आज़ादी का अमृत महोत्सव

G20 भारत 2023 INDIA

INTERNATIONAL YEAR OF MILLETS 2023

हर कदम, हर डगर किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद
Agrisearch with a human touch

वार्षिक प्रतिवेदन
Annual Report
2022

भाकृअनुप- भारतीय मृदा विज्ञान संस्थान
ICAR - INDIAN INSTITUTE OF SOIL SCIENCE

Nabibagh, Berasia Road, Bhopal – 462 038 (M.P.)
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Sardar Patel Outstanding ICAR Institution
King Bhumibol World Soil Day Awardee

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Preface

In agricultural domain, healthy soil is capable of providing numerous ecosystem services such as food production, nutrient supply, detoxification, water and nutrient retention, maintaining biodiversity, and carbon sequestration, which in turn, contribute to various Sustainable Development Goals (SDGs) of UN. In this context, Soil Health, the capacity of soils to contribute to ecosystem services in line with the UN-SDGs emphasizes the need for interdisciplinary research approaches for sustainable agricultural production. Presently, the intensive farming practices coupled with rapid urbanization and industrialization have led to deterioration of soil health and adversely affected the nutrient cycling and posed a great threat to soil and other biodiversity. Under such scenario, to prevent further decline in soil health and improve agricultural productivity, an in-depth knowledge of soils and its processes are essential as the ecology and biodiversity of the soil beneath our feet are relatively less understood. These challenges have bestowed a greater sense of responsibility on the scientists working in soil science and allied specializations towards thorough research on the sustainable management of soil resources. Conversely, shrinking agricultural land resources coupled with soil degradation in India and elsewhere poses a greater risk to food production system, which adversely affects crop yields and leads to malnourishment in many parts of the globe including India. Hence, it is presumed that the sustainable management of soil health is indispensable for sustaining agricultural productivity. This necessitates regular evaluation of our soil resources and provides appropriate technological interventions for enhancing soil health and crop productivity. Also, there is a need to create awareness among people on the roles and functions of soil for the sustenance of humanity through national / international campaigns.

ICAR-Indian Institute of Soil Science (ICAR-IISS), Bhopal is engaged in research with mandate “to provide scientific basis for enhancing and sustaining productivity of soil resource with minimal environmental degradation”. The institute has developed many potential and feasible technologies with field-level validation for the improvement of soil health to address the emerging issues and challenges. This annual report vividly illustrates the multi-scale approaches and work done in the area of soil health and input use efficiency, conservation agriculture and carbon sequestration, greenhouse gas emission, soil microbial diversity and genomics, soil pollution, remediation and environmental security. The report also describes the work done on farmers’ participatory research and demonstration of the technologies at farmers’ fields as well as across the length and breadth of the country through various AICRP/AINP/CRPcentres/ SCSP/ TSP programs.

During the period under report, some new technologies and methodologies were developed and refined by the institute, viz. development of prediction models for physico-chemical soil properties using MIR spectroscopy; biofertilizer consortia and PGPR for major crops; identification of nutrient use efficient wheat genotypes; CA practices for soybean and maize in vertisols. Besides, on the basic research front, endophytic fungal, methylotropic and thermophilic bacterial diversity identified for bio-prospecting and spatio-temporal variability of available sulphur and micronutrients in soils of a hilly region of northern India was investigated. It is thus, a great pleasure for me to bring out the Annual Report 2022 of the ICAR-Indian Institute of Soil Science.

I take this opportunity to express my sincere appreciation to all the In-charge Project Coordinators and In-charge Head of the 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 the institute.

I place on record, my sincere appreciation to Drs. A.B. Singh, R. Elanchezhian, A.K. Tripathi, Asha Sahu, Jitendra Kumar, Immanuel C Haokip, D.K. Yadav, Khushboo Rani and Abinash Das for their dedicated efforts in compiling and editing the report. The service rendered by Mr. S.K. Kori and Mr. S.K. Parihar in collecting information and typesetting the manuscript is appreciated.

I acknowledge, with a deep sense of gratitude and respect, Hon’ble Dr. Trilochan Mohapatra, the then Secretary, DARE and Director General, ICAR and Dr Himanshu Pathak, Secretary, DARE and Director General, ICAR for their consistent guidance, inspiration and encouragement as well as providing necessary financial support for the overall growth and development of the institute. I am highly thankful to Dr. S.K. Chaudhari, Deputy Director General (NRM) and Dr Adlul Islam the then ADG (SWM) and Dr. A. Velmurugan,Assistant Director General (SWM) and Dr. A.K. Patra, the then Director, ICAR-IISS, Bhopal for their active involvement and constructive suggestions in carrying out various research and development activities for the overall progress of the institute.

