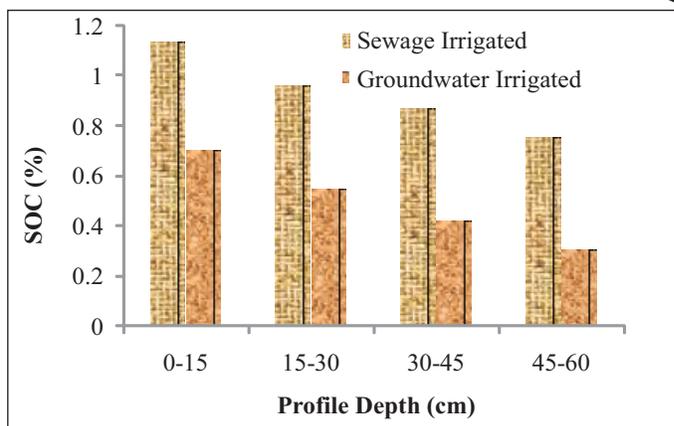


Fig. 2.7.2 Carbon sequestration through use of sewage water

2.7.3 Interactive effect of biochar and organic manures (Vermicompost, poultry manure, farmyard manure) on N₂O emission from Vertisol

Biochar (BC) use in agriculture has the potential to mitigate climate change. However, substantial uncertainties exist on the methods of its use to harness maximum potential abating GHG emission. A laboratory study, was carried out to define how BC and its size plays significant role in mitigating N₂O

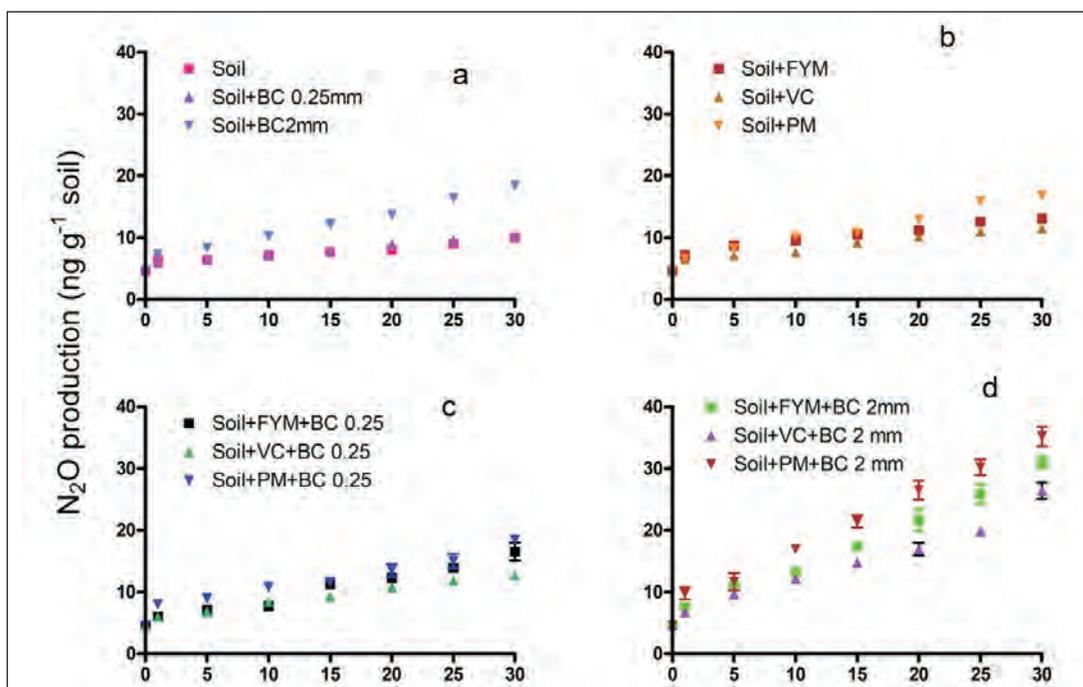


Fig 2.7.3 Effect of BC and organic manure on N₂O production in a tropical vertisol. Panel a : BC of different size, panel b : different organic manures, panel c : organic manures +BC <0.25 mm, panel d : organic manure + BC 0.25-2.00 mm.



production from soil (Vertisol) amended with different organic manure. Apart from the control treatment, BC of two different sizes (<0.25 mm or 0.25-2.00 mm) was mixed with vermicompost (VC), poultry manure (PM), or FYM. BC and organic manure were added to soil at 10 % w/w and 80 kg N ha⁻¹ respectively. BC and organic manures increased N₂O production in soil (Fig 2.7.3). The N₂O production potential of soil (µg N₂O produced g⁻¹ soil d⁻¹) was greater with the larger size BC (0.25 – 2.00 mm). Of the three organic amendments, PM produced highest N₂O (0.380) followed by FYM (0.240) and VC (0.210). Heterotrophic and ammonia oxidizing bacterial population were low in control soil and highest in soil+PM+BC 0.25-2mm. The study highlighted that smaller BC (<0.25mm) could be an effective strategy to mitigate atmospheric N₂O production in Vertisols amended with organic manures.

2.7.4 Sulphur metabolizing microbes to minimize odorous gaseous emission from poultry manure

Most often the odour from poultry manure is a result of the uncontrolled anaerobic decomposition of organic compounds and release of gaseous molecules such as H₂S. It is the biggest challenge to minimize odour problem of poultry manure for its extensive use in agriculture. An experiment was initiated with an aim to develop microbial technology that can oxidize elemental S to SO₄. In this context S oxidizing bacteria were isolated through enrichment technique. Poultry manure was collected from a poultry farm located near parwalia village, Bhopal. After 3 repeated enrichments six potential sulphur oxidizing bacteria were isolated. DNA from these isolates were extracted and purified for sequencing. S oxidation potential of the isolates was estimated (Fig 2.7.4). The S oxidation potential of the isolates determined from the amount of SO₄²⁻ produced over oxidation of elemental S. The isolates 3M and 4S+M were found most promising in terms of time and S oxidation potential.

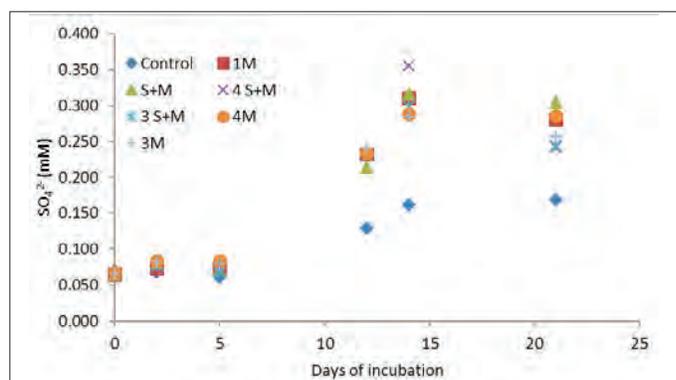


Fig. 2.7.4 Sulphur oxidation potential of bacterial species isolated from poultry manure.

2.7.5 Biodegradation of pesticides under changing climate and metagenomic profiling of functional microbes

To identify the pesticide degrading bacteria, soil was treated with pesticide (Chloropyrifos, Imidacloprid) and incubated at elevated CO₂ and temperature. After incubation, bacteria were isolated from soil samples. Genomic DNA from the isolate were expressed and 16S rRNA gene was amplified. Relative abundance of different bacterial species is depicted Fig 2.7.5. Bacterial community was higher in chloropyrifos than imidacloprid. Sequences obtained were homologous to Microbacteria, *Bacillus*, *Arthrobacter sp* in case of chloropyrifos. In case of imidacloprid DNA sequence were homologous to *Bacillus megaterium* and *Microcococcus sp*.

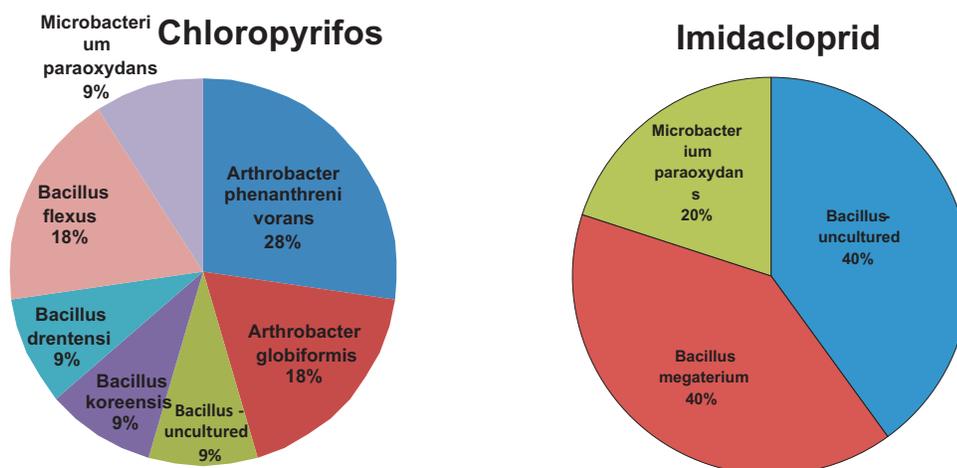


Fig. 2.7.5 16S rRNA gene diversity of bacteria in vertisol treated with pesticide ($10\mu\text{g g}^{-1}$) under elevated CO_2 (800 ppm) and temperature (45°C)

2.8. Soil Pollution and Remediation

2.8.1 Preparation of standard reference soil material for heavy metals analysis

In the process of preparation of standard reference soil material for heavy metals analysis, soil sample of about 250 kg were collected from the farm of the Indian Institute Soil Science, Bhopal (Location: N $23^\circ 18' 33.6''$ E $77^\circ 24' 27.2''$; area 1m^2 and 0-20 cm depth). The collected soil samples were air dried processed and passed through 2 mm sieve. Thus the obtained sample of about 160 kg was mixed by hand and split by coning and quartering, bulking opposite quarters to form the half samples, and setting one half samples aside, was done till about 40 kg of soil was obtained. Then it was ground using wooden pestle and mortar and manually homogenized for 72 hours using plastic rolling drum. After homogenization bottling was done as 10 samples were taken from the centre of the drum immediately upon stopping the rotation of the mixing drum to prevent segregation of fine particles, and were placed into 10 pre-cleaned brown glass bottles, so each contained a minimum of 100 g of soil. The drum was again rotated for a further 10 minutes and a further 10 samples were sub-sampled in the same way into bottles. The sub-sampling and bottling operation was continued until 250 bottles of the soil were obtained. About 25 bottles were randomly selected over the whole bottling procedure for homogeneity and stability testing. The moisture content of final soil sample was 1.07% (w/w), has clayey texture with 42.37% clay content, 0.46% SOC, pH 7.98 and CaCO_3 5.76%. The average total content (mg/kg) of Cu, Cd, Pb, Cr, Ni and Zn in the soil was 53.46, 0.12, 20.68, 74.91, 60.89 and 61.02, respectively. From the homogeneity test it was found that heavy metals like Cu, Pb, Cr, Ni, Zn had less than 10% co-efficient of variation (CV) and Cd had 27.45% CV.

2.8.2 Baseline concentrations of heavy metals in Sehore and Vidisha districts

Defining and understanding the current abundance and spatial distribution of metals in soils are essential and reliable information on this aspect are needed for proper legislation. To estimate the baseline concentrations and spatial distribution of heavy metals (HMs) in agricultural soils of Sehore and Vidisha districts, 100 surface

soil samples (0-20 cm) were randomly collected across these two districts and their physico-chemical properties and total HM contents were analyzed. Most of the soils in the region had neutral to alkaline pH (6.58-8.60), non saline (EC 0.11-1.3 d Sm⁻¹), medium organic carbon (0.6%), CaCO₃ 0.2-11.5% and clay >40%. The baseline concentrations of HMs (mg kg⁻¹) were Cu, 178.1; Cd, 0.7, Pb, 24.4, Cr, 116.9, Ni 81.8 and Zn, 85.2, respectively.

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

An experiment was conducted in the screen house to assess cotton crop for the remediation of soils contaminated with heavy metals (Cd, Pb and Cr). Cotton (Bt) (RCH-2) was exposed to different levels of Cd (0, 25, 50, 100 & 200 mg kg⁻¹ soil), Pb (0, 25, 500, 750 and 1000 mg kg⁻¹ soil) and Cr (0, 12.5, 25 & 50 mg kg⁻¹ soil). Data on various physiological (germination/emergence, total dry matter, root length and root dry weight, photosynthesis rate, yield components and yield) and biochemical (phenols, total soluble protein, proline, ascorbic acid, total free amino acids and nitrate reductase activity) were recorded. The study revealed that, all the three heavy metals studied did not affect the seedling emergence. No mortality was found even at the highest level of concentration except reduction in the growth. The application of heavy metals resulted in reduction of dehydrogenase activity in the soil and decreased the nitrate reductase activity of the leaves, but increased the contents of proline, ascorbate, total free amino acids and electrolyte leakage. The data on CFU count of heterotrophs (Plate 2.7.1) and actinomycetes revealed that, among the different heavy metals Pb inhibited heterotrophs significantly than other heavy metals. On the other hand, the count of actinomycetes, the stress indicator microbes were the highest in Cd, followed by Pb and Cr.

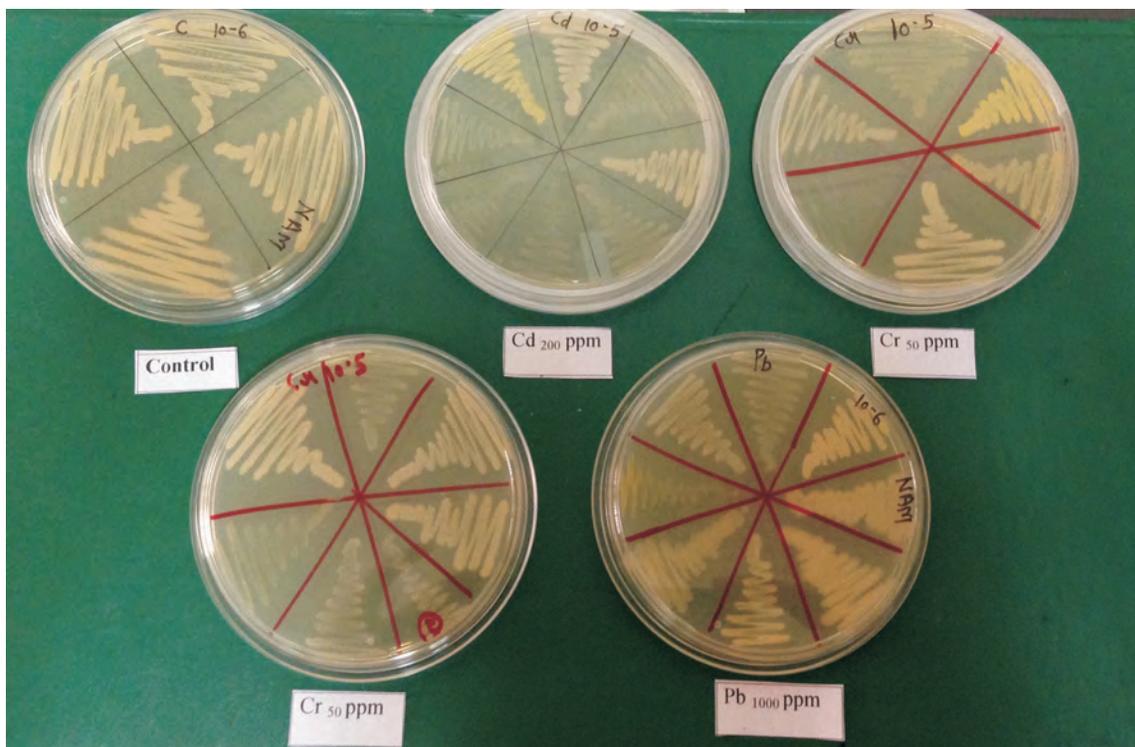


Plate 2.7.1 Screening of potential microbes from rhizosphere of cotton plant treated with heavy metals (Pb, Cd, Cr)



3. Transfer of technology:

A. Main Institute

3.1 Frontline Demonstration

Evaluation-cum-demonstration of IISS technologies under farmers' field conditions

Performance assessment of some of the innovative technologies developed by the ICAR-Indian Institute of Soil Science had been conducted in nine farmers' fields of Megra Kalan village located in the Berasia Tehsil (Bhopal) for the third crop season. Four technologies viz., Integrated Plant Nutrient Supply system (IPNS), phospho-sulpho-nitro (PSN) compost, soil test based fertilizer recommendation for targeted crop yields (STCR), and biofertilizers (liquid and powder formulations) were selected and evaluated as three technology packages i.e. IPNS-I, IPNS-II and STCR (Fig. 3.1.1). IPNS-I recommends the use of 5t farmyard manure and 50% recommended dose of NPKS with seed treatment of biofertilizers per ha for the *khari*f soybean and 75% NPKS and seed treatment of biofertilizers per ha for the *rabi* wheat. IPNS-II replaced the 5t farmyard manure with 2t phospho-sulpho-nitro compost. In the third *khari*f season the soybean crop showed a yield advantage of 10.2 per cent in IPNS-I, 27.0 per cent in IPNS-II, and 20.8 per cent in STCR over farmers' practice.