Bhopal
June 2023

(S.P. Datta)
Director

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कार्यकारी सारांश

विषयवस्तु -I : मृदा स्वास्थ्य एवं पोषक तत्व उपयोग दक्षता

आदान उपयोग दक्षता और मृदा स्वास्थ्य में सुधार

- लगभग 120 जीनोटाइप में से चुने गए गेहूँ के चौबीस जीनोटाइप का मूल्यांकन खेत की स्थितियों के तहत कम नाइट्रोजन, कम फास्फोरस और उर्वरक पोषक तत्व की सामान्य अनुशंसित खुराक (जीआरडी) (120–60–40 किग्रा./है. एनपीके) के साथ पोषक तत्व ग्रेडिएंट के प्लॉट के तहत किया गया था। इन गेहूँ जीनोटाइपों के बीच कृषि–आकृति विज्ञान और उपज संबंधी विशेषताओं में काफी विविधता देखी गई और 6 किस्मों को क्रमशः कम नाइट्रोजन और फॉस्फोरस आपूर्ति स्थितियों के लिए उपयुक्त पाया गया।
- वर्टिसोल में आईपीएनएस मॉड्यूल ने संकेत दिया कि एसटीसीआर आधारित आईएनएम मॉड्यूल (75 प्रतिशत एनपीके + 5 टन/है. गोबर की खाद) और मक्का और चने के मामले में हर साल क्रमशः 25 टन/है. की दर से गोबर की खाद की अवशिष्ट उर्वरता के साथ विकास मापदंडों और उपज विशेषताओं में काफी सुधार हुआ है। 75 प्रतिशत एनपीके+5 टन/है. गोबर की खाद आधारित आईएनएम मॉड्यूल के साथ काफी अधिक सिस्टम उत्पादकता देखी गई। गोबर की खाद के उच्च स्तर के मामले को छोड़कर सभी उपचारों में नाइट्रोजन और फॉस्फोरस के लिए स्पष्ट पोषक तत्व संतुलन नकारात्मक था, जबकि एसटीसीआर आधारित आईएनएम मॉड्यूल के तहत फॉस्फोरस संतुलन सकारात्मक था।
- नीम लेपित यूरिया (एनसीयू) और एग्रोटेन निगमित यूरिया (एआईयू) की विभिन्न खुराक के बीच धान की पैदावार और पोषक तत्व दोहन में कोई महत्वपूर्ण अंतर दर्ज नहीं किया गया।
- मध्य भारत के वर्टिसोल्स में धान –गेहूँ फसल प्रणाली के तहत तीन अलग–अलग बायोचार के उपयोग से खाद या उर्वरक के बिना, गेहूँ के दानों की उपज पर महत्वपूर्ण प्रभाव नहीं पड़ा। केवल उर्वरक के उपयोग पर बायोचार के उपयोग की सकारात्मक प्रतिक्रिया बैंगन की उपज और नुआपाड़ा, ओडिशा की अम्लीय मिट्टी में भिंडी की उपज के संबंध मे दिखी गई।
- मध्य भारत के वर्टिसोल में संरक्षित कृषि आधारित सोयाबीन–गेहूँ फसल प्रणाली के आठ वर्षों से पता चला कि 90% अवशेषों के अवधारण के परिणामस्वरूप पारंपरिक जुताई की तुलना में मिट्टी के कुल कार्बन में 47% सुधार और मिट्टी के कुल नाइट्रोजन में 17% सुधार हुआ।
- मध्य भारत के लिए विकसित कृषि–बागवानी मॉड्यूल के तहत, आँवला के बाग में सबसे अधिक कार्बन भंडार देखा गया और उसके बाद अमरूद का नंबर आया। फसलों में फेनोलिक सामग्री के साथ–साथ पत्तियों की मोटाई काली पॉलीथीन से मल्चिंग से काफी प्रभावित हुई।
- वर्टिसोल के महीन मिट्टी के अंशों के एक्सआरडी अध्ययन में मध्य भारत की 9 बेंचमार्क मिट्टी श्रृंखला में वर्मीक्यूलाइट और पेडोजेनिक क्लोराइट, अभ्रक, काओलिन, क्वार्ट्ज और फेल्डस्पार की थोड़ी मात्रा के साथ स्मेक्टाइट खनिज का प्रभुत्व दर्ज किया गया। मिट्टी के नमूनों के वर्णक्रमीय परावर्तन वक्र भी स्पेक्ट्रोरेडियोमीटर का उपयोग करके उत्पन्न किए गए।
- एससीएसपी के तहत चार समूहों के माध्यम से भोपाल जिले के 16 गांवों में आयोजित 86 प्रदर्शनों के माध्यम से अनुशंसित उर्वरक खुराक और एकीकृत पोषक तत्व प्रबंधन उपचारों ने मक्का और सोयाबीन फसल के लिए पोषक तत्व प्रबंधन के किसानों के अभ्यास में महत्वपूर्ण सुधार दिखाया है।
- चार अध्ययन जिलों में जारी पोषक तत्व प्रबंधन प्रथाओं के कारण मिट्टी के स्वास्थ्य में बदलाव पर अध्ययन से पता चला कि उधम सिंह नगर में लगभग 68 प्रतिशत कृषि योग्य भूमि, पश्चिम गोदावरी में 69 प्रतिशत, होशंगाबाद में 48 और दावेनगेरे जिला में 30 प्रतिशत में मिट्टी का स्वास्थ्य खराब हो गया है। इसके अलावा तीन जिलों (यूएस नगर, पश्चिम गोदावरी और दावेनगेरे) में भूजल के नमूने पीने के लिए असुरक्षित पाए गए।
- मध्य प्रदेश के बालाघाट जिले के आदिवासी गांवों, कवेली, कुल्फा और सर्रा के सतही और भूजल संसाधनों के मामले में जल गुणवत्ता मापदंडों का विश्लेषण किया गया और उन्हें सुरक्षित सीमा में पाया गया। हालाँकि, कुओं और नदियों में सिलिकॉन की मात्रा 144–262 mg/L की सीमा में पाई गई।
- एसटीसी/टीएसपी परियोजना के तहत मध्य प्रदेश के बैतूल जिले के किसानों की प्रथाओं के साथ एकीकृत राइजोबियम, पीएसबी, केएसबी, जेडएसबी, एजोटोबैक्टर, एसीटोबैक्टर, ट्राइकोडर्मा और स्यूडोमोनास जैसे तरल जैव–उर्वरक का सोयाबीन, मक्का और धान में प्रदर्शन किया गया।
- टीएसपी कार्यक्रम के तहत मृदा स्वास्थ्य और फसल उत्पादकता में सुधार के लिए छत्तीसगढ़ के आकांक्षी जिले राजनांदगांव में धान (एमटीयू 1010) और ग्रीष्मकालीन मूंग (आईपीएम 410–3) के संतुलित उर्वरक अनुप्रयोग और बेहतर उच्च उपज प्रजातियों का प्रदर्शन किया गया।

अखिल भारतीय समन्वित अनुसंधान परियोजनाएँ

- वर्टिसोल मृदा के तहत प्रमुख फसलों में उर्वरकों और खादों के दीर्घकालिक अनुप्रयोग ने स्पष्ट रूप से प्रदर्शित किया कि पोषक तत्वों के असंतुलन के कारण फसल उत्पादकता में गिरावट आई और 100 प्रतिशत एनपीके + गोबर की खाद (आईएनएम) के प्रयोग के साथ उत्पादकता अधिकतम पाई गई। पोषक तत्वों के असंतुलन के परिणामस्वरूप काली मिट्टी में पोषक तत्वों के दोहन में कमी आई। एलटीएफई के तहत विभिन्न वर्टिसोल में संतुलित और एकीकृत पोषक तत्व प्रबंधन (आईएनएम) के साथ सतत उपज सूचकांक (एसवाईआई) में बढ़ोत्तरी पाई गई।

- आईपीएनएस के तहत उर्वरक नुस्खे समीकरण सरसों (जीएससी–7), देर से बोए गए गेहूं (एचडी 3059), ब्लैक नाइजर (राजेंद्र श्यामा), कपास संकर (आरसीएच 659 बीजी II), मूंगफली (कैलाश), गेहूँ (एचडी–2967), बैंगन (हिसार श्यामल), मक्का (एनएमएच 8352), पत्तागोभी (एनएस–22), भिंडी (वीएनआर–999), स्वीट कॉर्न (सुगर–75), धान (सीजी हाइब्रिड –2), बाजरा (सुपर–82), मटर (एपी–3) लहसुन (स्वेता), बार्नयार्ड मिलेट (एमडीयू 1), चना (एनबीईजी 49), अलसी (प्रियम), धान (केटेकीजोहा), तिल (स्वेता), मूली (रवि तेजस), राजमा बीन (फुले राजमा) और चना (जेजी–36) उर्वरक नुस्खे समीकरण विकसित किए गए।
- भारत के निचले गंगा मैदान के नए जलोढ़ क्षेत्र के जैविक उत्पादन प्रणाली के तहत संभावित खनिजीकरण योग्य नाइट्रोजन का अनुमान लगाने के लिए फॉस्फेट बफर को एक उपयुक्त निष्कर्षक के रूप में देखा गया।
- छह वर्षों (2015–2021) में भारत के एक पहाड़ी क्षेत्र की खेती वाली मिट्टी में उपलब्ध सल्फर, उपलब्ध सूक्ष्म पोषक तत्व और कुछ चयनित मिट्टी के गुणों जैसे मिट्टी पीएच, विद्युत चालकता (ईसी) और मिट्टी कार्बनिक कार्बन (एसओसी) की स्थानिक–अस्थायी परिवर्तनशीलता वितरण मानचित्रण और साइट–विशिष्ट पोषक तत्व प्रबंधन के लिए मूल्यांकन किया गया।
- विभिन्न दरों और आवृत्तियों पर बोरॉन (बी) के उपयोग से नियंत्रण के तहत प्राप्त उपज की तुलना में मूंगफली और गोभी की उपज में काफी वृद्धि हुई। मूंगफली और गोभी की फसल की उपज बढ़ाने के लिए वैकल्पिक वर्षों में 1.0 किग्रा./है. बी के प्रयोग से बृद्धि इष्टतम पाई गई। बोरॉन के प्रयोग से मूंगफली की फली, हल्म, पत्तागोभी और मिट्टी में उपलब्ध बी की मात्रा में वृद्धि हुई।
- मक्के में वैकल्पिक वर्ष में 7.5 और 10 किग्रा./है. और प्रत्येक वर्ष 5.0 से 10 किग्रा./है. जस्ता के उपयोग से बगैर जस्ता उपचार की तुलना में मक्के की तुल्यांक उपज में काफी वृद्धि हुई है। बगैर जस्ता अनुप्रयोग की तुलना में प्रति वर्ष 10.0 किग्रा./है. जस्ता के उपयोग से अधिक उत्पादन, अनाज का आकार, भूसा, और कुल जस्ता सांद्रता मक्का और गेहूँ की फसलों में देखी गई। स्पष्ट जस्ता पुनर्प्राप्ति दक्षता मक्का की फसल के लिए 0.17 से 1.46% और गेहूं की फसल के लिए 0.34 से 1.70% तक जस्ता अनुप्रयोग का विभिन्न दरों और आवृत्तियों के तहत भिन्न पाई गई।