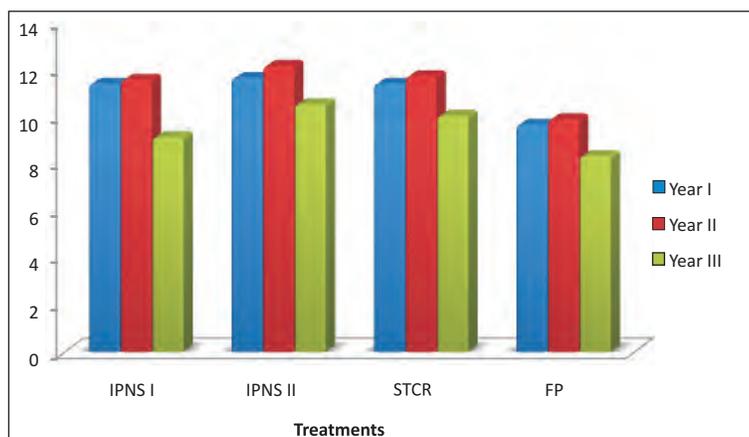


Fig 3.1.1 Performance of soybean for different treatments under Farmers' field condition

IPNS-I recommends the use of 5t farmyard manure and 50% recommended dose of NPKS with seed treatment of biofertilizers per ha for the *khari*f soybean and 75% NPKS and seed treatment of biofertilizers per ha for the *rabi* wheat. IPNS-II replaced the 5t farmyard manure with 2t phospho-sulpho-nitro compost. In the third *khari*f season the soybean crop showed a yield advantage of 10.2 per cent in IPNS-I, 27.0 per cent in IPNS-II, and 20.8 per cent in STCR over farmers' practice.

3.2 On Farm Demonstration

Demonstration trials in farmers' fields of Alirajpur, Jhabua and Dhar districts, M.P.

Frontline demonstration trials in the tribal farmers' fields in Alirajpur, Jhabua and Dhar districts (8 for soybean and 4 for maize during *khari*f and 10 for wheat during *rabi* 2015-2016) were conducted to disseminate the institute technologies like IPNS and STCR (Plate 3.1.1).



Plate 3.1.1 Seed and fertilizer distribution and demonstration trials in the farmers' fields



3.3 Farmers'/Field Days Organized

Kisan divas at Khamkheda to review success and promote conservation agriculture

One day Kisan divas was organized by ICAR- Indian Institute of Soil Science, Bhopal at Khamkhedha (Plate 3.1.2) on 5th March 2016 under Consortia Research Platform on Conservation Agriculture (CRP on CA). Dr. A.K. Patra, Indian Institute of Soil Science, Bhopal addressed to the farmers gathered from different villages and interacted with farmers and enquired about the problems of the villages in relation to conservation agriculture. Dr. A.K. Biswas, Lead Centre Platform Coordinator of CRP on CA and Dr. R.S. Chaudhary, Deputy Lead Centre Platform Coordinator described the benefits to farmers with respect to resource conservation and better utilization under conservation agriculture. All the scientists and farmers visited field experiments under Demonstration of Best-Bet Conservation Agriculture Practices on Farmers' Fields in Vertisols of Central India and witnessed the success of field experiments. The field visit was followed by Kisan Sangosthi for interaction between scientists and farmers to answer the questions related to the conservation agriculture.

Similar to the Khamkheda program, another Kisan Divas was organized at Momanpur to promote conservation agriculture in farmer's field on 11th March 2016 under CRP on CA. A field visit of best bet CA practices under farmer's conditions was followed by scientist-farmer.



Plate 3.1.2 Kisan Diwas at Khamkheda village





B. All India Coordinated Research /Network Projects

3.4 AICRP (LTFE)

3.4.1 Integrated nutrient management under Tribal Sub Plan

Under the tribal sub plan large scale demonstrations on finger millet (GPU – 28) and maize (Hybrid – Hema) were carried out in the tribal farmer's field in different states. In Karnataka field demonstration conducted in tribal clusters at Biligiri Rangana Hills, Yelandur Taluk, and tribal villages near Kollegal taluk of Chamarajanagar District. Representative soil samples were collected from these fields was analyzed for Soil Health Card preparation and was distributed. Before demonstration a training programme on importance of integrated nutrient management and awareness on soil sampling were imparted. The nutrients status of soils in the selected tribal beneficiaries was done in Chamarajanagar District, Karnataka state in two phases (i) TSP- I Phase (49 families of Soliga Tribes) with implementation at Purani Podu, Kalyani Podu in Biligiri Rangana Hills, and Yelandur Taluk and (ii) TSP- II Phase (53 families of Soliga Tribes) at Jeerige Gadde, Haavina Moole and Maavattur in Lokkanahalli Hobli, Kollegal Taluk.

3.4.2 Integrated nutrient management and productivity

a) GKVK, Bangalore

After imparting training, field demonstrations were carried out on tribal farmers' fields and the data revealed that average productivity of finger millet and maize is in the range of 25 to 28 q ha⁻¹ and 61 to 68 q ha⁻¹ respectively (Table 3.1.1). Improved practices were found to boost the productivity of finger millet and maize to the extent of 25 and 22%, respectively

Table 3.1.1 Average yield of finger millet and maize (kg/ha) in different tribal areas

Tribal cluster	Farmers practice	INM	Farmers practice	INM
	Finger millet		Hybrid maize	
Purani Podu*	2550	3350	6520	7885
Kalyani Podu*	2430	3150	6121	7706
Jeerige Gadde#	2450	3045	6712	8023
Haavina Moole#	2630	3125	6425	8156
Maavattur#	2850	3456	6852	8282
Average yield	2582	3225	6526	8010
Increase in yield (%) over FP	-	24.9%	-	22.7%

*B.R.Hills, Yelandur Tq; # Kollegal Tq Chamarajanagar: Farmers practice – Only DAP @ 50 kg /acre / and FYM @ 1 to 2 tonnes /acre

The farm inputs and soil health cards were distributed by the dignitaries including the honourable DG ICAR and Secretary DARE Dr. S. Ayyappan, who visited the tribal clusters at B.R. Hills in Chamarajanagar Dt. to interact with the beneficiaries in these tribal areas (Plate 3.1.3 and Plate 3.1.4). Besides training program on 'Importance of balanced nutrition to field crops' was also conducted (Plate 3.1.5)



Plate 3.1.3 Visit of Dr. S. Ayyappan, Hon'ble then DG ICAR to the tribal clusters of B.R. Hills, Chamarajanar District



Plate 3.1.4 Distribution of soil health cards and farm inputs to the beneficiaries



Plate 3.1.5 Training programme on 'Importance of balanced nutrition to field crops'

b) OUAT Bhubaneswar

Demonstrated the impact of balanced and integrated nutrient management in five villages viz., Banjhakusum of Dhenkanal dt, Kailash and Sadhupalli of Deogarh Dt, Khariadiha village of Keonjhar dt and Penala village of Kandhamal dt. covering 60 tribal farmers under Tribal Sub-Plan (TSP) during 2015-16 (Plate 3.1.6). The average increase in grain yield was 9 and 13 q ha⁻¹ due to balanced and integrated use of nutrients



Plate 3.1.6 Farmer's field in Kandhamal and Scientist's visit to Farmers' field in Dhenkanal





c) CSKHPKV Palampur

During *Kharif 2015*, farmers (*Tribe: Gaddi*) field demonstrations (50 nos.) were laid out at village Balla of Distt Kangra on integrated nutrient management (INM) in maize. The yield data of maize (Table 3.1.2) revealed a very quantum jump in yield to the tune of 27 q ha⁻¹ from improved practices. Besides, six training programmes were organized on balanced fertilization in different crops in dt Kinnaur, Chamba, Kangra and Mandi (Table 3.1.3 and Plate 3.1.7). Two Field Days were also organized on balanced fertilization in maize and wheat crops in district Kangra.

Table 3.1.2 Effect of INM on maize grain yield at farmers' fields at Palampur, HP

Treatment	Range (kg ha ⁻¹)	Mean (kg ha ⁻¹)
INM (N: 120, P: 60, K: 40 kg/ha + FYM 5 t/ha)	3750 – 6250	5030
FP (N: 60, P: 24, K: 16 kg/ha + FYM 5 t/ha)	1560 – 2810	2300

Table 3.1.3 Details of training camps organized under TSP component (2015-16)

Venue	No. of Farmers	Tribe
Lamu (Holi), District Chamba	81	Gaddi
Rakh (Nagri), District Kangra	81	Gaddi
Chaura (Bhawanagar), District Kinnaur	80	Gaddi
Gunehar (Bir), District Kangra	80	Gaddi
Tikri (Nushehra), District Mandi	80	Gujjar
Gujreda (Gopalpur), District Kangra	80	Gujjar



Demonstrations on INM in maize and wheat at Balla village (Dist Kangra)



Field Day on INM in wheat and maize (Balla)



Lamu (Holi), Dist Chamba (Tribe: Gaddi)



Gunehar (Bir), Dist Kangra (Tribe: Gaddi)



Rakh (Nagri), Dist Kangra (Tribe: Gaddi)



Chaura (Bhawanagar), Dist Kinnaur (Tribe: Gaddi)



Tikri (Chauntra), Dist Mandi (Tribe: Gujjar)



Gujreda (Gopalpur), Dist Kangra (Tribe: Gujjar)

Plate 3.1.7 Training Programme for tribal people in tribal areas in Himachal Pradesh

3.5 AICRP on STCR

Tribal Sub Plan Programme All India Coordinated Research Project on Soil Test Crop Response (AICRP on STCR) has implemented TSP across the country in various tribal belts.

IGKV, Raipur, Chattishgarh

STCR technology has been tested on tribal farmer's fields with wheat, mustard, maize and chickpea crops

Table 3.1.4 Details of FLD's conducted under TSP-STCR during Rabi season

Name of tribal districts	Village	Crop variety	No of beneficiaries	Range of % yield increased over FPD
Kanker	Aturgaon	Wheat (GW-273)	05	9.0 - 32%
		Maize (Vedanta)	05	16 – 27 %
Surajpur	Salyadih	Wheat (Lok -1)	10	23.72-36.65
Jagdapur	Mooli	Wheat= 10	10	15.87-45.11
Balrampur	Padhi	Wheat (Vidisha)	10	19.23-34.09
Raigarh	Mahloi	Wheat (GW-273)	10	23.59-45.48
Koreya	Mahora	Wheat (MP-2923)	10	29.48-58.81
Kondagaon	Bhagdeva	Maize (Hysel, & Bioseed)	10	All most the same yield
Dhamtari	Guhan Nala	Maize	10	36.84-53.41
Korba	Litiyakhar	Wheat (Kanchan)	10	34.07-40.91
Durg	Maravi	Chickpea (JG 11)	10	6.27-25.76



during *rabi* season in Chhattisgarh state. Out of total 100 demonstrations (one acre each), 65 for wheat, 10 for chickpea and 25 FLD's for maize were taken in all ten tribal districts. The percent yields increased due to soil test based fertilizer application over farmer's practices were recorded in the range from 9.00 to 58.8 % for wheat, 6.27 to 25.76 % for chickpea, and 16 to 53 % for maize (Table 3.1.4).

STCR technology has been tested on tribal farmer's fields successfully with rice and potato crops during kharif season (Table 3.1.5). One hundred and seventy field demonstrations (one acre each) for tribal farmers in 14 tribal districts (Balrampur, Koriya Ambikapur, Korba, Jashpur, Bilaspur, Narayanpur, Gariyaband, Rajnandgaon, Dhamtari, Kanker, Jagdalpur, Dantewada and Bijapur) of Chhattisgarh state were selected for successful conduction of FLD's during Kharif season.

Out of total 170 demonstrations, 130 for rice and 30 for potato were taken. Overall results show that the yield targets of rice and potato fixed for a definite goal were nearly achieved with the acceptable limit of $\pm 10\%$ variation accept in few cases.

Table 3.1.5 Training program and field days organized at different KVK's

Name of village, Block & district	No. of tribal farmers participated (Women)	Name of tribe	Any other information
Sonbachkachhar/Pendr a district Bilaspur	20	Gond	Training cum field day organized.
KVK Dhamtari District - Dhamtari	20	Netam Shori	Training programme organized.
KVK- Durg District - Durg	20	Gond	Training programme organized.
KVK - Balrampur District: Balrampur	20	Sai and Tirkey	“training programme organized.
Village: Siliyadih Block: Batoli District: Surajpur	20	Urao	“Field day-cum-training” programme organized.
KVK-Koriya District - Koriya	20	Gond	“Field day-cum-training” programme organized.
KVK- Dantewada District - Dantewada	30 (15 farmers from Bijapur and 15 from Dantewada district)	Muriya, Halbi	“Field day-cum-training” programme organized.
KVK-Kanker District - Kanker	50 (15 from Kondagaon, 15 from Narayanpur and 20 from Kanker district)	Gond Kuraiti, ShoriPotai, Salam	“Field day-cum-training” programme organized.
Village – Mahloi Block- Tamnar KVK-Raigarh District - Raigarh	20 (10 farmers from Jashpur and 10 from Raigarh district)	Kanwar,Sai , Paikra, Rathiya	“Field day-cum-training” programme organized.



Field demonstrations under TSP component during Rabi season

One hundred thirty field demonstrations (one acre each) were taken with wheat, tomato and brinjal crop Under TSP component in four tribal districts (Dantewada, Ambikapur, Korea and Balrampur) during *rabi* season. A 48.92 % yield increases over FPD was noticed in wheat, 33.55 percent in Tomato and 33.96% in Brinjal.

ICAR Res Com NEH, Imphal

Nine frontline demonstrations were conducted at farmers' field in Chandel district of Manipur on garden pea (Arkel). Response of crop to liming (furrow application) and fertilizer application (N, P₂O₅ and K₂O at 20, 40 and 40 kg ha⁻¹, respectively) was demonstrated. Green pod yield varied from 17.90 to 18.45 q ha⁻¹ with a mean value of 18.10 q ha⁻¹ for garden pea, 14.35 q ha⁻¹ for field pea, 9.51 q ha⁻¹ for Rape seed (M-27), 4.44 t ha⁻¹ for Rice (RC Maniphou 6) and 23.48 t ha⁻¹ for Groundnut (ICGS 76)

CRIJAF, Barrackpore, West Bengal

Ten front line demonstrations were conducted in village-Hanumanhir, Grampanchyte-Nakaijuri, Block-Onda. The average grain yield of mustard was recorded 6.30 q ha⁻¹ under soil test and targeted yield based fertilizers application (Table 3.1.6) against farmers practice 3.48 q ha⁻¹. Thirty-five front line demonstrations were conducted in Village-Saresh, Grampanchyte-Nakaijuri, Block-Onda. The grain yield of mustarded varied from 4.35 to 7.13 q ha⁻¹ in soil test and targeted yield based fertilizers treatment as compared to farmers practice varied from 2.50 to 4.10 q ha⁻¹. The average grain yield of mustard was recorded 5.97 q ha⁻¹ under soil test and targeted yield based fertilizers application against farmers practice 3.19 q ha⁻¹. A total fifteen front line demonstrations were conducted in village-Daldali, Grampanchyte-Nakaijuri Block-Onda. The average grain yield of mustard was recorded 5.71 q ha⁻¹ under soil test and targeted yield based fertilizers application against farmers practice 3.14 q ha⁻¹. Twenty-two front line demonstrations were conducted in Village - Bamundia, Grampanchyate - Lachmanpur, Block- G. Ghati, District. The average grain yield of mustard was recorded 6.27 q ha⁻¹ under soil test and targeted yield based fertilizers application against farmers practice 3.83 q ha⁻¹. Similarly, in Village-Majharpara, Grampanchyate- Chingani, Block- Chhatna, District Bankura, where covering about 28 bigha (3.73 ha⁻¹) and success area recorded about 24.5 bigha (3.25 ha⁻¹) at fifteen locations. Grain yield of mustard ranged from 5.60 to 9.75 q ha⁻¹ under soil test and targeted based treatment whereas 2.73 to 4.60 q ha⁻¹ recorded in farmers practice treatments. The fixed targeted yield of mustard (10 q ha⁻¹) could achieve only in two locations within ±10% yield deviations. The average grain yield of mustard was recorded 6.58 q ha⁻¹ in soil test and targeted yield based treatment as against 3.44 q ha⁻¹ under farmers practice. The net return (Rs. 6055 ha⁻¹) was recorded higher over farmers practice.