विषयवस्तु – II: संरक्षण कृषि, कार्बन पृथक्करण और जलवायु परिवर्तन

- बिना जुताई के तहत सोयाबीन और मक्के की उपज अपेक्षाकृत अधिक थी, जो कम जुताई अवशेष प्रतिधारण के बराबर है। एसटीसीआर आधारित उर्वरक अनुप्रयोग में 100 प्रतिशत आरडीएफ और 75 प्रतिशत आरडीएफ की तुलना में काफी अधिक उपज दर्ज की गई। मृदा कार्बनिक कार्बन आँकड़ों ने संकेत दिया कि जुताई प्रथाओं की परवाह किए बिना, सतह परत ने उच्च मान दर्ज किए।
- जल उपयोग दक्षता (डब्ल्यूयूई) स्प्रिंकलर और बाढ़ सिंचाई की तुलना में ड्रिप सिंचाई के तहत काफी अधिक थी। बाढ़ सिंचाई की तुलना में सिंचाई की ड्रिप और स्प्रिंकलर प्रणाली के तहत उच्च जल उत्पादकता प्राप्त की गई।
- संरक्षण कृषि प्रणाली ने समय, श्रम और आदान लागत की सहवर्ती बचत और मिट्टी के स्वास्थ्य मापदंडों और उपज की स्थिरता में सुधार के साथ पारंपरिक कृषि पद्धतियों के बराबर सोयाबीन उपज स्तर बनाए रखा।
- सोयाबीन–गेहूँ प्रणाली की तुलना में मक्का–चना फसल प्रणाली में मिट्टी के नुकसान और अपवाह की तुलनात्मक रूप से अधिक संभावना देखी गई। हालाँकि, दोनों फसल प्रणालियों के तहत पारंपरिक जुताई में संरक्षण कृषि के अन्य उपचारों की तुलना में सबसे अधिक मिट्टी की हानि और अपवाह दर्ज किया गया।
- कृषि–हाइड्रोलॉजिकल मृदा–जल–वायुमंडल–संयंत्र (एस डब्ल्यू ए पी) मॉडल को कैलिब्रेट किया गया था और उचित सटीकता के साथ क्षेत्र के जल संतुलन की भविष्यवाणी करने के लिए इसका उपयोग किया गया था। इस अध्ययन से संकेत मिलता है कि आरसीपी 4.5 और आरसीपी 8.5 के तहत मिट्टी का तापमान 2 से 3 डिग्री सेल्सियस अधिक होगा और आरसीपी 8.5 में शुद्ध जल संतुलन वर्तमान परिदृश्य की तुलना में 1.57 सेमी^{3}/सेमी^{3} कम है।
- RothC मॉडल ने प्रदर्शित किया कि गोबर की खाद के साथ प्रबंधन प्रथाओं में धान आधारित फसल प्रणाली में मृदा कार्बनिक कार्बन जब्ती को बढ़ाने की काफी संभावना है। जलवायु परिवर्तन से अध्ययन किए गए सभी कृषि पारिस्थितिकी तंत्रों में मृदा कार्बनिक कार्बन पृथक्करण की दर कम हो जाती है, आरसीपी 8.5 के तहत उच्च गिरावट दर्ज की गई, इसके बाद आरसीपी 6.0, आरसीपी 4.5 और आरसीपी 2.6 आते हैं।
- APSIM फसल मॉडल के माध्यम से मध्य प्रदेश में अरहर की उपज के अंतर का आकलन किया गया और पता चला कि नवंबर के अंतिम सप्ताह के दौरान 60 मिमी की एक सिंचाई से मध्य भारत में अरहर की उपज में 300 किग्रा./है. का सुधार हुआ।
- मध्य प्रदेश के रायसेन जिले के डिजिटल मृदा मानचित्र को एकीकृत करते हुए एक निर्णय समर्थन प्रणाली विकसित की गई, जिसे अन्य जिलों/राज्यों के लिए बढ़ाया जा सकता है।
- कृषि सूखे को चिह्नित करने के लिए मध्य प्रदेश के भोपाल, सीहोर और शाजापुर जिलों के लिए उपग्रह डेटा से सूखा सूचकांक यानी मानकीकृत वर्षा सूचकांक (एसपीआई–3) और मानकीकृत वनस्पति सूचकांक (एसवीआई) की गणना की गई। एसपीआई–3 के अनुसार, अत्यधिक और गंभीर सूखा खरीफ 2001 और 2002 और रबी 2001, 2008, 2012 और 2017 में पाया गया। एसवीआई के अनुसार, रबी 2001, 2002, 2003, 2005, 2006, 2007, 2008, 2009, 2016 और 2018 में सूखा पाया गया। शाजापुर जिले को सीहोर और भोपाल के बाद सूखे से अधिक प्रभावित पाया गया।

विषयवस्तु – III: सूक्ष्मजैविक विविधता और जैव प्रौद्योगिकी

- सोयाबीन, गेहूँ, सरसों, चना और अलसी की बीज उपज 50 प्रतिशत जैविक , 50 प्रतिशत अकार्बनिक उपचार के बाद 100 प्रतिशत जैविक उपचार में सबसे अधिक दर्ज की गई। क्षेत्र परीक्षण के बाद यह पाया गया कि मूंगफली की जीपीबीडी–5

किस्म (2111 किग्रा./है.) और सरसों की अरावली किस्म (1144 किग्रा./है.) ने अन्य किस्मों की तुलना में उच्चतम प्रदर्शन दिखाया।