Table 3.1.6 Targeted yield equations used for conduction of front line demonstration on mustard and lentil in farmer's field

Mustard (B 9)	Lentil (B 256)
FN = 16.5 T – 0.08 SN	FN = 4.76 T – 0.15 SN – 0.08 ON
FP = 4.66 T – 0.41 SP	FP = 3.76 T – 0.07 SP – 0.07 OP
FK = 5.71 T – 0.03 SK	FK = 6.87 T – 0.42 SK – 0.07 OK



BCKV, Kalyani, West Bengal

Field Demonstrations were conducted in 21 tribal farmers under the scheme of Tribal Sub-Plan (TSP). The villages selected for demonstrations were Suoapara and Kannan of Hoogly and Kalanabagram of Burdwan district respectively. It was found that in most of the cases STCR technologies excel over farmers' practices.

TNAU, Coimbatore, Tamil Nadu

Field demonstrations on STCR technology were conducted at tribal farmer's field with maize, groundnut, onion, carrot and tomato in Western and North western zones of Tamil Nadu. At Alangandi and Gopanari, Coimbatore district, highest Maize (CO 6) yield was recorded in the STCR IPNS treatment followed by STCR-NPK alone treatment. In Groundnut (CO 6), STCR-IPNS and STCR NPK alone recorded relatively higher yield and response ratio when compared to blanket recommendation. Similar response was noticed in Onion (Co 4), Carrot (Hybrid Tokita), Tomato (PKM1), Turmeric (BSR1) and Tapioca (Mulluvadi), Maize (CP 808), Gingelly (TMV 3), Cotton (Surabhi), Bhendi (Kaveri 909), Rice (ADT (R) 45) etc.

ANGRAU, Hyderabad conducted frontline demonstrations on maize (7), rice (2) and groundnut (3) in Vizianagaram and warangal district. RAU, Pusa, Bihar conducted demonstrations in wheat. MPKV, RAHURI, MAHARASHTRA conducted demonstrations Kharif- Soybean, *Kharif* Sorghum, Pigeon pea, Drilled paddy, *Rabi*- Wheat, Chickpea, *rabi* sorghum and Maize.

3.6 AINP on BF

Biofertilizer Extension

Biofertilizer technology for soybean and wheat was demonstrated in nine farmers' fields of Menghra Kalan village, Berasia Tehsil, Bhopal District. *Rhizobium* and Plant growth promoting bacteria consortium (mixture of three PGPR strains) for soybean; and PGPR only for wheat. Soybean and wheat yield increased in INM mode with Biofertilizer by ~10% with FYM and ~25% with enriched compost over farmers' practice. Recommendation was released in Maharashtra for soybean-wheat: For enhanced grain yield, improved quality of the produce, soil fertility improvement and more monetary returns; seed treatment of liquid biofertilizers i.e., *Bradyrhizobium* + PSB @ 50 ml each/10 kg seed to soybean and *Azotobacter* + PSB @ 100 ml each/10 kg seed to wheat should be used. K-solubilizing bacteria and consortia for decomposition crop residues in short period were released to farmers in A.P.

Biofertilizer technology (*Rhizobium* and *Bacillus* co-inoculation) intervention among farmers of Bhagalpur and Katihar Dt. for black gram and among Vaishali and Samatipur Dt. for lentil gave grain yield increase of 10-14% for lentil and 6-9% for blackgram. Microbial consortium based bionutrient package for rice in farmer's fields in Samastipur, Muzaffarpur and Vaishali Dt. resulted in 5-15 % increase in grain yield over farmers' practice. Imbalance use of chemical fertilizers and higher doses of fertilizer application was common among poor farmers' due to fragmented land holdings.

In five multi-locational field trials, *Bacillus licheniformis* (i.e. Soil drenching of apple plant basin with one litre of liquid formulation diluted to five liters) increased the yields of apple in H.P. by 12-86%.

In cauliflower, the application of *Bacillus pumilus* at 3 locations, saved 25% NPK and improved yield by 22%. In pea the application of *Rhizobium leguminosarum* R2 at 3 locations saved 40% NPK and improved



yield by 26%. Organic farming for rice in Assam consisting of enriched compost (EC) @ 5.0t/ha with biofertilizer as organic input for rice was tested in several KVKs of Assam and found to give additional yield of 0.5-1.2 tonnes/ha over farmers's practice.

In Tribal area sub-programme in Kalahandi and Rayagada on vegetable crops, cotton and banana (125 farmers) increase in yields ranging from 8-20% were obtained with biofertilizers, generating an additional income ranging from Rs.6000 to 12,000 ha⁻¹ with the investment of Rs.1000-1500 ha⁻¹ on BFs. The construction of small vermicompost units enabled farmers to save 25% cost on chemical fertilizers. In nine tribal settlements in Wayanad district, 1400 kg of biofertilizers Azotobacter chroococcum, Azospirillum and PGPR mix-1 were distributed to 125 farmers for application in ginger and black pepper. Two training classes were conducted at two places. In tribal settlements of Attapady, Kerala 312 kg of PGPR mix I were distributed to tribal farmers engaged in the cultivation of vegetables, pulses, banana, sorghum, groundnut, ragi etc Training programmes on application of Biofertilizers were created. 312 tribal farmers from 3 locations and 54 extension officers participated.

160 MT of solid and 23MT of liquid biofertilizers worth Rs 133 lakhs produced at ANGRAU, Amaravathi. About 3.1 lakh biofertilizer packets worth Rs. 71.7 lakhs produced at JNKVV, Jabalpur. Biofertilizer sale was Rs. 5.3 lakhs at VN MAU, Parbhani. Total BF production in project was ~210 lakhs representing 69% return on funding of Rs 305 lakhs received by the project.

3.7 Mera Gaon Mera Gaurav (MGMG) activities

An innovative initiative “Mera Gaon Mera Gaurav” has been initiated to promote the direct interface of scientists with the farmers to hasten the lab to land process. The objective of this scheme was to provide farmers with required information, knowledge and advisories on regular basis by adopting villages. Under this scheme, the team of scientists have selected villages and remain in touch with the selected villages and provide information to the farmers on technical and other related aspects in a time frame through personal visits or on telephone. Being a resource person for the village, the scientists monitor the process of adoption of agricultural technologies by the farmers with the cooperation of KVKs, ATMA, etc. Besides providing information to farmers on market rates and market trends, the information on various agricultural organisations associated with agriculture are given so that the farmers can contact these organisations for finding solutions to their agriculture related problems. Scientists also created awareness among farmers about climate change, other customized services, protective measures and other issues of local and national importance. The list of scientist groups and their adopted villages are given in the Table 3.2.1.

Table ICAR-IISS, Bhopal Adopted Villages under MGMG

S.N.	Group	Name of five adopted villages
1	Dr. A.K. Patra, Director, IISS Dr. A.B. Singh, PS, SBD & Nodal Officer Dr. Abhay 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, Arwali, Hazampura and Parewalia sahani





S.N.	Group	Name of five adopted villages
3	Dr. M. Singh PC, LTFE Dr. S. Kundu, PS, ESS Dr. R.H. Wanjari, SS, LTFE Dr. K. Bharti, SS, 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, NC, BNF 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, MSN Dr. R. Elanchezhian, PS, SC&F Dr. R.K. Singh, SS, 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, SS, SC&F Dr. S.R. Mohanty, SS, SBD Dr. A.K. Vishwakarma, SS, SPD	Raipur, Kanera, Momanpur, Kadhैया 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, SS, ESS	Ratibad, Rasuliya Pathar, Mugaliahat, Ratanpur Sadak, Chandukhedi
10	Dr. A.K. Tripathi, PS, SBD Dr. S. Ramana, PS, SBD Dr. J. Somasundaram, SS, 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 Barkedda, Sagoni, and Barkeddi Hajam

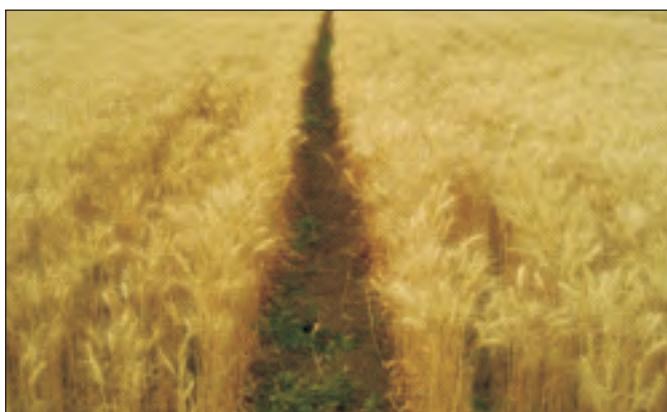


Plate: 3.7.1 Glimpses of activities under MGMG program





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 2015 -March 2016
1	Scientist	15
2	Technical	3
3	Administration & Finance	6
4	Skilled supporting staff	-
	Total	24

b. HRD fund allocation and utilization (Rs. In lakhs)

RE for HRD 2015-16	Actual Expenditure for HRD 2015-16
1.17	1.1675

c. Trainings attended during 2015-16

Scientists

Participant	Title	Organization	Duration
Dr. R.K. Singh and Dr BP Meena	International Training Programme on “Conservation Agriculture: Developing Resilient System”	CIMMYT& ICAR - CSSRI at Karnal	2-11 September 2015
Dr K. Ramesh and Dr BP Meena	Annual progress-cum-Review Meeting of CRP on CA	ICAR-Indian institute of Soil Science, Bhopal	29 March 2016.
Dr Pradip Dey, Dr R.S. Chaudhary, Dr. K.M. Hati, Dr. M. Mohanty, Dr. NK Sinha and Dr J K Thakur, Dr. P. Jha, Dr. Vassanda Coumar	Training on Soil health assessment using Mid-infrared spectroscopy and pXRF	ICAR-Indian Institute of Soil Science, Bhopal	December 14-15 2015
Dr. K.M. Hati	Training workshop on “Competency Development for HRD Nodal Officers of ICAR”	ICAR-NAARM, Hyderabad	10-12 February 2016



Technical

Name of employee	Name of training programme attended	Organizing institute	Duration (days)
Shahab Siddiqui	Advance tools and techniques for analysis of micro- and secondary nutrients and pollutant element	ICAR-IARI, New Delhi	10
R.K. Mandloi	Infrared Spectroscopy use in Soil Health Assessment	ICAR-IISS, Bhopal under ICAR-ICRAF Collaboration	5
Deepak Kaul	11 th Advanced level course in soil and water analysis techniques	ICAR-IARI, New Delhi	21

Administrative

Name of employee	Name of training programme attended	Organizing institute	Duration (days)
Neeraj Tahiliani	Administrative and financial issues	ICAR- NAARM, Hyderabad	4
A.S. Rajput	FMS-MIS	ICAR-IISS, Bhopal	7
Sh. Bansilal Sisodia	FMS-MIS	ICAR-IISS, Bhopal	7
Mrs. Babita Tiwari	FMS-MIS	ICAR-IISS, Bhopal	7
Jineshwar Prasad	FMS-MIS	ICAR-IISS, Bhopal	7
Mrs Raksha Parsai	FMS-MIS	ICAR-IISS, Bhopal	7

4.2. Short Term Professional Attachment Training Organized for Scientists

Name of the Scientist	Name of the College/Institute/University	Duration (month)	Name of the Scientist/Mentor
Dr. Sheetal K Radhakrishnan	ICAR-CAZRI, Jodhpur	3	Dr. J.K. Saha
Dr. Abir Dey	ICAR-IARI, New Delhi	3	Dr. M. C. Manna
Mr. G.S.Bandeepa	ICAR IIRR, Hyderabad	3	Dr. S. R. Mohanty
Mr. Mahipal Chaudhary	ICAR-VPKAS, Almora, Uttarakhand	3	Dr. M. Mohanty
Dr Ram Lal Jat	ICAR-IIPR, Kanpur	3	Dr Pramod Jha
Dr Amrit Lal Meena	ICAR-IIFSR, Modipuram	3	Dr Pramod Jha
Mr. Pravin Kumar Upadhyay	ICAR-IARI, New Delhi	3	Dr K. Ramesh
Mr. T. Basanta Singh	ICAR RCNEH Umiyam	3	Dr. Rajendran, S



4.3. Research Guidance for Degree Students

Name of the Student	Name of the College/Institute/University	Degree	Name of the Co-Guide
Mr. Satish Aher	Vivekanand University, Belur Matt, Kolkata	PhD	Dr Brijlal Lakaria
Mr. Rohit Patidar	RVSKVV, RAK College of Agriculture, Sehore	M Sc.	Dr. M. Mohanty
Mr. Dameshwar Kumar	College of Agriculture, IGKV, Raipur	M.Sc.	Dr R. Elanchezhian
Ms. Annusuiya Panda	College of Agriculture, IGKV, Raipur	M Sc.	Dr Pramod Jha
Ms. Priyank Singh	College of Agriculture, IGKV, Raipur	M Sc.	Dr Pramod Jha
Ms. Chandraprabha Miri	College of Agriculture, IGKV, Raipur	M Sc.	Dr Sanjay Srivastava
Mr. Prakash Patidar	RVSKVV, RAK college of Agriculture, Sehore	M Sc.	Dr Brijlal Lakaria
Miss Megha Sharma	RVSKVV, RAK college of Agriculture, Sehore	M Sc.	Dr. M Vassanda Coumar
Ms Poonam Mandale	RVSKVV, RAK college of Agriculture, Sehore	M Sc.	Dr Brijlal Lakaria

Off-farm Contingency planning farmer –scientist interactive meet for Kharif 2015

An awareness-cum-interactive meeting on “Contingency Planning Programme for Kharif 2015” was organized at Sagoni Kalan and Parwalia Sadak, Bhopal on 18th June 2015 and 20th June 2015, respectively, with an objective to bring awareness among the farmers of village clusters and the various service providers under one roof on the preparations and action points on agricultural operations.



Shri Alok Sanjar M.P. (Bhopal MP) and Shri. Vishnu Katri, MLA (Berasia, MP) inaugurated the program. Around 100 farmers from 10 villages surrounding Parwalia sadak like Mughaliaghat, Satarpur etc. participated in the awareness meeting.

Soil and Crop Management Advisory at Krishi Sanghosthi at Raisen, M.P. at KVK, Raisen on 30.06.2015

Scientists from ICAR-IISS, Bhopal have participated in the Krishi Vigyan Mela, organized by KVK, Raisen on 30.06.2015. About 110 farmers from different parts of the district participated in the sanghosti cum mela.



The importance of conservation of soil and nutrient for crop production, and management practices to mitigate soil and nutrient losses in different crops and cropping systems were highlighted and discussed in the sanghosthi.

Demonstration of Mridaparikshak

Mridaparikshak technology was demonstrated at several forums viz., Kisan Melas at IARI, ICAR foundation day at Patna, before Hon'ble Minister of Agriculture in Krishi Bhavan, State Department of Agriculture Meet at Udaipur etc.

Training programme on portable pXRF in Soil Health Assessment

A follow-up training on 'Infrared Spectroscopy use in Soil Health Assessment' was organized from 14-17 December 2015 under the ICAR-ICRAF collaborative programme. Dr. Erick Towett, Scientist (Soil Spectroscopy) from World Agroforestry Centre, Nairobi, Kenya imparted training on Mid-Infrared and portable X-ray fluorescence (pXRF) spectroscopy for soil and plant analysis totwelve scientists from ICAR-Indian Institute of Soil Science, and Central Agroforestry Research Institute Jhansi.



Hon'ble Prime Minister Shri Narendra Modi distributing Mridaparikshak to rural youth on July 25, 2015 during 87th Foundation Day of ICAR at Patna

Training to students and farmers

- Dr S R Mohanty coordinated visit of about 50 students and 5 faculties from Loyola College, Kunkuri, Chhattisgarh on 12 October 2015 and described the activities of the institute.
- Dr A B Singh organized One day State Level programme in the institute in collaborations with M P Jan Abhiyan Parishad Bhopal on 25 January 2016.
- Dr A B Singh organised one day Kisan Sangosthi on 16 March 2016 at Perwalia Sadak Bhopal under MGMG
- Dr A B Singh gave training on Organic farming and Vermicompost production in Kisan Sangosthi, arranged by DDA Agriculture, Bhopal on 10 June 2015 & 12 June 2015 at ICAR-CIAE, Bhopal.
- Dr A B Singh had given training on “Organic farming” to the farmers on 02 September 2015, arranged by Project Director, ATMA at Berkheda Baramad, Pipalia, Berasia Block, Bhopal.



- Dr A B Singh had given training on “Soil health management in Organic farming” on 01 October 2015, arranged by DDA, ATMA, Bhopal at CIAE, Bhopal.
- Dr A B Singh had given training on “Components of Organic Pest management” on dated 13 October 2015, arranged by State Institute of Agriculture Extension & Training, Bhopal.
- Dr A B Singh had given training on Organic farming in the Kisan Sangosthi, arranged by DDA, ATMA, Bhopal on 31 October 2015 at Phanda Farm Bhopal.
- Dr A B Singh had given training as resource person under Sansad Adarsh Village on Organic nutrient management and importance of Soil health” 02 January 2016.
- Dr A B Singh had given TV programme on “organic farming and vermicomposting” on dated 18 February 2016 at Bhopal, Doordarshan Kendra, Bhopal.
- Dr A B Singh had given training on Integrated Nutrient Management (INM) under NABARD supported SRI/SWI project at Village Chattarpura District Raisen on 17 February 2016.
- Dr A B Singh had given training as resource person in Capacity Building Programme on Improving quality of agricultural produce through organic farming for economic sustainability” during 27-29, February, 2016, College of Agriculture, Khandwa, Madhya Pradesh.
- Dr A B Singh had given training on Organic farming and its importance in soil health, on 10 March 2016, organised by Department of Farmer Welfare and & Agriculture, Govt. of M. P at ICAR-IISS, Bhopal.
- Dr A B Singh had given training on Organic farming and its importance in soil health, on 21 March 2016, organized by Department of Farmer Welfare and & Agriculture, Govt. of M. P. at ICAR-IISS, Bhopal



5. AWARDS, HONOURS AND RECOGNITIONS

1. IISS received a cash prize of Rs 2.11 lakh on account of the performance and achievements made in Mridaparikshak project from Mahindra.



ICAR-Indian Institute of Soil Science, Bhopal has been awarded the National Winner of Mahindra Samridhi Krishi Sansthan Samman 2016, a recognition given to a Public Sector Organization (PSO) in recognition of its noteworthy and purposeful contribution to the field of agriculture.

The award was presented to Dr. Ashok K. Patra, Director, ICAR- Indian Institute of Soil Science, Bhopal by the Hon'ble Union Minister of Agriculture & Farmers Welfare, Shri Radha Mohan Singh, at the Mahindra Samridhi India Agri Awards Ceremony on 03 March, 2016 at New Delhi. Dr. Patra was accompanied by Dr. Sanjay Srivastava, Principal Scientist, ICAR-Indian Institute of Soil Science, Bhopal and Principal Investigator, Mridaparikshak, a mini laboratory for soil testing. The award, instituted in 2011, is given every year by Mahindra & Mahindra's Farm Equipment Sector, India's leading tractor manufacturer. The award is given to ICAR-IISS, Bhopal in view of the institute's significant contribution in the area of soil health assessment and management. The institute has recently come out with a mini laboratory "Mridaparikshak" that can estimate the important soil health parameters and disseminate the results to the farmers.

2. ICAR-IISS technologies were demonstrated in "Bhopal Vigyan Mela" organized by Department of Science & Technology, Government of Madhya Pradesh during 19-22 February 2016 and ICAR-IISS, Bhopal was adjudged as the Best Vigyan Pavilion award. Dr A.K. Vishwakarma, B.P. Meena and A.O. Shirale participated in the mela.
3. Dr Pramod Jha received Dr B.C. Deb Memorial Award for Soil/Physical Chemistry of Indian Science Congress Association and acted as member of judging committee for zonal award of ISSS for best doctoral research at AAU, Anand, Gujrat.
4. Dr. A. K. Vishwakarma received Agri Innovation award form GKV Society during the National Conference on RAINFED, 2015 held at PJTSAU, Hyderabad during 3-4 May, 2015.
5. Dr. RH Wanjari, Sr. Scientist (Agronomy) received the Outstanding Achievement Award GRISAAS 2015 (in Agronomy) of the Astha Foundation, Meerut (UP) at RVSKVV Gwalior.





6. Dr. Tapan Adhikari, Dr J Somasundaram and Dr Sangeeta Lenka awarded Endeavour Research Fellowship 2015, Government of Australia.
7. Dr. S. Rajendiran Awarded Fellowship for Young Scientist Training, 2015 by MPCOST, Bhopal
8. Dr. Asha Sahu Awarded Young Scientist Fellowship 2016 for training by MPCOST, Bhopal
9. Dr. A.K. Patra elected as Vice President of the Indian Society of Soil Science, New Delhi for the period of 2016-17.
10. Dr. A.K. Patra elected as Sectional President of the Indian Science Congress Association, Kolkata for the period of 2016-2017.
11. Dr. A.K. Patra elected associate Editor, European Journal of Soil Science, UK
12. Dr. A.K. Patra elected as Thesis Examiner, University of Helsinki, Finland.
13. Dr. D.L.N.Rao, NC (BF) delivered the 7th Professor S.K. Mukherjee memorial lecture on "Brave New Soil Science" Indian Society of Soil Science, Kolkata, 8 October, 2015.
14. Dr. D.L.N.Rao, NC (BF) participated as Member, Research Advisory Committee, National Bureau of Agriculturally Important Microorganisms, Mau at RAC meeting on 11 March, 2016.
15. Dr. D.L.N.Rao, NC (BF) delivered an invited lecture, International Year of Soils celebration, Assam Agricultural University, Jorhat, Assam on 27 April, 2015 on `Recent advances in Soil Biodiversity and Genomic Indicators of Soil Biological Health.
16. Dr. D.L.N. Rao, NC (BF) delivered a special lecture on `Bright new horizons in Soil science', International Year of Soils Celebration, Science Centre, Bhopal, Nov 17, 2015.
17. Dr. D.L.N.Rao, NC (BF) delivered a special lecture on "Soil Biology and Microbial Diversity -New Paradigms", ICAR- IYS Brain storming session on "Managing Soil Health" Nov 23-24, 2015, NAAS, New Delhi.
18. Dr. Pradip Dey Co-Chaired Technical Session in National Seminar on "Integrated Agri-Horticultural and Allied Research for Food and Nutritional Security in the Era of Global Climate Disruption" on March 4, 2016.
19. Dr. Pradip Dey nominated as member secretary, National level Committee under Mission Soil Health Card Scheme constituted by Honourable Secretary, DARE & DG, ICAR.
20. Dr. Pradip Dey Member, Institute Management Committee, ICAR-CSSRI, Karnal.
21. Dr. Pradip Dey Editor, *Research Journal of Environmental and Earth Sciences* (ISSN 0051-1335).
22. Dr. Pradip Dey Consulting Editor (National), Journal of Soil Salinity and Water Quality.
23. Dr. Pradip Dey Vice President, Indian Society of Agrophysics, New Delhi
24. Dr. Sanjay Srivastava elected as Councillor of Indian Society of Soil Science for the biennium 2016-17 and 2017-18.
25. Dr Elanchezhian recognized as Examiner for Evaluation of Ph.D. Thesis in Biotechnology from Jawaharlal Nehru Technological University, Hyderabad.
26. Dr Elanchezhian nominated as Chairman, Screening Committee for the post of Laboratory Technical Assistant (T-3) at IISS, Bhopal during Jan-Feb 2016.



27. Dr. R. Elanchezhan invited for a lead paper presentation on Research and development in climate smart agriculture with special reference to integrated nutrient management. *In* workshop on “Moving towards Climate Smart Agriculture in Madhya Pradesh: Technology, Policy and Farmers” held on 17-18 April, 2015 at Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior.
28. Dr K. Ramesh acted as Invited panelist at the National Conference on “Balanced Fertilization: A Key to Food Security & Environmental sustainability” during 24-25 February 2016 at Amity University, Noida, Uttar Pradesh
29. Dr K. Ramesh Invited to chair a session at the workshop on Youth Ready for Climate Change Transformation during 28-29 July, 2015 at Indian Institute of Forest Management, Bhopal
30. Dr K. Ramesh invited to present a discussion paper at the IFPRI South Asia workshop on “Moving Towards Climate Smart Agriculture in Madhya Pradesh: Technology, Policy and Farmers” held on 17-18 April, 2015 at Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior
31. Dr K. Ramesh elected as Indian Society of Agronomy Councillor, Madhya Pradesh 2015-17
32. Dr K. Ramesh elected as Executive council member-Association of Agrometeorologists, India 2015-17
33. Dr K. Ramesh recognized as Examiner for Evaluation of M.Sc (Ag) thesis in Agronomy and M.Tech. Agricultural Nanotechnology from Tamil nadu Agricultural University, Coimbatore
34. Dr K. Ramesh recognized as Examiner for Evaluation of M. Phil Thesis Forest Resource Management from Indian Institute of Forest Management, Bhopal.
35. Dr P. Jha delivered presentation on Soil Carbon Dynamics and Stabilization in different Agroecosystems of India during 103rd Indian Science Congress held at Mysore University, Mysuru during 3-7 Jan 2016.
36. Dr P. Jha delivered presentation on Phosphorus Dynamics in vertisols under soybean based cropping systems in National Seminar on Evaluation of available nutrient of soil from the view point of Rhizosphere with special reference to soybean crop grown in vertisols under MP-JICA held on 17.06.2015 at JNKVV, Jabalpur.
37. Dr P. Jha Delivered lecture on Carbon sequestration and soil health in MTC entitled Advances in Soil Health Assessment and Preparation of Soil Health Cards for Enhancing Crop Productivity and Improving Soil Quality during 14-21 December, 2015.
38. Dr. K. Ramesh was invited for a lead paper presentation on organic Package of Practices in aiding below and above ground biodiversity in international conference on sustainability development goals through organics” at Angamaly, Kochi (Kerala) during 5-7, Nov 2015.
39. Dr. S.R. Mohanty acted as External Ph. D examiner- Indian Institute of Science Education and Research, Bhopal
40. Dr. S.R. Mohanty and Dr. K. Bharati recognized as Thought Leader - National Mission for Clean Ganga, India
41. Dr. A. K. Vishwakarma Acted as Co-chairman in the technical session on integrated farming systems and presented lead paper on IIFS in the National Conference on RAINFED, 2015 held at PJTSAU, Hyderabad on 3-4May, 2015.





42. Dr. A. K. Vishwakarma was nominated as expert member for attending meeting on Economic and industrial assessment of silt as a result of Koshi disaster in Bihar at BAMETI Patna Bihar.
43. Dr Sangeeta Lenka delivered a guest lecture on “Conservation tillage and manure interactive effect on soil properties, carbon storage and global warming potential in Vertisol of India” in Soil health workshop at Ranchi on 12 and 13 January, 2016 organized by Cornell University and Birsa Agricultural University.
44. Dr Sangeeta Lenka Co-Chaired technical Session on “Energy and Environment” at International conference on Water, Environment, Energy and Society during 15-18 March, 2016 at Bhopal (MP).
45. Dr. M. L. Dotaniya awarded Second Best Oral Paper Presentation Award by Search & Research Society, Bhopal during 27-28 November, 2015.
46. Dr. S. Rajendiran Co-Chaired a Technical Session in International Conference on Water, Environment, Energy and Society organized by AISECT University, Bhopal and A & M University, Texas, USA held in Bhopal during March 15-18, 2016.
47. Dr K Ramesh and Dr M Vassanda Coumar nominated as the External Expert Committee members for PhD student (Ms. Pooja Verma) from Indian Institute of Forest Management IIFM, Bhopal.
48. Dr. M. Mohanty acted as Rapporteur in the session “Integrated Modelling Framework” of the 4th Annual review Workshop of NICRA, CRIDA, Hyderabad organized during August 13-14, 2015 by ICAR-CMFRI, Cochin.
49. Dr. M. Mohanty selected as Editorial Board Member of the journal International Journal of Agricultural Education and Extension.
50. Dr. M. Mohanty selected as the Executive Editorial Board Member of the journal International Journal of Agricultural Science and Research (IJASR).



Plate 1. Dr RH Wanjari receiving Outstanding Achievement Award GRISAAS 2015 (in the discipline of Agronomy) of the Astha Foundation, Meerut (UP)



Dr. J. Somasundaram successfully completed post doctoral research (May to Oct, 2015) on “Impact of Long-Term No-Tillage and crop residue retention on soil aggregation and carbon sequestration” under the supervision of Prof. Ram C. Dalal DSITI, Ecosciences Precinct (ESP), Australia sponsored by Endeavour Research Fellowship, Australian Government



6. Linkages and Collaboration

Institute has linkages with several ICAR institutes and SAUs located throughout the country. The three AICRPs and one Network Project co-operating units located at IISS Bhopal have 58 cooperating centers spread across almost all the SAUs. Also, efforts have been made to strengthen research collaborative activities with SAUs through guidance of PG students by the institute scientists. Besides, Nagarjuna Fertilizers and Chemicals Pvt. Ltd., Hyderabad, BASF Pvt. Ltd. (Mumbai), NUALGI, Biotech, Bangalore, PRII, Gurgaon, Zuari Agro Chemicals Ltd, Indofil Industries Ltd, are collaborating on various R&D activities.