- मृदा एंजाइम गतिविधियां जैसे फ्लोरोसिन डाई एसीटेट (एफडीए), डिहाइड्रोजनेज और क्षारीय फॉस्फेट 100% कार्बनिक प्लॉट के तहत उच्चतम पाए गए, जो 100 प्रतिशत अकार्बनिक की तुलना में 50 प्रतिशत कार्बनिक. प्राकृतिक खेती प्लॉट और 50 प्रतिशत कार्बनिक. गेहूँ 50 प्रतिशत अकार्बनिक प्लॉट के समान पाया गया।
- कुल मिलाकर गेहूँ की उच्चतम अनाज उपज रासायनिक कीटनाशकों (आईसीएमपी) के साथ एकीकृत फसल प्रबंधन प्रथाओं में दर्ज की गई, जो प्राकृतिक खेती (आईसीएमएनएफ) और एआई–एनपीओएफ पैकेज के साथ एकीकृत फसल प्रबंधन प्रथाओं के बराबर थी।
- एंडोफाइटिक फंगल आइसोलेट्स जैसे फ्यूसेरियम और कर्वुलरिया एसपी भारी धातु सहनशीलता की विस्तृत श्रृंखला दिखाते हैं और लैड, कैडमियम, क्रोमियम और पारा भारी धातुओं की उपस्थिति में अच्छी तरह बढ़ते हैं।
- एक संभावित गुलाबी पिगमेंटिंग मिथाइलोट्रॉफ जीवाणु मिथाइलो बैक्टररेडियो टोलरेंस N39 को धान के पौधे (ओरिजा सैटिवा) के फाइलोप्लेन से अलग किया गया, जो 0.45 से 3.09 की दर ($\mu g\ mL^{-1}\ d^{-1}$) पर β कैरोटीन का उत्पादन करता था। β कैरोटीन का जैव संश्लेषण प्रति 2 दिनों में 10 मिनट के लिए यूवी के संक्षिप्त संपर्क से उत्तेजित होता है। इस प्रकार, एन 39 कोशिकाओं या कैरोटीनॉयड अर्क के पत्ते के अनुप्रयोग ने पौधे (मटर) के यूवी विकिरण के प्रतिरोध को बढ़ा सकते हैं।
- मध्य भारत के तीन गर्म झरनों से 101 थर्मोफिलिक जीवाणु पृथक किए गए। छोटी अनहोनी (सीए), बड़ी अनहोनी (बीए) और तातापानी (टीए) को उनके पोटेंसी इंडेक्स गणना के माध्यम से लिग्निन और सेलूलोज डिग्रेडिंग जीवाणुओं के लिए आगे जांचा गया।
- तीन अलग–अलग मिट्टी में उगाई गई सरसों (प्रजाति पूसा मेहक) के राइजोप्लेन और एंडोराइजोस्फीयर से 37 आइसोलेट्स प्राप्त किए गए। वर्टिसोल्स, इन्सेप्टिसोल्स और अल्फिसोल्स और उनके पौधों के विकास को बढ़ावा देने वाले गुणों का परीक्षण किया गया।
- एलटीएफई बैरकपुर, एलटीएफई पालमपुर और एलटीएफई परभणी में 100 प्रतिशत एनपीके+गोबर की खाद उपचार में मृदा एंजाइम गतिविधियों (जीएमईए), शैनन विविधता सूचकांक (एच) और सिम्पसन यूल इंडेक्स (एसवाईआई) का उच्चतम ज्यामितीय माध्य देखा गया।
- क्षेत्र अध्ययन से संकेत मिलता है कि फॉसफोरस उर्वरक के साथ बीज प्राइमिंग के रूप में सिलिका का उपयोग करने से मध्य भारत के वर्टिसोल में धान–गेहूँ फसल प्रणाली पर महत्वपूर्ण प्रभाव पड़ सकता है।
- पारंपरिक जैव उर्वरक उपचार की तुलना में बीजों की मशीनीकृत कोटिंग में मिट्टी की एंजाइम गतिविधियां (डीहाइड्रोजनेज, एसिड और क्षारीय फॉस्फेट गतिविधियां) और पोषक तत्व की स्थिति (नाइट्रोजन, फॉस्फोरस, पोटाश और जस्ता) में वृद्धि हुई।

विषयवस्तु –IV: मृदा प्रदूषण, निवारण और पर्यावरण सुरक्षा

- 200 और 400 टन/है. की दर से तालाब की राख के प्रयोग से गेहूँ और सोयाबीन की फसल के अनाज और भूसे की उपज में उल्लेखनीय वृद्धि हुई। विशेष रूप से उच्च दर पर तालाब की राख के उपयोग से काली मिट्टी में मिट्टी के गुणों पर काफी प्रभाव पड़ा। 200 टन/है. या अधिक की दर से राख डालने से ऊपरी मिट्टी का थोक घनत्व (0–15 सेमी.) काफी कम हो गया।
- अकेले या गोबर की खाद के संयोजन में मिट्टी में संशोधक के रूप में प्रेसमड और स्टील स्लैग के प्रयोग से सीसा और कैडमियम से दूषित मिट्टी में क्रमशः लैड और कैडमियम की गतिशीलता को कम करने की अधिक संभावना होती है।
- एमएसडब्ल्यूसी में संभावित विषाक्त तत्वों की उपस्थिति माइक्रोबियल गतिविधि पर नकारात्मक प्रभाव डालती है। CO_2 विकास में कमी पर MSW में भारी धातुओं (Cd + Pb +Cr + Ni) का संयुक्त प्रभाव व्यक्तिगत भारी धातु प्रभाव (एकमात्र प्रभावय Cd/Pb/Cr/Ni) के प्रभाव की तुलना में काफी अधिक (42 प्रतिशत) था।
- उपचारित सीवेज जल (टीएसडब्ल्यू) से सिंचित मिट्टी और 50 प्रतिशत आरडीएफ. वर्मीकम्पोस्ट 5 टन/है. से ताजे पानी से सिंचित मिट्टी की तुलना में पालक की ताजी पत्ती का वजन 95 प्रतिशत तक बढ़ जाता है। 50 प्रतिशत आरडीएफ के साथ बायोचार/फ्लाई ऐश/वर्मीकम्पोस्ट का सह–अनुप्रयोग टीएसडब्ल्यू–सिंचित मिट्टी में 100 प्रतिशत आरडीएफ की तुलना में N_2O उत्सर्जन में 88 प्रतिशत की कमी आई। 100 प्रतिशत आरडीएफ . एफडब्ल्यू की तुलना में टीएसडब्ल्यू–सिंचित मिट्टी में 50 प्रतिशत आरडीएफ. बायोचार/फ्लाई ऐश/वर्मीकम्पोस्ट में मीथेन की खपत 3.2 गुना अधिक पाई गई।
- बायोचार (0, 5 और 10 टन है.) और चूने (0 और 800 कि.ग्रा. है.) जैसे संशोधन के साथ अलग–अलग खुराक (0, 20 और 40 टन/है.) पर सूखे और ताजा–कीचड़ के साथ माइक्रोकोस्म प्रयोग किया गया था। बुवाई के 60 दिन बाद दर्ज किया गया पीएच 30 दिन बुवाई के बाद से काफी अधिक था। 30 दिन बुवाई के बाद के दौरान एकत्रित लीचेट का ईसी 3 डीएस/मीटर से अधिक था। हालाँकि, ईसी मूल्य 60 दिन बुवाई के बाद पर काफी कम हो गया था। 30 और 60 दिन बुवाई के बाद के दौरान एकत्र किए गए लीचेट्स में सकारात्मक ओआरपी मान हैं।
- अमलाई कोयला खदान क्षेत्र से एकत्र किए गए पानी का पीएच मध्यम से अत्यधिक क्षारीय पाया गया और ईसी 100–4000 µS/सेमी. के बीच थी। हालाँकि, मिट्टी प्रकृति में बहुत मजबूत से थोड़ी अम्लीय पाई गई और ईसी 105–210 µS/सेमी. के बीच भिन्न थी। शारदा कोयला खदान क्षेत्र की मिट्टी में कार्बनिक कार्बन उच्च, उपलब्ध फॉस्फोरस में निम्न से मध्यम और उपलब्ध पोटैशियम में मध्यम पाया गया।
- पाइरीन सांद्रता को 0 से 200 मिलीग्राम/किग्रा तक बढ़ाने से वर्टिसोल, अल्फिसोल और इंसेप्टिसोल में डिहाइड्रोजनेज गतिविधियों में क्रमशः 61 प्रतिशत, 65 प्रतिशत और 57 प्रतिशत