List of Cooperating Centres under AICRPs/AINP

AICRPs/AINP	No. of cooperating centres		
	ICAR	SAUs/SGUs	Total
AICRP on LTFE : Hyderabad, Raipur, Junagarh, Palampur, Ranchi, Bangaluru, Pattambi, Jabalpur, Akola, Parbhani, Bhubaneswar, Ludhiana, Udaipur, Coimbatore, Pantnagar, Barrakpore, IARI and IASRI New Delhi	4	14	18
AICRP on STCR : Hyderabad, Pusa, Raipur, New Delhi, Hisar, Palampur, Bangaluru, Vellanikkara, Jabalpur, Rahuri, Bhubaneswar, Ludhiana, Bikaner, Coimbatore, Pantnagar, Kalyani, Barrackpore, Puduchery, BHU, AAU, Gujarat, Srinagar, Ranchi, Lucknow, Manipur	4	21	25
AICR on MSPE: Hyderabad, Pusa, Anand, Hisar, Jabalpur, Akola, Bhubaneswar, Ludhiana, Coimbatore, Pantnagar, Lucknow, Jorhat, Kalyani, ranchi, Palampur, Kanpur, KAU Kerala, UAS Bengaluru, Manipur, NIANP Bengaluru, IARI New Delhi	2	19	21





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. Study on nanoporous zeolites for soil and crop management.
K. Ramesh and I. Rashmi
3. Studies on soil resilience in relation to soil organic matter in selected soils
N. K. Lenka, Sangeeta Lenka, Brij Lal Lakaria and Asit Mandal
4. Biofortification of grain sorghum and finger millet varieties with zinc through agronomic measures.
Ajay, A.K. Shukla and J.K. Saha
5. 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)
6. Impact of crop covers on soil and nutrient losses through runoff in Vertisol.
R. K. Singh, J. Somasundaram and I. Rashmi
7. Characterizing rooting behaviours, soil water patterns and nutrient uptake of soybean- chickpea under different tillage and water regimes in Vertisols.
N. K. Sinha, M. Mohanty, Ritesh Saha and I. Rashmi
8. 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)
9. Nano particle delivery and internalization in plant systems for improving nutrient use efficiency
R. Elanchezian, A.K. Biswas, Tapan Adhikari, K. Ramesh, S. Kundu, A.K. Shukla and K. Raju Kumar
10. 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
11. Evaluating rock phosphates for their suitability for direct application
Sanjay Srivastava, K. Ramesh, A.K. Tripathi, I. Rashmi and P Dey
12. 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. Elanchezian



13. 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

B. Externally Funded Projects

14. Network Project on Organic Farming
A. B. Singh, K. Ramesh, Brij Lal Lakaria, S. Ramana and J.K. Thakur
15. Use of nano sensors network for field detection of temperature and moisture stress in plant and soil (CRP-Nanotechnology)
Tapan Adhikari, S. Kundu, C.D. Singh, Ajay, N.K. Sinha, A.K. Patra, Navkanta Bhat, K.S. Subramaniam and Bajendra
16. 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
17. Simulating the effect of elevated CO₂ and temperature on water productivity and nutrient use in soybean-wheat cropping system (NASF)
N.K. Lenka, Sangeeta Lenka, A.K. Shukla, R. Elanchezhian, J.K. Thakur, I. Rashmi and Pradip Dey
18. 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, A.B. Singh, A.K. Patra, Muneshwar Singh, D.L.N. Rao, A.K. Shukla, Pradip Dey.

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

A. Institute Projects

19. Evaluating conservation tillage on various sequences/rotations for stabilizing crops productivity under erratic climatic conditions in black soils of Central India
J. Somasundaram, R. S. Chaudhary, Neenu S and ajay
20. Assessing impacts of climate change on different cropping systems in Central India and evaluating adaptation studies through crop simulation models
M. Mohanty, K.M. Hati, N.K. Sinha, Sangeeta Lenka, Pramod Jha, Neenu S., R. S. Choudhary and R. Elanchezhian
21. Weed Management for major cropping systems under conservation agriculture in Vertisols
A.K. Vishwakarma, R.S. Choudhary, N.K. Sinha, B.P. Meena, K. Bharati and Sobha Sondhia

B. Externally Funded Projects

Other externally funded

22. 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, RH Wanjari, RK Singh, KC Shinogi, AK Tripathi
- c. Fine-tuning of conservation agricultural practices for Vertisols of central India
J Somasundaram, K Ramesh, S. Ramana, BP Meena and Abhay Shirale
- d. Development of water and nutrient management practices in conservation agriculture for Vertisols of central India
Sanjay Srivastava, KV Ramana Rao, I Rashmi and NK Sinha
- e. Impact of conservation agricultural practices on soil health, carbon sequestration and greenhouse gas emissions in different production systems
Pramod Jha, Brij Lal Lakaria, M Mohanty, JK Thakur and K. Bharati

NICRA

23. 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

24. Developing technique for acceleration of decomposition process using thermophilic organisms
Asha Sahu, U. B. Singh (NBAIM), J.K. Thakur, V. K Bhargav (CIAE), H.L. Kushwaha (CIAE), Asit Mandal, M.C. Manna and A. Subba Rao
25. 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

26. Biodegradation of pesticides under changing climate and metagenomic profiling of functional microbes funded by Department of Biotechnology, New Delhi
K Bharati, T K Radha, and S R Mohanty
27. Archaea and Actinobacteria in Vertisols of Central India-Assessment of Diversity, Biogeochemical Processes and Bioinoculant Potential funded by AMAAS
D.L.N. Rao, S.R. Mohanty, K. Bharati and T.K. Radha
28. 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

Programme IV: Soil Pollution, Remediation and Environmental Security

A. Institute Project

29. 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
30. 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
31. 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

B. Externally Funded Projects

32. 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

New Projects (Institute)

33. 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, Javed Rizvi
34. Potential of Cotton for the remediation of soils contaminated with heavy metals
S. Ramana, A.K. Tripathi, K. Bharati, Asha Sahu
35. 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, S. Bhattacharya

Collaborative projects in other institutes where IISS scientists are associated in

36. 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 Abhay Shirale
37. 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





8. Consultancies, Contractual Services, Patents and Technology commercialization

Consultancies / Contractual Services

S. No.	Title	Sponsorer	Project team
1	Evaluation of plant nutrition product (NP - 1) for nutrient use efficiency in cereal crops	Nagarjuna Fertilizers and Chemicals Pvt. Ltd., Hyderabad	R. Elanchezhian, A.K. Biswas, K. Ramesh, N.K. Lenka, A. Subba Rao, Brij Lal Lakaria
2	Evaluation of urease inhibitor product (limus) for nutrient use efficiency in cereal crops	BASF Pvt. Ltd., Mumbai	Pramod Jha B.P. Meena, A.K. Biswas
3	Evaluation of nano-nutrients product (NUALGI) for improving nutrient use efficiency of crops	NUALGI Biotech, Bangalore	R. Elanchezhian, A.K. Biswas K. Ramesh, A.K. Shukla J.K. Thakur, A.K. Patra
4	Evaluation of efficacy of polysulphate on oil seed crops (soybean-mustard)	PRII, Gurgaon	K. Ramesh Sanjay Srivastava A.K. Biswas
5	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
6	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, Pankaj K. Tiwari
7	Upgradation of Mridaparikshak mini lab	Nagarjuna Agro Chemicals Pvt. Ltd., Hyderabad	S. Srivastava, P. Jha, I. Rashami, A.K. Biswas, P. Dey, M.V. Coumar, A. Shirale, A.K. Patra
8	Development of customized fertilizer solutions to promote balanced fertilization in selective agriculturally important states of India towards crops productivity and farm profitability	Nagarjuna Agro Chemicals Pvt. Ltd., Hyderabad	P. Dey, Sanjay Srivastava, A.K. Biswas, A.K. Patra

Commercialization

Released Mridaparikshak Mini Lab technology to Nagarjuna Agrochemicals Pvt. Ltd., Hyderabad for commercialization. The technology has been already adopted by different Krishi Vigyan Kendras and other stakeholders for the assessment of soil fertility.

Patent filed

Submitted a patent (application No. 2522/DEL/2015) on “Device and method for measurement of soil health parameters and fertilizer recommendation” on Mridaparikshak mini lab technology.



9. Publications

A. Research Papers (National/International)

International/ National (NAAS rating more than 6)

- Adhikari Tapan, Kundu S, BiswasAK, Tarafdar J C and Rao A S (2015). Characterization of zinc oxide nano particles and its effect on growth of maize (*Zea mays* L.) plant. *Journal of Plant nutrition* 38: 1505-1515.
- Adhikari Tapan, Kundu S, and Rao A S (2016). Zinc delivery to plants through seed coating with nano zinc oxide particles. *Journal of Plant Nutrition* 39: 136-146.
- Behera Sanjib K, Shukla Arvind K, Singh M V, Wanjari Ravi H and Singh Pooja (2015) Yield and zinc, copper, manganese and iron concentration in maize (*Zea mays* L.) grown on Vertisol as influenced by zinc application from various zinc fertilizers. *Journal of Plant Nutrition* 38:10, 1544-1557, DOI: 10.1080/01904167.2014.992537.
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4	Sh. Deepak Kaul, T-7-8	Member
5	Sh. P.S. Sunil Kumar, AAO	Member
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3	Co-PI/Associate	Member
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5	Mrs. Babita Tiwari, Assistant	Member
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3	Dr. K.M. Hati, Pr. Scientist	Member
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2	Dr. R.H. Wanjari, Sr. Scientist	Member
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Central Lab		
1	Dr. S.R. Mohanty, Sr. Scientist	Incharge
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Training Hostel		
1	Dr. Manoranjan Mohanty, Scientist	Controlling Officer
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Swachh Bharat Mission		
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	Sh. Vinod Babu Pal, T-6 (Alternate)	Incharge
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	Dr. Asha Sahu, Scientist (Alternate)	Incharge
Library		
	Dr. S. Ramana, Pr. Scientist	
	Ms. Shinogi K.C., Scientist (Alternate)	Incharge
HRD (Training)		
	Dr. K.M. Hati, Pr. Scientist	Nodal Officer
Mera Gaon Mera Gaurav		
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2	Dr. K. Ramesh, Pr. Scientist	Co-Nodal Officer



11. Important Meetings/Activities

Institute Research Council Meeting

The Institute Research Council (IRC) meeting was held during 27th May 2015 and 15-16 January, 2016 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. He also requested all the scientists to present the research findings for ten minutes followed by discussion for 5-10 minutes. The 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.

Institute Management Committee Meeting

39th meeting of IMC was held on 14 July 2015 under the Chairmanship of Dr. Ashok K. Patra, Director, ICAR-IISS, Bhopal.

ICAR-IISS Foundation Day

The 28th Foundation Day of ICAR-IISS Bhopal was celebrated on 16 April, 2015. The programme was graced by Dr. P. K. Verma, Director General, Madhya Pradesh Council of Science and Technology Bhopal and Dr. R. K. Gupta, Team Leader, Research Station Developments, Borlaug Institute for South Asia (BISA), CIMMYT, New Delhi besides other dignitaries. Dr A.K. Patra, Director, IISS appraised the progress made by the institute.





Independence Day

The 69th 'Independence Day' was celebrated on 15th August, 2015 in the Institute premises with great gaiety and fervor. Various cultural events were organized for the family members of the staff on the day and program was concluded with the distribution of prizes to the winners.



World Soil Day

The World Soil Day was celebrated on 05 December, 2015 at the ICAR- Indian Institute of Soil Science, Nabibagh, Bhopal by organising a *Kisan Mahasammelan* and soil health card distribution ceremony in association with Government of Madhya Pradesh, in the presence of Chief Minister of Madhya Pradesh, Shri



Plate 1. Kisan Mahasammelan and Soil Health Card Distribution Program on World Soil Day – 5th December 2015



Shivraj Singh Chouhan. This was attended by more than 25,000 farmers from the State. Among other dignitaries were Shri Gauri Shankar Bisen, Hon'ble Minister of Agriculture, Government of Madhya Pradesh; Shri Vishwas Sarang, M.L.A (Bhopal).; Shri Manmohan Nagar, Chairman, Zila Panchayat, Bhopal; Shri Prem Chand Meena, IAS, Agriculture Production Commissioner, Madhya Pradesh; Dr Rajesh Rajora, IAS, Principal Secretary (Department of Farmer Welfare & Agriculture) of Government of Madhya Pradesh. The importance of soil health was highlighted and its testing in sustainable agriculture. The Chief Minister elaborated upon the plan of Government of Madhya Pradesh for state wide soil testing for preparation of soil health cards for the farmers. The importance of soil testing and balanced fertilization in preserving the quality of soil, water and food for the present and future generations for overall care of human health were also emphasized. This was followed by a Kisan Sangosthi.

Exhibition stalls on agricultural technologies were also showcased. Several experts from ICAR institutes, Agricultural Universities, and State Department discussed on soil health, conservation agriculture, irrigation techniques, pests and disease management, credit availability and Government schemes in agriculture

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, 2015. 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. On 30th September, Sh. M.L. Meena Director Agriculture, Govt of MP, Chief Guest distributed prizes to the winners.



Swachh Bharat Mission

The Institute staff members participated in the nation-wide program of “Swachh Bharat Mission” launched by the Government of India. The Swachhta Spath was administered to all the staff members by the Director





of the Institute on 2nd October, 2014. 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 Awareness Week

As per the directive of the Central Vigilance Commission, vigilance awareness week was observed in the Institute during 26–31 October, 2015 with the theme on “Preventing Vigilance-A tool for Good Governance”. A debate competition on the theme Digital India: Will Reduce Corruption was organized on 28th October, and a speech competition on the theme “Ways and means to combat Corruption in Government Offices” was organized for the staff members on 29th October, 2015. The concluding function of the Vigilance Awareness Week was held on 31st October, 2015. Mr. Arjun Kadam, CBI Officer Bhopal was the Chief Guest.



New Year Day

The Staff Recreation Club (SRC) organized the 'New Year Day' celebration on 01 January, 2016.

Republic Day

The 67th '**RepublicDay**' was celebrated on 26th January, 2016 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 day. Activities include racing and drawing competition for children, musical chair for adults etc.

Women's Day

ICAR-IISS celebrated International women's day with great enthusiasm on the theme of “Planet 50-50 by 2030: Step It Up for Gender Equality” on 11th March 2016. The Women Cell organized various competitions for women staff and spouses. The program was attended by Dr Lekha Sushil, Mrs Aradhana Hans and Mrs Reena Patra. Dr Lekha Sushil emphasized on various burning issues like female foeticide, women empowerment and undernourishment during pregnancy, non-preference of vaccination for girl child, etc. Mrs Aradhana Hans emphasized on the need of technical studies like polytechnic degree and its importance for sustaining women's livelihood and self-dependency in rural and urban areas. Mrs Reena Patra spoke about the significance of International Women's Day and the challenges being faced by women in today's society. Director IISS reiterated the importance of women's role in society and nation building. He further stressed upon, let us stop heinous crime against women and adore and respect women. Several competitions such as Rangoli, Spot the city, Housie and Quiz were organized.



Van Mahotsav celebrations at ICAR-IISS

ICAR-IISS celebrated Van Mahotsav during 1-7 July 2015. Dr. A.K. Singh, IFS, Chief Conservator of Forests inaugurated the week on 01st July 2015.



Organization of Jai Kisan Jai Vigyan week

As a part of the celebrations of *Jai Kisan-Jai Vigyan week*, a two-day farmer-scientist interaction meet was organized by ICAR-Indian Institute of Soil Science, Bhopal during December 28-29, 2015. The program was conducted to highlight the significance of soil health and scientific methods of cultivation.

On, 28th Dec 2015, around 60 farmers from the IISS adopted villages under *Mera Gaon Mera Gaurav* participated in the celebrations.



Sports Activities

A cricket match was organized on 27th December, 2015 in which sports persons from IISS and CIAE took part. The Director, Dr. A.K. Patra inaugurated the event and praised the efforts in this direction. He suggested to keep on organizing such activity more frequently on closed holidays. An one day volley ball championship was organized in the institute on 3rd January, 2016. In this championship many teams participated. The Director, Dr. AK Patra appreciated the efforts being made to the sports activities and assured to provide necessary facilities.





12. Participation of Scientists in Conferences/Symposia/Seminars/Workshops/meeting

Name	Programme	Venue	Period
Dr. A.K. Patra	Meeting with Director (Research)	BCKVV, Kalyani on TSP and visited Tribal villages for TSP	2 - 5 April, 2015
Dr R Elanchezhian and Dr K. Ramesh	Workshop on “Moving Towards Climate Smart Agriculture in Madhya Pradesh: Technology, Policy and Farmers”	Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior.	17-18 April, 2015
Dr RH Wanjari and Dr K Ramesh	The Review-cum-Action Workshop on ‘Soil fertility management’ by Zonal Project Directorate (ZPD-VII), Jabalpur for Krishi Vigyan Kendra (KVKs) for the states of Odisha, Madhya Pradesh and Chhattisgarh	ICAR-IISS, Bhopal	20-21 April, 2015
Dr. A.K. Patra	Meeting of the Board of Post Graduate Studies	Nagaland University, Medziphema Campus, Dimapur, Nagaland	23 April, 2015
Dr R. Elanchezhian	National training on “Right to Information for Public Information Officers”	ISTM, New Delhi.	27-28 April, 2015
Dr. A.K. Vishwakarma	Attended National Conference on RAINFED, 2015	PJTSAU, Hyderabad	3-4 May, 2015
Dr. Sudeshna Bhattacharjya	Professional Attachment Training	ICAR-Indian Agricultural Research Institute, New Delhi	11 May - 11 August, 2015
Dr. A.K. Patra	Meeting of the Vice-Chancellors of Agricultural Universities and the Directors of ICAR Institutes	NAAS Complex, New Delhi	14-16 May, 2015
Dr. A.K. Patra	Meeting of CRP on CA called by DDG (NRM), ICAR	ICAR, New Delhi	20-21 May, 2015
Dr. S. Kundu	General body meeting of NAAS	NASC, New Delhi	3-5 June, 2015
Dr. A.K. Patra	Conducted Ph.D. via-voce examination	SHIATS, Allahabad	8 June, 2015
Dr S. Srivastava	Seminar on “Evaluation of available nutrient of soil from the view point of rhizosphere	Jawahar Lal Nehru Krishi Vishwavidyalaya, Jabalpur	17 June, 2015
Dr. A.K. Patra	A consultation meeting to develop ICAR-ICRAF collaborative work plan for 2016-2020	ICAR, KAB-II, PUSA, New Delhi	23-24 June, 2015





Name	Programme	Venue	Period
Dr. K. Ramesh and Dr M. L. Dotaniya	Krishi Sanghosi on Soil and Crop Management Advisory	KVK, Raisen	30 June, 2015
Dr A. B. Singh	Attended State Level Inter Media Publicity Coordination Committee Meeting	Narmada Guest House, BHEL, Bhopal	30 June, 2015
Dr M. Vassanda Coumar	National seminar on application of radioisotopes and radiation technology in industries, agriculture, healthcare and its impact on environment	AISECT University, Bhopal	3-4 July, 2015
Dr. A.K. Patra	A meeting regarding implementation of projects under Indo-Africa Forum Summit-II (IAFS-II) –PPT presentation before Secretary (DARE), ICAR	NASC, Pusa, New Delhi	6 July, 2015
Dr. A.K. Patra	Workshop of contractual project under AICRP on Micro and Secondary Nutrients (MSN)	Ahmedabad	8-10 July, 2015
Dr. A.K. Patra	A meeting regarding celebration of International Year of soils	ICAR-NRM Division, New Delhi	12-13 July, 2015
Dr. Sangeeta Lenka	Global Centre for land based Innovation workshop on Mining microbial dark matters	Leura, Blue Mountains, New South Wales, Australia.	16-17 July, 2015
Dr. Asha Sahu	ICAR sponsored summer school on “Biomass and biofuel: technologies, climate change and environment”	ICAR-CIAE, Bhopal	22 July-11 August, 2015
Dr. A.K. Patra and Dr S. Srivastava	87 th Foundation Day of ICAR	Patna, Bihar	24-26 July, 2015
Dr. AB Singh and Dr K. Ramesh	Workshop on Youth ready for climate change transformation	Indian Institute of Forest Management, Bhopal	27-28 July 2015
Dr. A.K. Patra	Participated in the Brainstorming session on “Potash Nutrition” during the 19 th Annual Convention and National Conference on “Application of Clay science in Agriculture, Environment and Industry” organized by the Clay Minerals Society of India	Kolkata, W.B.	7-8 August 2015
Dr. J. K. Saha and Dr. M. Vassanda Coumar	Orientation Programme organized by Ministry of Environment, Forest & Climate Change (MoEF & CC)	Indra Paryavaran Bhawan, New Delhi	12 August, 2015



Name	Programme	Venue	Period
Dr. M. Mohanty	4 th Annual Workshop of National Initiative on Climate Resilient Agriculture (NICRA)	ICAR-CMFRI, Cochin	13-14 August, 2015
Dr. K. Ramesh Dr. Asit Mandal Dr. Rajendiran,S	Principle and functioning of Mridaparikshak- a soil minilab developed by ICAR-IISS, Bhopal in collaboration with NAC, Hyderabad	ICAR-IISS, Bhopal	17-19 August, 2015
Dr A. B. Singh	10 th Annual Group Meeting of Net Work Project on Organic Farming	MPUA & T Udaipur (Rajasthan)	19-21 August, 2015.
Dr. J. K. Saha	National Conference on ‘sustaining agriculture productivity in arid system, challenges and opportunities SAPECO-2015’	Regional Research Station of CAZRI, Leh, J & K	19-22 August, 2015
Dr. Muneshwar Singh	National Seminar on organic ameliorants for soil resilience and environmental securities	RVSKVV, Gwalior	19-21 August, 2015
Dr. K. Ramesh and Mr. Deepak Kaul	Agricultural Fair-cum-Exhibition	Motihari, Bihar	20-21 Aug 2015
Dr. A.K. Patra	One-day workshop to discuss the drafting of the publication “State of Indian Agriculture: Soils”	NASC complex, New Delhi by NAAS, New Delhi	21 August, 2015
Dr. A.K. Patra and Dr S. Srivastava	National Workshop on soil health card	Udaipur, Rajasthan	24 August, 2015
Dr. A.K. Patra	XXII Zonal Workshop of KVK	Ujjain, MP	9-11 September, 2015
Dr. A.K. Patra	Agriculture Leadership Summit	New Delhi	18 September, 2015
Dr. A.K. Patra & Dr DLN Rao	National Dialogue on "Efficient Nutrient Management for improving soil health"	New Delhi	28-29 September, 2015
Dr. A. K. Vishwakarma	Workshop on Quality control of soil testing Software of soil health card, soil testing data management PPP mode of soil health card promotion	BAMETI, Patna	5 October, 2015
Dr. K.M. Hati and Dr. B.L. Lakaria	National Seminar on ‘Soil Health Management and Food Security: Role of Soil Science Research and Education’	NBSS & LUP Kolkata Centre, Kolkata	8-10 October, 2015
Dr. Shinogi KC	Gender Sensitization and Training Workshop: Concepts and Tools for Gender Analysis	ICRAF South Asia Regional Office, NASC Complex New Delhi	12-13 October, 2015





Name	Programme	Venue	Period
Dr. Shinogi KC	Gender Sensitization and Training Workshop: Concepts and Tools for Gender Analysis	ICRAF South Asia Regional Office, NASC Complex New Delhi	12-13 October, 2015
Dr. A.K. Vishwakarma and Dr R.H. Wanjari	Attended 25 th Asia Pacific weed science conference	PJTSAU, Hyderabad	13-16 October, 2015
Dr. A. B. Singh	Sensitization Workshop on MGMG	ATARI, Jabalpur	14 October, 2015
Dr. A. B. Singh	Attended National Conference on Carbon Materials for Energy Applications-2015	National Physical Laboratory, New Delhi	15-16 October, 2015
Dr. A.K. Patra	Brainstorming session on “Organic Farming”	NAAS, New Delhi	16-18 October, 2015
Dr. A.K. Patra	A review meeting of Fertilizer Quality Control System by Inter-Ministerial Committee (IMC)	IASRI, New Delhi	26 October, 2015
Dr. A. K. Vishwakarma	State Level Seminar on “Soil and Water Quality: A Concern”	Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola	2-3 November, 2015
Dr. N.K. Lenka	Developing roadmap for the Agroclimatic Zone – IX (Western Plateau and Hills)	Directorate of Soybean Research, Indore	04 November, 2015
Dr. J. K. Saha	Rural and Urban Solid Waste Management for better Agriculture and Environment	Defence Research & Development Establishment , Gwalior, Madhya Pradesh	19 November, 2015
Dr. Sudeshna Bhattacharjya	ICAR training on “Geoinformatics in Natural Resource Management and Climate Change Mitigation	ICAR-IISS, Bhopal	20-29 November, 2015.
Dr. M. L. Dotaniya and Dr. Rajendiran S.	International Conference on Innovative Agriculture for Rural Prosperity	Search & Research Society of Bhopal	27-28 November, 2015
Dr. Shinogi KC	Symposium on Intellectual Property (IP) Leverage and Management	Courtyard by Marriott, Bhopal	30 November, 2015
Dr. M. Mohanty	Workshop on “Measurements of Greenhouse Gas Emission and Development of Inventory for Agriculture” organized by from	Centre for Environment Science and Climate Resilient Agriculture, ICAR-IARI, New Delhi	3-4 December, 2015



Name	Programme	Venue	Period
Dr. M.C. Manna K. Ramesh, Asha Sahu, Sudeshna Bhattacharjya	80 th Annual Convention of Indian Society of Soil Science	University of Agricultural Sciences, Bengaluru	5-8 December, 2015
Dr. A.K. Patra	A Technical Session in the Annual Convention of ISSS and National Seminar on Developments in Soil Science 2015	UAS, Bengaluru	5- 8 December, 2015
Dr. J.K. Thakur	56 th Annual Conference of Association of Microbiologists of India (AMI-2015) & International Symposium on “Emerging Discoveries in Microbiology”	JNU, New Delhi	7-10, December, 2015
Dr. A.K. Patra	National Seminar "Issues, challenges and strategies for sustaining soil health in the humid tropics" and delivered a keynote lecture at Forest Research and Management Institute	Peechi, Kerala	10 December, 2015
Dr R. Elanchezhian	3 rd International Plant Physiology Congress - Challenges and Strategies in Plant Biology Research	JNU, New Delhi, India	11-14 December, 2015
Dr A. B. Singh	3 rd International Conference on Environmental Friendly Agriculture, Horticulture in Planning of a Smart City	Noor us Sabha Bhopal, Madhya Pradesh	12-14 December, 2015
Dr. R.H. Wanjari	National Conference on “Global Research Initiative for Sustainable Agriculture and Allied Sciences (GRISAAS 2015)’	RVSKVV, Gwalior	12-13 December, 2015
Dr. M. Mohanty	Training programme on Soil health assessment using infrared spectroscopy and pXRF	ICAR-IISS, Bhopal	14-15 December, 2015
Dr. A.K. Patra	ASRB assessment meeting	ASRB, New Delhi	15 December, 2015
Dr. Asha Sahu and Dr. Sudeshna Bhattacharjya	Brain storming on waste management	ICAR-IISS, Bhopal	15 December, 2015
Dr. Asit Mandal	CAFT (Centre for Advance Faculty Training) on “Application of computer algorithms and software packages in Agriculture	ICAR-IASRI, New Delhi	18 December 2015 - 7 January, 2016
Dr K. Ramesh, Dr Pramod Jha and Dr Asha Sahu	103 rd Indian Science Congress	University of Mysore	03-07, January 2016





Name	Programme	Venue	Period
Dr. A.K. Patra	103 rd Indian Science Congress	University of Mysore, Mysuru	5 January, 2016
Dr A. B. Singh	Workshop on Organic farming	ICAR-IIFSR, Modipurum (U.P.)	7-8 January, 2016
Dr. A.K. Patra	ICAR nominee in the site selection committee for establishment of new/additional KVKs	Chhattisgarh	10 January, 2016
Dr. Sangeeta Lenka	Soil health workshop in Ranchi	Birsa Agricultural University, Ranchi	12-13 January, 2016
Dr. A.K. Patra	A Jury Member in the Mahindra and Mahindra "Samridhi Award"	New Delhi	22 -25 January, 2016
Dr. A.K. Patra	Interactive meeting of Vice Chancellors of SAUs and ICAR Directors and ICAR Directors' Conference	New Delhi	23-24 January, 2016
Dr. A.K. Patra	Review Meeting of work progress in land resource inventory (LRI) and Agricultural Land Use Planning (LUP) flagship projects	NBSS&LUP, Nagpur	29-30 January, 2016
Dr. A.K. Patra Dr. Shinogi KC	Interface Meeting with DRDO Sixth International Conference on Technology Innovation and Management for Sustainable Development (TiMS-2016)	New Delhi ITM University, Gwalior, Madhya Pradesh	10 February, 2016 11-13 February, 2016
Dr. A.K. Patra	Technical Committee Meeting	Krishi Bhawan, New Delhi	12 February, 2016
Dr. A.K. Vishwakarma, Dr. B.P. Meena Dr. A.K. Patra	5 th Bhopal Vigyan Mela Visited experimental site of contractual project operated from ICAR-IISS, Bhopal of Indo-Gulf Fertilizers	M.P.Council of Science and Technology, Bhopal Lucknow, U.P.	20-23 February, 2016 19- 21 February, 2016
Dr. A.K. Patra	ASRB Selection Committee meeting	ASRB, New Delhi	24-25 February, 2016
Dr. Asha Sahu and Dr. Rajendiran S.	31 st M.P. Young Scientist Congress	Vigyan Bhawan, MPCST, Bhopal	28 -29 February, 2016
Dr. A.K. Patra	Joint Interest Group on Agricultural Data (IGAD) pre-meeting at Research Data Alliance (RDA) 7th Plenary	Tokyo, Japan.	28 February - 1 March, 2016
Dr. A.K. Patra	Mahindra Samridhi India Agri Award 2016 Ceremony	New Delhi	3 March, 2016
Dr. N.K. Lenka, Dr. S. Lenka, Dr. M.L. Dotaniya and Dr. T. Adhikari	International conference on Water, Environment, Energy and Society	AISECT University, Bhopal	15-18March, 2016



Name	Programme	Venue	Period
Dr S. Srivastava	Interaction Meeting cum Sensitization Workshop of ITMU/ZTMU	ICAR Complex for NEH Region, Umiam, Meghalaya, India	16-17 March, 2016
Dr S. Srivastava	IARI Krishi Mela	ICAR-IARI, New Delhi	19 March, 2016
Dr. K. Ramesh Dr. A.K. Vishwakarma	Review meeting of CRP on Conservation Agriculture	ICAR-CIAE, Bhopal	19-20 March, 2016
Dr. A.K. Vishwakarma	Participated and displayed Institute technologies in the PUSA Krishi Unnati Mela	ICAR-IARI, New Delhi	19-21 March, 2016
Dr. A.K. Patra	Krishi Unnati Mela	IARI, Pusa, New Delhi	21 March, 2016
Dr. A.K. Patra	India Consultation Meeting CGIAR and ICAR	NAAS	22 March 2016
Dr. R.S. Chaudhary, K. M. Hati, R. K. Singh, A. Vishwakarma, M. Mohanty, K. Ramesh and Nishant K. Sinha	Review meeting of CRP on Conservation Agriculture	ICAR-IISS, Bhopal	29 March, 2016





13. Workshops, Seminars and Trainings Organized

Training/Short Courses Conducted

Programme	Course Directors/ Coordinators	Duration	Sponsored by
ICAR Short course on geoinformatics in natural resource management and climate change mitigation	Dr. A.K. Patra and Dr. M. Mohanty	20-29 November, 2015	ICAR
Infrared Spectroscopy use in Soil Health Assessment	Dr. K. M. Hati	14-17 December, 2015	ICAR-ICRAF
Enhancing the Preparedness for Agricultural Contingencies in Kharif 2015 for Madhya Pradesh	Dr. M. Mohanty	26 June, 2015	ICAR-NICRA
Training Programme on Online Farmer's Subsidy Tracking System and Preparation of Soil Health Card (Bhopal Division)	Dr. A. K. Vishwakarma	February 9, 2016	ICAR-IISS, Bhopal and Madhya Pradesh State Agro Industries Development corporation Ltd
One Day Training Programme on Preparation of Soil Health Card	Dr. A. K. Vishwakarma	26 March, 2016	Directorate of Farmers Welfare and agriculture Development Govt of M.P. Bhopal.
Training on "Soil health card preparation and soil testing".	Dr K. Ramesh and B. P. Meena	9-10 March, 2016	Directorate of Farmers Welfare and agriculture Development Govt of M.P. Bhopal.
Training on "Soil health card preparation and soil testing".	Dr K Ramesh and B. P. Meena	21-22 March, 2016	Directorate of Farmers Welfare and agriculture Development Govt of M.P. Bhopal.
MTC on Advances in Soil Health Assessment and Preparation of Soil Health Cards for Enhancing Crop Productivity and Improving Soil Quality	Drs Sanjay Srivastava, Pramod Jha and Brij Lal Lakaria	14-21 December, 2015	Directorate of Extension, Government of India
Training on "Soil testing and preparation of soil health card"	Dr. Brij Lal Lakaria	8 -12 February, 2015	Directorate of Farmers Welfare and agriculture Development Govt of M.P. Bhopal.
Farmers training cum awareness programme on "Improving soil health for sustainable crop production" for the tribal farmers at Jhabua, Alirajpur and Dhar	Drs. J. K. Saha, S. Kundu, M. Vassanda Coumar, M. L. Dotaniya and S. Rajendiran	8, 9, 13 October, 2015.	Tribal Sub Project. ICAR, New Delhi