की कमी आई। इसी तरह, पाइरीन के अनुप्रयोग पर भी मृदा क्षारीय फॉस्फेट गतिविधियाँ पर भी नकारात्मक प्रभाव पड़ा।

- कानपुर अपशिष्ट डंप से 120 भू–संदर्भित मिट्टी के नमूनों के भारी धातु विश्लेषण से पता चला कि स्फेरिकल मॉडल क्रोमियम और जस्ता (आरएमएसई मूल्य 582.65 और 57.12) के लिए सबसे अच्छा था, जबकि गुआसियन मॉडल सीसा और कैडमियम (आरएमएसई मूल्य 13.79 और 2.86) के लिए सबसे उपयुक्त था। साधारण क्रिगिंग अंतर्वेशन विधि के साथ भू–सांख्यिकीय विश्लेषण से क्रोमियम (एनःएस अनुपात 21.6 प्रतिशत) के लिए मजबूत स्थानिक निर्भरता और सीसा, कैडमियम और जस्ता (एनःएस अनुपात 52.9 प्रतिशत, 51.5 प्रतिशत और 28.7 प्रतिशत) के लिए मध्यम स्थानिक निर्भरता का पता चला।
- सोयाबीन–गेहूँ फसल प्रणाली में, गेहूँ के तने और जड़ों की औसत क्षय दर सोयाबीन के तने और जड़ की तुलना में क्रमशः 3.6 और 4.7 गुना अधिक थी। हालाँकि, मक्का–चना फसल प्रणाली में, मक्का के तने की अपघटन दर चने के तने की तुलना में 0.7 गुना से कम थी। विभिन्न प्रकार के अवशेषों और पोषक तत्वों के प्रबंधन में जमीन के ऊपर के भूसे की अपघटन दर जमीन के नीचे की जड़ों की तुलना में काफी अधिक थी।
- मेसोकोसम प्रयोग में मीथेन उत्सर्जन और खपत पर अवशेषों के प्रकार, पोषक तत्व और मिट्टी की नमी का एक महत्वपूर्ण परस्पर प्रभाव बताया गया। फसल अवशेषों और पोषक तत्वों के स्तर में, मिट्टी की नमी को 80 से 60 प्रतिशत तक कम करने से क्षेत्र की क्षमता में मीथेन की खपत बढ़ गई। औसत मीथेन दो मिट्टी की नमी पर फलक्स क्रमशः 2.72 और –6.97 $\mu g\text{-}C\ kg^{-1}$ मिट्टी पाई गई।
- मिट्टी की सतह के ऊपर नमी के स्तर को मापकर मिट्टी की नमी के स्तर का अनुमान लगाने के लिए एक गैर–संपर्क नैनो सेंसर विकसित किया गया था। सेलूलोज मैट्रिक्स की आकृति विज्ञान या संपत्ति को बदले बिना कोबाल्ट क्लोराइड के साथ कार्यात्मक सेलूलोज मैट्रिक्स विकसित किया गया था। इस कार्यात्मक सेलूलोज मैट्रिक्स का उपयोग विकसित प्रोटोटाइप (एमईजीएच) का उपयोग करके आगे के अध्ययन के लिए स्ट्रिप्स बनाने के लिए किया गया है।
- प्लास्टिक मल्च फिल्म को अपनाने से छोटे किसानों की आजीविका में बदलाव आया। क्षेत्र प्रयोग में पॉली–मल्चिंग से मक्के की उपज में दो गुना वृद्धि दर्ज की गई।
- नगर निगम के ठोस अपशिष्ट कंपोस्टिंग इकाई के छोटे शहरों से एकत्र किए गए नमूनों में बड़े शहरों की तुलना में धातुओं का भार कम है। जैसा कि स्वच्छ सूचकांक से संकेत मिलता है, किसानों के खेत से एकत्र किए गए खाद के नमूनों में धातु की मात्रा अपेक्षाकृत कम थी। एकत्रित नमूनों का एक्सआरएफ विश्लेषण किया जा रहा है।

Executive Summary

Theme - I: Soil Health and Nutrient Use Efficiency

Improving input use efficiency and soil Health

- Twenty four genotypes of wheat selected from about 120 genotypes were evaluated under plots of nutrient gradient with low Nitrogen, low Phosphorus and general recommended dose of fertilizer (120-60-40 kg ha^{-1} of NPK) under field conditions. Great diversity in agro-morphology and yield attributing traits were observed among these wheat genotypes and six varieties were found to be suitable for low N and P supply conditions, respectively.
- The IPNS module in vertisols indicated that growth parameters and yield attributes significantly improved with STCR based INM module (75% NPK +5 t FYM) and residual fertility of FYM @ 25 t ha^{-1} every year in case of maize and chickpea, respectively. Substantially higher system productivity was noticed with 75% NPK +5t FYM based INM modules. Apparent nutrient balance was negative for N and K in all treatments except in case of higher level of FYM while P balance was positive under STCR based INM modules.
- No significant difference in rice yields and uptake were recorded between the different doses of neem coated urea (NCU) and agrotain incorporated urea (AIU).
- Application of three different biochar under rice-wheat cropping system in Vertisols of Central India did not result in significant effect on wheat grain yield without manure or fertilizer addition.Positive response of biochar addition over fertilizer application alone was observed with respect to yield of brinjal and okra in acidic soils of Nuapada, Odisha.
- Under agri-horticultural module developed for central India, highest carbon stock was observed in aonla orchard followed by guava. Phenolic content as well as leaf thickness in fruit crops was significantly influenced by mulching with black polyethene.
- XRD study of fine clay fractions of vertisol recorded the dominance of Smectite mineral with small amount of vermiculite and pedogenic chlorite, mica, kaolin, quartz and feldspar in nine benchmark soil series of Central India. The spectral reflectance curves of the soil samples were also generated using spectroradiometer.
- Study on changes in soil health due to the continuing nutrient management practices over four study districts, revealed that soil health has deteriorated in about 68% arable land in Udham Singh Nagar, 69% in West Godavari, 48% in Hoshangabad and 30% in Davengere district. Also in three districts (US Nagar, West Godavari and Davengere), ground water samples were found to be unsafe for drinking.
- Recommended fertilizer dose and integrated nutrient management treatments showed significant improvement over farmer practice in maize and soybean crop as observed through 86 demonstrations conducted in 16 SC dominated villages of Bhopal district.
- Water quality parameters were analyzed and found to be in safe limits in case of surface and ground water resources of the tribal villages, Kaweli, Kula and Sarra of Balaghat district in Madhya Pradesh. However, Silicone (Si) content in wells and rivers was in the range of 144-262 mg L^{-1}.
- Liquid bio-fertilizers such as *Rhizobium*, PSB, KSB, ZSB, *Azotobacter, Acetobacter*, bio- formulations of *Trichoderma* and *Pseudomonas* was demonstrated in soybean, maize and paddy in tribal farmer's field of Betul district.
- The seed yield of soybean, wheat, mustard, chickpea and linseed yield were recorded to be highest in 50 % organic + 50% inorganic treatment followed by 100 % organic treatment.After field testing it was found that GPBD-5 variety of groundnut (2111 kg ha^{-1}) and Aravali variety of mustard(1144 kg ha^{-1}) showed highest performance as compared to other varieties.
- Soil enzyme activities like fluorescein diacetate, dehydrogenase and alkaline phosphatase were found to be highest under 100% organic plot which was closely similar to 50% organic+ natural farming plot and 50% organic+50 % inorganic plot as compared to 100 % inorganic in wheat.
- A non-contact nano sensor was developed for the estimation of soil moisture levels by measuring the humidity levels above the soil surface. A functionalised cellulose matrix has been developed and utilised to make strips for further studies using developed prototype (MEGH).
- Balanced fertilizer application and improved HYVs of rice (MTU 1010) and summer moong (IPM 410-3) were demonstrated in tribal farmer's fields at Rajnandgaon, Chhattisgarh for improving soil health and crop productivity under TSP program.

AICRPs

- The long-term application of fertilizers and manures in major crops under Vertisols clearly demonstrated that the crop productivity declined due to imbalance nutrient application and found to be maximum with application of 100% NPK+FYM (INM). The Sustainable Yield Index (SYI) found to be enhanced with balanced and Integrated Nutrient Management (INM) across different Vertisols under LTFE.

- Spatio-temporal variability of available Sulphur, available micronutrients, and selected soil properties in cultivated soils of a hilly region of India in 6 years (2015-2021) was assessed for distribution mapping and site-specific nutrient management.
- The addition of 1.0 kg B ha^{-1} in alternate years was found optimum for enhancing the yield of groundnut and cabbage crops. Boron application enhanced B content in groundnut pod, haulm, cabbage and available B in soil.
- Application of 10.0 kg Zn ha^{-1} per year produced higher grain size, straw, and total Zn concentrations in maize and wheat crops. Apparent Zn recovery efficiency varied from 0.17 to 1.46% for maize crop and 0.34 to 1.70% for wheat crop under different rates and frequencies of Zn application.
- Fertilizer prescription equations under IPNS was developed for mustard (GSC-7), late sown wheat (HD 3059), black niger (Rajendra Shyama), cotton hybrid (RCH659 BG II), groundnut (Kailash), wheat (HD-2967), brinjal (Hisar Shymal), maize (NMH 8352), Cabbage (NS-22), Okra (VNR-999), sweet corn (Sugar-75), rice (CG Hybrid -2), pearl millet (Super-82), garden pea (AP-3) garlic (Sweta), barnyard millet (MDU 1), Bengalgram (NBeG 49), linseed (Priyam), sweet corn (Sugar 75), rice (Ketekijoha), sesamum (Swetha), radish (Ravi Tejas), rajma bean (Phule Rajma) and chickpea (JG-36).
- Phosphate buffer was observed as a suitable extractant for estimating potentially mineralisable N under the organic production system of New Alluvial Zone of the Lower Gangetic Plain of India.

Theme II: Conservation Agriculture, Carbon Sequestration and Climate Change

- Eight years of CA based soybean-wheat cropping system in vertisol of central India revealed that retention of 90% residue resulted in 47% improvement in total carbon and 17% improvement in total nitrogen in comparison to conventional tillage in soil.
- Soybean and maize yield was relatively higher under no tillage, which was on par with reduced tillage+residue retention. STCR based fertilizer application recorded significantly higher yield compared to 100% RDF and 75% RDF. Soil organic carbon data indicated that surface layer recorded higher values, regardless of tillage practices.
- Water use efficiency (WUE) was significantly higher under drip irrigation than the sprinkler and flood irrigation. Higher water productivity was attained under drip and sprinkler system of irrigation compared to that under flood irrigation.
- Conservation agricultural system-maintained soybean yield level on par with the conventional agricultural practices with concomitant savings of time, labour and input cost and improvement in soil health parameters and sustainability of yield.
- Maize-chickpea cropping system was observed comparatively more prone to soil loss and run off than soybean-wheat system; however, conventional tillage under both the cropping system was recorded with highest soil loss and runoff than other treatments of conservation agriculture.
- The agro-hydrological Soil–Water–Atmosphere–Plant (SWAP) model was calibrated and used topredict field water balance with reasonable accuracy. This study indicated that the soil profile temperature will be 2 to 3^{0} C higher under RCP 4.5 and RCP 8.5 and net water balance in RCP 8.5 was lesser by 1.57cm^3/cm^3 compared to present scenario.
- The RothC model demonstrated that management practices with FYM have great potential to increase SOC sequestration in the rice-based cropping system with climate change and higher decreases in the rate of SOC sequestration was observed under RCP 8.5, followed by RCP 6.0, RCP 4.5, and RCP 2.6.
- Through APSIM crop model, assessed the pigeon pea yield gap in Madhya Pradesh and identified that one irrigation of 60 mm during the last week of November improved pigeon pea yield by 300 kg ha^{-1} in central India.
- A decision support system was developed, integrating digital soil map of Raisen district of Madhya Pradesh, which can be upscaled for other districts/ states.
- Drought indices i.e., Standardized Precipitation Index (SPI-3) and Standardized Vegetation Index (SVI) were computed from the satellite data. As per SPI-3, the extreme and severe drought were found in kharif 2001 and 2002 and rabi 2001, 2008, 2012, and 2017. As per SVI, drought was found in rabi 2001, 2002, 2003, 2005, 2006, 2007, 2008, 2009, 2016, and 2018. Shajapur district was found to be more affected by drought followed by Sehore and Bhopal.
- In the soybean-wheat cropping system, the wheat stem and roots' mean decay rate was 3.6 and 4.7 times higher than soybean and in the maize-chickpea cropping system, the maize stem's decomposition rate was 0.7 times less than chickpea stem. The decomposition rate of above-ground straw was significantly higher than that of below-ground roots across residue types and nutrient management.
- In mesocosm experiment. Across crop residue and

nutrient levels, reducing soil moisture from 80%to 60% field capacity increased methane consumption. The average methane fluxes at the two soil moistures were 2.72 and -6.97 µg-C kg^{-1} soil, respectively.

Theme III: Microbial Diversity and Biotechnology

- Overall, the highest grain yield of wheat was recorded in integrated crop management practices with chemical pesticide (ICMP), which was at par with integrated crop management practices with natural farming (ICMNF) and AI-NPOF package.
- The endophytic fungal isolates *viz. Fusarium* and *Curvularia* sp. show wide range of heavy metal tolerance and grow well in the presence of Pb, Cd, Cr and Hg heavy metals.
- A potential pink pigmenting methylotroph bacterium *Methylobacter radiotolerans* N39 was isolated from the phylloplane of the rice plant which produced β carotene at a rate of 0.45 to 3.09 (µg mL^{-1} d^{-1}) and enhanced the plant's (Pigeon pea) resistance to UV irradiation.
- Thermophilic bacterial isolates (101 nos) from three hotsprings of Central India viz. ChotiAnhoni (CA), BadiAnhoni (BA) and Tatapani (TA) were further screened for lignin and cellulose degrading candidates through their potency index calculation.
- Isolates (37 nos) were obtained from rhizoplane and endorhizosphere of Mustard (cv Pusa Mehak) grown in three different soil viz. Vertisols, Inceptisols and Alfisols and tested for their Plant growth promoting attributes.
- The highest Geometric mean of soil enzyme activities (GMea),Shannon diversity index (H) and Simpson Yule index (SYI) have been noticed in 100% NPK+FYM treatment in LTFE Barrackpore, LTFE Palampur and LTFE Parbhani.
- The field study indicated that using Si as seed priming, along with P fertilizer, could have a significant impact on rice-wheat cropping system in the Vertisols of Central India.
- Soil enzyme activities (Dehydrogenase, acid and alkaline phosphatase activities) and nutrient status (N, P, K& Zn) were increased in mechanized coating of seeds than traditional biofertilizer treatment.