Programme	Course Directors/ Coordinators	Duration	Sponsored by
CRP on CA annual programme cum review meeting	Dr. A.K. Biswas and Dr. R.S. Chaudhary	29 March, 2016	ICAR, New Delhi
Capacity building training on “Importance of soil health card for soil management”	Dr. Brij Lal Lakaria	27-28 January, 2016	RVSKVV, Gwalior
“Exposure visit cum Training programme to the farmers of Alirajpur, Jhabua and Dhar districts, Madhya Pradesh”	Dr Rajendiran S., M. L. Dotaniya, M. Vassanda Coumar, J. K. Saha, S. Kundu	3-5 th Dec., 2015 at	ICAR-IISS, Bhopal.
Kisan Sangoshthi on “Soil Health and Conservation Agriculture”	Dr AK Biswas and Dr BP Meena	5 th March, 2016	ICAR-IISS, Bhopal



Dr Ashok K Patra, Director giving the certificate to a participant on 21 December, 2016 for successful completion of the MTC



Plate Inaugural session of the Follow-up Training Program on Infrared Spectroscopy use in Soil Health Assessment



Hands-on training on pXRF



Brainstorming on Waste Management





ICAR Sponsored Short Training Course on
"Geoinformatics in Natural Resource Management and Climate Change Mitigation"
 held on 20-29 November 2015 at ICAR-Indian Institute of Soil Science, Bhopal



Winter school on "Advance soil biological approaches for managing carbon sequestration and climate change mitigation" during 2-22September, 2015



Kisan sanghosthi cum Exhibition at Motihari, Bihar and Directorate of Soybean Research, Indore



Student outreach programme

14. Distinguished Visitors

- Shri Shivraj Singh Chouhan Hon'ble Chief Minister of M.P., Shri Gauri Shankar Bisen, Hon'ble Minister of Agriculture, M.P.; Shri Vishwas Sarang, M.L.A (Bhopal).; Shri Manmohan Nagar, Chairman, Zila Panchayat, Bhopal; Shri Prem Chand Meena, IAS, Agriculture Production Commissioner, Madhya Pradesh; Dr Rajesh Rajora, IAS, Principal Secretary (Department of Farmer Welfare & Agriculture) of Government of Madhya Pradesh visited on 5th December 2015. On occasion of Kisan Maha Sammelan.
- Dr. Trilochan Mohapatra, Secretary (DARE) and Director General (ICAR) visited ICAR- Indian Institute of Soil Science, Bhopal on 24 February, 2016. along with Dr. J.S. Sandhu DDG (Crop Science), Dr. P.K. Ghosh Director ICAR-IGFRI Jhansi, and Dr. N.P. Singh Director ICAR-IIPR Kanpur.
- Dr. A.K.Sikka, Hon'ble DDG (NRM), Dr. S.K.Chaudhari, ADG (SWM), Dr. C.L. Acharya, Former Director of IISS and Chairman (RAC) inaugurated 1st Annual progress cum review meeting of CRP on Conservation Agriculture held on 29th March, 2016.
- Dr. A.R. Sharma, Director, DWR, Jabalpur and Dr. P.K. Ghosh, Director, IGFRI, Jhansi visited the institute on 29th March, 2016.
- Dr. Raj K. Gupta, Team Leader, CIMMYT, New Delhi, visited the institute on 15 April, 15.
- Dr. Pramod K. Verma, DG, MPCOST, visited on 16 April, 2015.
- Ethiopian delegation visited this institute on 24 April, 2015
- Prof. Jintendra Chauhan, Scientific Advisor to Hon'ble Union Minister of Agriculture visited on 24th June, 2015.
- A group of Legislators and Secretaries from Jharkhand visited the institute on
- Dr. S.S. Khanna, Ex-Member, Planning Commission & VC, GBPUAT visited the institute on
- Dr. Ch. Srinivasa Rao, Director, CRIDA, Hyderabad, Shri R.K. Swain, APC, Govt. of M.P., Shri Rajesh Rajora, Pr. Secretary (Agri.) and Sh. M.L. Meena, Director Agriculture, Govt. of M.P. visited the institute on 26th June, 2015 for a consultation meeting on Enhancing the preparedness for agricultural contingencies in kharif 2015 for M.P.





15. Infrastructure Development

Instrument/Equipment Purchased

Digital multifunctional Copier Machine (1no.), Biometric Attendance Device (10 no.), Autoclave Vertical (1no.), Desktop Computer (5nos), Small leveler (1no), Angel Rotor for High Speed Centrifuge (1no), Flame photometer (1no), Supply of Spares of ICP-OES (1no), pH-EC Meter (2nos), Drinking water cooler with dispenser (1no), Computer notebook (1no), Power supply for Gel Electro (1no), Water purification system (1no), Tractor operated high capacity power sprayer with trolley (1no), Split Air Conditioner with rotary compress (R22 Refrigerant) (25nos) and inclined plate planter with herbicides application unit (1no).

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 2015-16	Total
Books	Nil	2591
Bound Journals	Nil	2555
Annual Reports	99	2251
Foreign Journals	3	3
Indian Journals	19	19

Training Hostel

During the year different items were purchased for smooth functioning in training hostel including LED Televisions, Five split Air Conditioner (ACs), Light Lamp for training hostel, and new curtains.

Farm Activities

1. A revenue of Rs. 10.62 lakhs have been generated through sale of farm produce.
2. Red gram (4.50 ha) crop was raised in the farm during the kharif season 2015 with a production of 22.72q.
3. Maize was raised in an area of 4.00 ha with a production of 75.92 q
4. Small leveler has been procured worth Rs. 15000/-
5. Fish has been reared in water harvesting ponds.
6. New plantation has been taken up and 359 guava, 92 mango and 340 teak plants have been planted during Van Mahotsav week.



16. Scientific, Technical, Administrative Personnel

DETAILS OF MANPOWER

Name	Designation	Discipline	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
Sh. Thomas Joseph	PS	Office Staff	18.09.1989	18.09.1989
Smt. Yojana Meshram	PA	Office Staff	12.05.1997	12.05.1997
Sh. Sukh Ram Sen	T-3	Tech. Asstt (Driver)	25.01.1991	25.01.1991
Sh. Bhoilal Uikey	Lab Attendant	Skilled Supporting Staff	13.11.1995	13.11.1995
Sh. 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. J. Somasundaram	Sr. Scientist	Soil Physics/Soil & Water Conservation	12.11.2001	22.12.2008
Dr. A. K. Vishvakarma	Sr. Scientist	Agronomy	16.04.2003	01.08.2013
Dr. M. Mohanty	Scientist	Soil Physics/Soil & Water Conservation	10.11.1999	10.11.1999
Dr. R.K. Singh	Sr. Scientist	Soil Physics/Soil & Water Conservation	25.01.1993	16.10.2002
Dr. N.K. Sinha	Scientist	Agriculture Physics	20.04.2010	27.08.2010
Sh. R.K. Mandloi	T-7-8	Asstt. Chief Technical Officer	19.06.1989	19.06.1989
Sh. Hukum Singh	T-3	Technical Assistant	30.12.1988	30.12.1988
Sh. 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. Brij Lal Lakaria	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	01.10.1997	15.01.2007
Dr. R. Elanchezian	Pr. Scientist	Plant Physiology	09.11.1998	17.2.2012
			30.11.2000	09.10.2009





Name	Designation	Discipline	Date of Joining ICAR	Date of Joining IISS
Dr. N. K. Lenka	Pr. Scientist	Soil Physics/Soil & Water Conservation	30.11.2000	09.10.2009
Dr. K. Ramesh	Sr. Scientist	Agronomy	04.09.2008	04.09.2008
Dr. Pramod Jha	Sr. Scientist	Soil Chemistry/ Fertility/ Microbiology	16.04.2003	17.07.2009
Dr. (Mrs.) I. Rashmi	Scientist	Soil Chemistry/Fertility	21.04.2009	27.08.2009
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
Sh. Deepak Kaul	T-7-8	Asstt. Chief Technical Officer	29.12.1988	29.12.1988
Sh. Khilan Singh Raghuvanshi	SI-5	Technical Officer	29.12.1988	29.12.1988
Sh. Bhanwar Singh Yadav	Messenger	Skilled Supporting Staff	01.09.1993	23.01.1999
DIVISION OF SOIL BIOLOGY				
Dr. M.C. Manna	Head & Pr. Scientist	Soil Chemistry/ Fertility/ Microbiology	21.01.1992	11.01.1993
Dr. A.B. Singh	Pr. Scientist	Biochemistry	22.03.1999	22.03.1999
Dr. A.K. Tripathi	Pr. Scientist	Soil Chemistry/ Fertility/ Microbiology	05.08.1991	25.07.1992
Dr. S. Ramana	Pr. Scientist	Plant Physiology	06.02.1997	06.02.1997
Dr. S.R. Mohanty	Sr. Scientist	Soil Chemistry/ Fertility/ Microbiology	18.06.2009	18.06.2009
Dr. Kollah Bharati	Sr. Scientist	Microbiology - Plant Science	29.10.2009	05.04.2011
Dr. Asit Mandal	Scientist	Soil Chemistry/Fertility	23.06.2009	30.10.2009
Dr. J. K. Thakur	Scientist	Agricultural Microbiology	20.04.2010	27.08.2010
Dr. Asha Sahu	Scientist	Soil Chemistry/Fertility	03.05.2010	03.05.2010
Dr. Sudeshna Bhattacharjya	Scientist	Soil Chemistry/Fertility	01.01.2015	10.04.2015
Sh. Vinod Babu Pal	T-6	Sr. Technical officer	15.02.1993	15.02.1993
Mrs. K.S. Baise	PA	Office Staff	05.05.1997	18.02.2002
Sh. Vinod Choudhary	T-3	Tech. Assistant	14.06.1989	14.06.1989
Sh. Ram Bharose	Lab attendant	Skilled Supporting Staff	20.03.1990	20.03.1990
DIVISION OF ENVIRONMENTAL SOIL SCIENCE				
Dr. J.K. Saha	Head & Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	21.01.1992	02.01.1993
Dr. S. Kundu	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	22.07.1986	03.07.2007
Dr. Ajay	Pr. Scientist	Plant Physiology	12.04.1993	31.08.1999



Name	Designation	Discipline	Date of Joining ICAR	Date of Joining IISS
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. Vasudev Meena**	Scientist	Agronomy	15.09.2011	23.12.2011
Smt. Seema Sahu	T-7-8	Asstt. Chief Technical Officer	14.04.1987	24.01.1989
Sh. Sant Kumar Rai	T-3	Technical Asstt.	15.06.1989	15.06.1989
Sh. 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
Sh. Sunny Kumar	Steno. GR.III	Office Staff	21.12.2011	21.12.2011
Sh. 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
Sh. P.K. Tiwari**	Scientist	Soil Chemistry/Fertility/ Microbiology	01.01.2013	11.04.2013
Sh. Sahab Siddiqui	T-6	Sr. Technical Officer	05.10.1992	05.10.1992
Sh. Jai Singh	T-5	Technical Officer	22.05.1999	22.05.1990
Sh. Venny joy	PA	Office Staff	14.02.1991	23.03.1998
Sh. Harish Kumar	Lab attendant	Skilled Supporting Staff	14.03.1990	14.03.1990
AICRP-STCR				
Dr. Pradip dey	Project Co-ordinator	Soil Chemistry/Fertility/ Microbiology	03.06.1993	01.02.2012
Dr. N.S. Bhogal	Pr. Scientist	Soil Chemistry/Fertility/ Microbiology	14.05.1999	26.05.2014
Sh. 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
Sh. Janak Singh Mehra	Khalasi	Skilled Supporting Staff	08.09.1997	08.09.1997



Name	Designation	Discipline	Date of Joining ICAR	Date of Joining IISS
AINP-BIOFERTILIZERS				
Dr. D.L.N. Rao	Network Coordinator (Biofertilizer)	Soil Chemistry/Fertility/ Microbiology	29.07.1978	25.06.1998
Sh. A.B. Mate	Lab attendant	Skilled Supporting Staff	15.06.1999	15.06.1999
PME CELL				
Dr. R. Elanchezhian	Pr. Scientist	Plant Physiology	09.11.1998	17.2.2012
Sh. 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	Sr. Scientist	Officer In-Charge	12.11.2001	22.12.2008
STATISTICS AND COMPUTER APPLICATION SECTION				
Dr. Kollah Bharati	Sr. Scientist	In-Charge	29.10.2009	05.04.2011
Sh. Kavita Bai	Safaiwala	Skilled Supporting Staff	20.12.1988	20.12.1988
LIBRARY SECTION				
Smt. Nirmala Mahajan	T-6	Sr. Technical Officer	15.03.1993	15.03.1993
Sh. P.K. Raut	Beldar	Skilled Supporting Staff	21.07.1992	21.07.1992
Smt. Geesi Devi	Trainee	Supporting Staff	31.05.2014	31.05.2014
CENTRAL LAB				
Dr. S.R. Mohanty	Sr. Scientist	Officer In-Charge	18.06.2009	18.06.2009
Sh. 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	Sr. Scientist	Officer In-Charge	16.04.2003	01.08.2013
Sh O.P. Shukla	T-4	Tractor Mechanic	22.04.1989	22.04.1989
Sh. C.T. Wank hede	T-5	Technical Officer (Tractor Mechanic)	03.08.1992	03.08.1992



Name	Designation	Discipline	Date of Joining ICAR	Date of Joining IISS
Sh. D.R. Darwai	T-5	Technical Officer (Field Assistant)	23.01.1993	23.01.1993
Sh. P.K. Chouhan	T-5	Technical Officer	15.02.1993	15.02.1993
Sh. Bhagwat Prasad	Beldar	Skilled Supporting Staff	24.01.1992	24.01.1992
Sh. Lalaram Sahu	Beldar	Skilled Supporting Staff	24.07.1992	24.07.1992
Sh. 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
Sh. N.S. Yadav	T-4	Asstt. Tech. Officer (Driver)	23.09.1987	03.05.1999
ADMINISTRATION SECTION				
Shri V. K. Derashri	AO	Administration	19.05.1976	16.06.2012
Mr. Neeraj Tahiliani	FAO	Audit & account	12.06.2012	22.07.2014
Sh. Rajesh Dubey	AF&AO	Audit & account	21.12.1988	26.11.1998
Sh. P. S. Sunil Kumar	AAO	Administration	30.01.1989	30.01.1989
Sh. A.S. Rajput	Assistant	Establishment section	14.03.1990	14.03.1990
Smt. Babita Tiwari	Assistant	Central store	30.05.1996	30.05.1996
Sh. Bansilal Sarsodia	Assistant	Purchase section	10.09.1997	10.09.1997
Sh. Hiralal Gupta	UDC	Bill section	23.12.1988	23.12.1988
Sh. O.P. Yadav	UDC	Audit & Account	19.12.1988	19.12.1988
Sh. Jineshwar Prasad	UDC	Administration	13.12.1988	13.12.1988
Sh. Sanjay Katinga	LDC	Cash Section	20.06.1989	20.06.1989
Smt. Raksha Parsai	LDC	Administration	24.05.2013	24.05.2013
Sh. Sanjay N Gharde	Lab attendant	Skilled Supporting Staff	15.06.1999	15.06.1999
Sh. Anurag	Security Supervisor	Security section	29.09.1997	29.09.1997
Sh. L.N. Chouksey	Messenger	Skilled Supporting Staff	17.12.1988	17.12.1988
Sh. S.K. Batham	Messenger	Skilled Supporting Staff	19.12.1988	19.12.1988
Sh. D.R. Singh	Messenger	Skilled Supporting Staff	10.09.1993	14.06.1999

*on deputation; ** on study leave



Joining

Dr. Sudeshna Bhattacharjya, Scientist and Dr. Abhay Omprakash Shirale, Scientist joined on 10.04.2015 at ICAR-IISS, Bhopal

Transferred/Resigned

Dr. (Mrs.) I. Rashmi, Scientist to ICAR- IISWC, Regional Centre, Dadwara, Kota, Rajasthan on 31.12.2015

Sh. S. Mukharjee, LDC transferred to ATARI, Zone-II, Kolkata, WB on 14.05.2015

Ms. Radha, T.K Scientist to ICAR- Indian Institute of Horticultural Research, Bengaluru, Karnataka on 11.12.2015

Superannuation

Shri V. K. Derashri, Administrative Officer retired from ICAR service on 30.04.2015.