Theme-IV: Soil Pollution, Remediation and Environmental Security

- Grain and straw yield of wheat and soybean crops were significantly increased withapplication of pond ash at the rate 200 and 400 t ha^{-1}. Bulk density of top soil (0-15 cm) significantly decreased with application of ash at the rate 200 t ha^{-1} or more.
- Press mud and steal slag application as soil amendment either alone or in combination with FYM has greater potential in reducing the mobility of Pb and Cd in a soil contaminated with lead and cadmium, respectively.
- The presence of potential toxic elements in the MSW compost exert negative effect on microbial activity. The combined effect of heavy metals (Cd + Pb +Cr + Ni) in the MSW on reduction in CO_2 evolution was significantly higher (42%) as compared to the effect of individual heavy metal effect (sole effect; Cd/Pb/Cr/Ni).
- Treated sewage water irrigation with 50% RDF + vermicompost @ 5t ha^{-1} significantly enhanced the spinach fresh leaf weight by 95% over fresh water irrigated soils.The co-application of biochar/fly ash/vermicompost with 50% RDF reduced N_2O emission and enhanced methane consumption.
- Microcosm experiment was conducted with dry- and fresh- sludge at varying doses (0, 20 and 40 t ha^{-1}) with amendment like biochar (0, 5 and 10 t ha^{-1}) and lime (0 and 800 kg ha^{-1}) and application of biochar reduced the TDS of leachate.
- The pH of water collected from Amlai coal mine area was found to be medium to strongly alkaline and EC ranged between 100-4000 µS/cm.However, soils were found to be very strong to slightly acidic in nature and EC varies from 105-210 µS/cm.The soils ofSharda coal mine area were found to be high in organic carbon, low to medium in available P and medium in available K.
- Increasing the pyrene (PAHs) concentration from 0 to 200 mg/kg resulted in the reduction of dehydrogenase activities in Vertisol, Alfisol, and Inceptisol to the extent of 61%, 65%, and 57% respectively.Similarly, the application of pyrene also negatively influenced soil alkaline phosphatase activities.
- The heavy metal analysis of 120 georeferenced soil samples from Kanpur waste dumps, revealed that Spherical Model was best for chromium and zinc whereas Guassian Model was best fitted for lead and cadmium. Geostatistical analysis with Ordinary kriging interpolation method revealed strong spatial dependency for chromium and moderate spatial dependency for lead, cadmium and zinc.
- The adoption of plastic mulch film has transformed the livelihoods of smallholder farmers. The poly-mulching in field experiment recorded two-fold increases in maize yield.
- Samples collected from smaller cities of municipal solid waste composting unit have lower metals load as compared to larger cities. Compost samples collected at farmers' field had relatively lower metals loads as indicated by clean index.

1. Introduction

Soil science research contribute significantly to soil health, food and nutritional security, human wellbeing, ecosystem services and global development. Sustainable soil management is a predicament for achieving Sustainable Development Goals (SDGs) of United Nations SDG1 (End Poverty), 2 (Zero Hunger), 3 (Good Health and Wellbeing), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), 13 (Climate Action), and 15 (Life on Land) and thereby sustaining agricultural production. Hence, it is essential to understand the properties and processes of soil at regional, national and global scales to realize these SDGs. Accordingly, Govt. of India has initiated a several measures nationwide under National Mission of Sustainable Agriculture and Soil Health Card Mission to improve the soil productivity. Though, intensive agricultural production system with over exploitation of scarce soil resources worldwide has produced more food grain, yet soil health has declined at faster rate with higher rates of erosion, declining factor productivity and reduced nutrient use efficiency NUE, loss of soil biota and degradation of land due to environmental pollution. Therefore, increasing food-grain production from shrinking land resources requires prioritization of research pursuits, addressing the emerging issues like enhancing inputs (nutrient and water) use efficiency; sustaining soil and produce quality; conservation agriculture to adapt to climate change and carbon sequestration;exploitation of soil biodiversity and genomics; minimizing soil pollution etc.

ICAR-IISS was established on 16 April, 1988 with the mission of "Providing scientific basis for enhancing and sustaining productivity of soil resources with minimal environmental degradation". Since its inception, the institute has made rigorous efforts to attain its mission and received national and international recognitions. Presently, the institute activity has been strengthened further by the scientific and managerial activities of three All India Coordinated Research Projects, one All India Network Project and one Consortia Research Platform project. These five institute based projects act as a part of the "Network-Support Programmes" of the Institute with their centers located in various State Agricultural Universities and ICAR institutes, thereby providing access to the diverse soils, agro-ecosystems across the agro-ecological zones of the country for effective implementation of the various programs of the Institute at national level. During the year under report the institute has made significant scientific contributions in the frontier areas of soil science such as input use efficiency, carbon sequestration and climate change, integrated plant nutrient supply system (IPNS), nutrient transformation and dynamics in soil-plant systems, organic matter recycling and management, soil biodiversity and genomics, environmental impact on agricultural production, utilization of solid wastes and waste water, bio and phyto-remediation, etc. The salient research findings, infrastructural development, technology transfer, human resource development, awards and recognitions and linkages and collaborations etc. are briefly highlighted in this annual report.

1.1 Mission and Mandate

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

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

1.2 Priorities and Thrust Areas

The priorities of the institute are to broaden the soil science research by encouraging multidisciplinary research for efficient utilization of already created infrastructure and, therefore, 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
- Fertilizer fortification
- Resilience of degraded soils
- Developing a workable index of soil quality
- Organic farming and produce quality

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

- Conservation agriculture and carbon sequestration sustainable management of land and soil resources
- Tillage and nutrient interactions
- Crop simulation modeling and adaption to climate change
- Remote sensing and GIS

Programme 3: Microbial Diversity and Genomics

- Characterization and prospecting of soil bio-diversity
- Testing of mixed bio-fertilizer formulations
- Quality compost production and quality standards
- Exploring microbial diversity for improvement of contaminated soil and water
- Exploring C-sequestration potential mediated microbes under different agro-eco-systems

Programme 4: Soil Pollution, Remediation and Environmental Security

- Soil pollution impact assessment and toxicity amelioration
- Phytoremediation and bioremediation of contaminated soils
- Developing technology for efficient reuse/disposal of city and industrial waste
- Developing soil management practices for minimizing emission of greenhouse gases
- Environmental impact risk assessment of nanoparticles on soil health and plant nutrition