Results-framework Document for Indian Institute of Soil Science (2014-2015)



RFD
Results-Framework Document
For
Indian Institute of Soil Science
(2014-15)

SECTION 1
Vision, Mission, Objectives and Functions

Vision

Basic and strategic research on physical, chemical and biological processes in soils for improving soil health and crop productivity

Mission

To provide scientific basis for enhancing and sustaining productivity of soil resource with minimal environmental degradation

Objectives

1. Appraisal and management of soil health
2. Improving nutrient use efficiency
3. HRD & capacity building

Functions

1. To plan, coordinate, implement and monitor research and development programmes for improvement of soil health and serve as a knowledge repository in the field of soil science.





Section 2 : Inter se priorities among Key Objectives, Success Indicators and Targets

Section 2 : Inter se priorities among Key Objectives, Success Indicators and Targets											
S. No.	Objectives	Weight	Actions	Success Indicators	Unit	Weight	Target / Criteria				
							Excellent	Very good	Good	Fair	Poor
							100%	90%	80%	70%	60%
1	Appraisal and management of soil health	40	Assessment of soil health	Soil health assessment under different crops and cropping systems	No.	10	8	6	4	2	0
			Management of soil health	INM packages developed for different agro-eco regions of the country	No.	15	10	8	6	4	2
				Developed conservation agricultural practices for crops / cropping systems	No.	10	3	2	1	0	0
				Developed management practices for remediation of polluted soils	No.	5	3	2	1	0	0
2	Improving nutrient use efficiency	25	Balanced and judicious use of fertilizers	Soil test based balanced fertilizer prescription equations developed	No.	15	4	3	2	1	0
				Technologies developed for improving nutrient use efficiencies	No.	5	3	2	1	0	0
				Efficient bio-fertilizers strains/formulations developed	No.	5	6	5	4	3	2
3	HRD & capacity building	15	Transfer of technology and creation of awareness/knowledge	Frontline demonstrations conducted	No.	8	30	25	20	15	10
				Farmers' trainings organized	No.	4	7	5	3	1	0
				Workshop/ seminar/ summer/winter school organized	No.	3	10	8	6	4	2
*	Publication/Documentation	5	Publication of the research articles in the journals having the NAAS rating of 6.0 and above	Research articles published	No.	3	43	36	29	22	15
			Timely publication of the Institute Annual Report (2013-2014)	Annual Report published	Date	2	30.06.2014	02.07.2014	04.07.2014	07.07.2014	09.07.2014
							4	2014	7.2014	014	4
									14		



Section 2 : Inter se priorities among Key Objectives, Success Indicators and Targets

S. No.	Objectives	Weight	Actions	Success Indicators	Unit	Weight	Target / Criteria				
							Excellent	Very good	Good	Fair	
							100%	90%	80%	70%	60%
*	Fiscal resource management	2	Utilization of released plan fund	Plan fund utilized	%	2	98	96	94	92	90
*	Efficient Functioning of the RFD System	3	Timely submission of Draft RFD for 2014-2015 for Approval Timely submission of Results for 2013-2014	On-time submission On-time submission	Date Date	2 1	May 15, 2014 May 1 2014	May 16, 2014 May 2 2014	May 19, 2014 May 5 2014	May 20, 2014 May 6 2014	May 21, 2014 May 7 2014
*	Enhanced Transparency / Improved Service delivery of Ministry/Department	3	Rating from Independent Audit of implementation of Citizens' / Clients' Charter (CCC) Independent Audit of implementation of Grievance Redress Management (GRM) system	Degree of implementation of commitments in CCC Degree of success in implementing GRM	% %	2 1	100 100	95 95	90 90	85 85	80 80
*	Administrative Reforms	7	Update organizational strategy to align with revised priorities Implementation of agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC) Implementation of agreed milestones for ISO 9001	Date % of Implementation % of implementation	Date % %	2 1 2	Nov.1 2014 100 100	Nov.2 2014 90 95	Nov.3 2014 80 90	Nov.4 2014 70 85	Nov.5 2014 60 80
			Implementation of milestones of approved Innovation Action Plans (IAPs)	% of implementation	%	2	100	90	80	70	60




Section 3: Trend Values of the Success Indicators

S. No.	Objectives	Actions	Success Indicators	Unit	Actual value for FY 2012-13	Actual value for FY 2013-14	Target value for FY 2014-15	Projected value for FY 2015-16	Projected value for FY 2016-17
1	Appraisal and management of soil health	Assessment of soil health	Soil health assessment under different crops and cropping systems	No.	-	8	6	6	6
		Management of soil health	INM packages developed for different agro-eco regions of the Country Developed conservation agricultural practices for crops / cropping systems Developed management practices for remediation of polluted soils	No.	8	10	8	9	9
2	Improving nutrient use efficiency	Balanced and judicious use of fertilizers	Soil test based balanced fertilizer prescription equations developed Technologies developed for improving nutrient use efficiencies Efficient bio-fertilizers strains/formulations developed	No.	4	4	3	4	4
3	HRD capacity building	Transfer of technology and creation of awareness/knowledge	Frontline demonstrations conducted Farmers' trainings organised Workshop/ seminar/ summer/winter school organized	No.	15	28	25	26	28
*	Publication/Documentation	Publication of the research articles in the journals having the NAAS rating of 6.0 and above Timely publication of the Institute Annual Report (2013-2014)	Research articles published Annual Report published	No.	34	35	36	37	38
			Annual Report published	Date	-	-	02.07.2014	-	-



S. No.	Objectives	Actions	Success Indicators	Unit	Actual value for FY 2012-13	Actual value for FY 2013-14	Target value for FY 2014-15	Projected value for FY 2015-16	Projected value for FY 2016-17
*	Fiscal resource management	Utilization of released plan fund	Plan fund utilized	%	99.9	99.8	96	98	98
*	Efficient Functioning of the RFD System	Timely submission of Draft RFD for 2014-2015 for Approval Timely submission of Results for 2013-2014	On-time submission	Date	-	-	May 16 2014	-	-
*	Enhanced Transparency / Improved Service delivery of Ministry/Department	Rating from Independent Audit of implementation of Citizens' / Clients' Charter (CCC)	Degree of implementation of commitments in CCC	%	-	-	95	-	-
		Independent implementation of Grievance Management system	Degree of success in implementing GRM	%	-	-	95	-	-
*	Administrative Reforms	Update organizational strategy to align with revised priorities	Date	Date	-	-	Nov.2, 2014	-	-
		Implementation of agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC)	% of Implementation	%	-	-	90	-	-
		Implementation of agreed milestones for ISO 9001	% of implementation	%	-	-	95	-	-
		Implementation of approved milestones of approved Innovation Action Plans (IAPs)	% of implementation	%	-	-	90	-	-





Section 4(a): Acronyms

S. No.	Acronym	Description
1	HRD	Human Resource Development
2	INM	Integrated Nutrient Management
3	IPNS	Integrated Plant Nutrient Supply System
4	KVK	Krishi Vigyan Kendra

Section 4(b): Description and definition of success indicators and proposed measurement methodology

S. No.	Success Indicator	Description	Definition	Measurement	General Comments
1	Soil health assessment under different crops and cropping systems	Soil health monitoring with the use of imbalanced and inadequate fertilizer application is essential to monitor the changes in different agro-eco regions. Assessment of soil health through delineating nutrient deficiency areas is essential for location specific fertilizer recommendation.	Long-term fertilizer experiments are assets to address the issue of soil health under continuous use of imbalanced and inadequate fertilizer application and also balanced and integrated nutrient use.	Soil health assessment/ improvement through different interventions.	
2	INM packages developed for different agro-eco regions of the country	Agricultural inputs like nutrient and water are not only costly but also scarce. Therefore, development of INM nutrient prescriptions for various crops and cropping systems is essential for attaining higher productivity levels.	Integrated plant nutrient supply systems (INM/ IPNS) encompassing conjunctive use of both chemical and organic nutrient sources will be developed to provide optimum nutrition to crops for sustaining better crop productivity for different crops and cropping systems.	No. of IPNS systems developed for crops and cropping systems	
3	Developed conservation agricultural practices for crops / cropping systems	Conservation agriculture is an important aspect in improving soil health through optimization of tillage and residue retention for better soil health.	Various crops and cropping systems would be evaluated and best practices would be identified for improved soil health.	Conservation agriculture technologies for sustainable crop production	



S. No.	Success Indicator	Description	Definition	Measurement	General Comments
4	Developed management practices for remediation of polluted soils	Judicious use of polluted water/sewage is important to meet the nutrient and water demand of crops especially near to urban areas	Assessment of soils polluted with sewage water and its remediation through plant at different sites	Technologies for use of polluted water	
5	Soil test based balanced fertilizer prescription equations developed	Soil test based fertilizer prescription is the demand of the hour due to large scale field variability on the farm level. Also the resource availability with the client need to be included sometimes to provide nutrients to crops through various resources than alone from the fertilizers.	Soil test based prescription equations would be developed for different crops in different agro-eco-regions.	No. of prescriptions developed	
6	Technologies developed for improving nutrient use efficiencies	Enhancing nutrient use efficiency is of utmost importance keeping in view the high cost of fertilizers and less availability due to limited production.	Different techniques will be employed to enhance the nutrient use efficiency.	No. of technologies developed	
7	Efficient bio-fertilizers strains/formulations developed	Soil is full of microbial life and very limited organisms have to be exploited for increasing nutrient use efficiency.	A continuous effort is required to research upon the beneficial microbial strains and their formulations to enhance nutrient use efficiency.	No. of formulations/strains identified	
8	Frontline demonstrations conducted	Frontline demonstrations (on-farm and off-farm) at different agro eco-regions is required to convince the stakeholders that the technology works at their location too.	Frontline demonstrations would be conducted at different locations in the country	No. of demonstrations conducted	
9	Farmers' trainings organised	Human resource development is a dynamic process. Farmers need to be educated through the experts directly. At this level they feel the pulse of high end research and many a time come to know the things they never heard at their farms.	Farmers' training will be conducted for farmers from different regions for faster technology transfer	No. of trainings organized	
10	Workshop/seminar/summer/ winter school organized	Human resource development is a dynamic process. Scientists working in narrow research areas many a time need to be updated on recent techniques/advances in research.	Scientists interaction would be facilitated through these activities	No. of workshops/summer/winter schools organized	





Section 5: Specific performance requirement from other departments that are critical for delivering agreed results

Location Type	State	Organization Type	Organization Name	Relevant Success Indicator	What is your requirement from this organization	Justification for this requirement	Please quantify your requirement from this organization	What happens if your requirement is not met
Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Section 6: Outcome/ Impact of activities of Department/ Ministry

S. No.	Outcome/ Impact	Jointly responsible for influencing this outcome/ impact with the following organisation(s)/ departments/ ministry(ies)	Success Indicator (s)	Unit	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
1.	Ensuring good soil health through balanced fertilization	State Agricultural Universities/ KVKs/ State Agricultural Departments	Increase micronutrient fertilizer use Increase in bio fertilizer use over previous year Increase in organic manure use	in % % in %	2 5 2	5 5 3	5 5 3	5 5 3	5 5 3



Performance Evaluation Report

S.No.	Objective(s)	Weight	Action(s)	Success Indicator(s)	Unit	Weight	Target / Criteria Value					Achievements	Raw Score	Performance Weighted Score	Percent achievements against Target values of 90% Col.	Reasons for shortfalls or excessive achievements, if applicable
							Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%					
1	Appraisal and management of soil health	40	Assessment of soil health	Soil assessment under different crops and cropping systems	No.	10	8	6	4	2	0	7	95	9.5	116.7	The achievement is within and very good category
			Management of soil health	INM packages developed for different agro-eco regions of the country	No.	15	10	8	6	4	2	9	95	14.3	112.5	The achievement is within and very good category
				Developed conservation agricultural practices for crops / cropping systems	No.	10	3	2	1	0	0	3	100	10.0	150.0	The achievement is within and very good category
				Developed management practices for remediation of polluted soils	No.	5	3	2	1	0	0	3	100	5.0	150.0	The achievement is within and very good category
2	Improving nutrient use efficiency	25	Balanced and judicious use of fertilizers	Soil test based balanced fertilizer prescription equations developed	No.	15	4	3	2	1	0	4	100	15.0	133.3	The achievement is within and very good category
				Technologies developed for improving nutrient use efficiencies	No.	5	3	2	1	0	0	3	100	5.0	150.0	The achievement is within and very good category
				Efficient bio-fertilizers strains/formulations developed	No.	5	6	5	4	3	2	6	100	5.0	120.0	The achievement is within and very good category





S.N o.	Objective(s)	Weight	Action(s)	Success Indicator(s)	Unit	Weight	Target / Criteria Value					Performance		Percent achievements against Target values of 90% Col.	Reasons for shortfalls or excessive achievements, if applicable	
							Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%	Achievements	Raw Score			Weighted Score
3	HRD & capacity building	15	Transfer of technology and creation of awareness/knowledge	Frontline demonstrations conducted Farmers' trainings organized	No.	8	30	25	20	15	10	28	96	7.7	112.0	The achievement is within excellent and very good category
4	Publication/ Documentation	5	Publication of the research articles in the journals having the NAAS rating of 6.0 and above	Research articles published	No.	3	43	36	29	22	15	47	100	3.0	130.6	The achievement is within excellent and very good category Some papers got published than expected
5	Fiscal resource management	2	Utilization of released plan fund	Plan fund utilized	%	2	98	96	94	92	90	100	100	2.0	-	-
6	Efficient Functioning of the RFD System	3	Timely submission of Draft RFD for 2014-2015 for Approval	On-time submission	Date	2	May 15, 2014	May 16, 2014	May 19, 2014	May 20, 2014	May 21, 2014	7 May 2014	100	2.0	-	-
7	Enhanced Transparency / Improved Service	3	Rating from Independent Audit of implementation	Degree of implementation of commitments in CCC	%	2	100	95	90	85	80	100	100	2.0	-	-
					Date	1	May 1 2014	May 2 2014	May 5 2014	May 6 2014	May 7 2014	21 April 2014	100	1.0	-	-



S.N o.	Objective(s)	Weight	Action(s)	Success Indicator(s)	Unit	Weight	Target / Criteria Value				Achievements	Performance		Percent achievements against Target values of 90% Col.	Reasons for shortfalls or excessive achievements, if applicable	
							Excellent 100%	Very Good 90%	Good 80%	Fair 70%		Poor 60%	Raw Score			Weighted Score
	delivery of Ministry/Department		n of Citizens' / Clients' Charter (CCC) Independent Audit of implementation of Grievance Redress Management (GRM) system	Degree of success in implementing GRM	%	1	100	95	90	85	80	100	100	1.0	-	-
8	Administrative Reforms	7	Update organizational strategy to align with revised priorities Implementation of agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC) Implementation of agreed milestones for ISO 9001 Implementation of approved milestones of Innovation Action Plans (IAPs)	Date Date % of Implementation	Date	2	1 Nov. 2014	2 Nov. 2014	3 Nov. 2014	4 Nov. 2014	5 Nov. 2014	100	100	2.0	-	-
					%	1	100	90	80	70	60	100	100	1.0	-	-
					%	2	100	95	90	85	80	100	100	2.0	-	-
					%	2	100	90	80	70	60	100	100	2.0	-	-

Total Composite Score: 98.50
Rating: Excellent