1.3 Organization Set-Up

Divisions

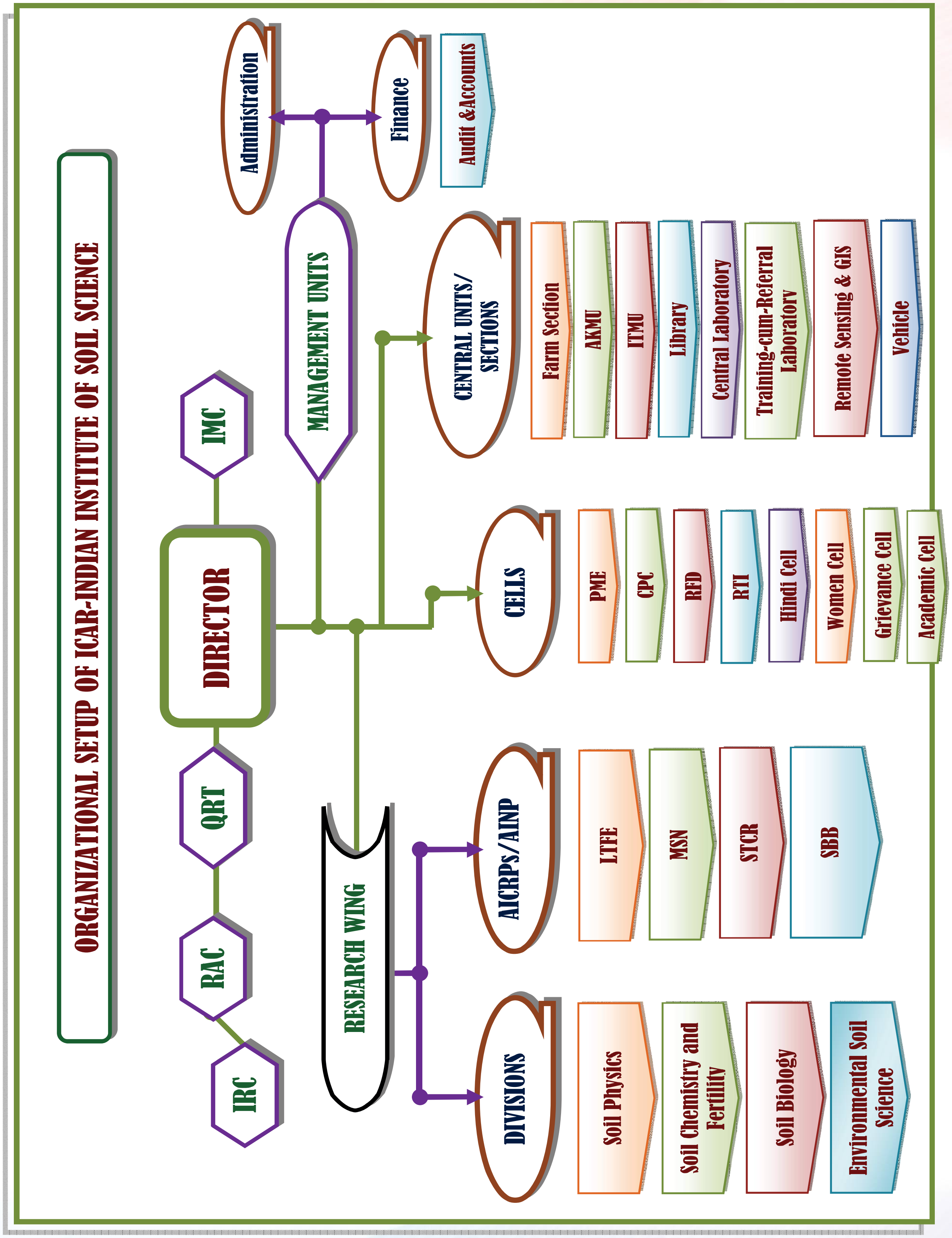
- Soil Physics
- Soil Chemistry & Fertility
- Soil Biology
- Environmental Soil Science

Sections/Central Units/Technical Units/Cells

- Farm
- Administration
- Remote Sensing & GIS
- Prioritization, Monitoring and Evaluation Cell (PME)
- Agriculture Knowledge Management Unit (AKMU)
- Institute Technology Management Unit (ITMU)
- Library, Information and Documentation Unit
- Right to Information (RTI) Cell
- Consultancy Processing Cell (CPC)
- Official Language Cell (Hindi Cell)
- Vehicle
- Training Hostel
- Referral Lab
- Women Cell

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

- AICRP on Long -Term Fertilizer Experiments to Study Changes in Soil Quality, Crop Productivity and Sustainability (LTFE)
- AICRP on Soil Test and Crop Response (STCR)
- AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (MSPE)
- AINP on Soil Biodiversity and Biofertilizers (SBB)
- CRP on Conservation Agriculture (CRP-CA)


ORGANIZATIONAL SETUP OF ICAR-INDIAN INSTITUTE OF SOIL SCIENCE
DIRECTOR
IMC
QRT
RAC
IRC
MANAGEMENT UNITS
Administration
Finance
Audit &Accounts
CENTRAL UNITS/ SECTIONS
Farm Section
AKMU
ITMU
Library
Central Laboratory
Training-cum-Referral Laboratory
Remote Sensing & GIS
Vehicle
CELLS
PME
CPC
RFD
RTI
Hindi Cell
Women Cell
Grievance Cell
Academic Cell
RESEARCH WING
AICRPs/AINP
LTFE
MSN
STCR
SBB
DIVISIONS
Soil Physics
Soil Chemistry and Fertility
Soil Biology
Environmental Soil Science

1.4 Manpower

Scientific

S. No.	Discipline	Sanctioned				In Position			
		PS	SS	S	Total	PS	SS	S	Total
1	Agricultural Chemicals	0	0	1	1	0	0	1	1
2	Agricultural Economics	0	0	2	2	0	0	0	0
3	Agricultural Extension	0	0	1	1	0	0	1	1
4	Agricultural Microbiology	0	1	2	3	0	1	2	3
5	Agricultural Physics	0	1	0	1	0	0	0	0
6	Agricultural Statistics	0	0	1	1	0	0	0	0
7	Agronomy	0	1	4	5	0	1	3	4
8	Electronics & Instrumentation	0	1	0	1	0	0	0	0
9	Fruit Science	0	0	1	1	0	0	1	1
10	Plant Biochemistry	0	1	0	1	0	1	0	1
11	Plant Physiology	1	1	1	3	1	1	0	2
12	Soil Science	0	4	27	31	5	8	23	36
	Total	1	10	40	51	6	12	30	48
13	HODs	4	0	0	4	0	0	0	0
14	Project Coordinators	0	0	0	0	0	0	0	0
15	RMP	1	0	0	1	1	0	0	1
	GRAND TOTAL	6	10	40	56	7	12	30	49

Technical

S. No.	Posts	Sanctioned	In Position
1	T-1	11	9
2	T-2	-	-
3	T-3	7	6
4	T-4	-	-
5	T-5	-	-
6	T-6	1	0
7	T-7-8	-	-
8	T-9	-	-
	Total	19	15

Administrative

S. No.	Designation	Sanctioned	In Position
1	Sr. Administrative Officer	1	0
2	Sr. Finance & Accounts Officer	1	1
3	Administrative Officer	1	1
4	Assistant Finance & Accounts Officer	1	0
5	Assistant Administrative Officer	2	2
6	Private Secretary	3	3
7	Assistant	8	3

8	Personal Assistant	4	2
11	Upper Division Clerk	3	2
12	Lower Division Clerk	4	4
13	Skilled Supporting Staff	17	12
	Total	45	30
	Grand total	120	94

1.5 Finance: Budget statement (Lakhs) 2022

Institute/AICRPs	Budget	Expenditure
Main ICAR-IISS Institute	2588.94	2588.94
AICRP on MSN	914.99	914.99
AICRP on STCR	1087.85	1087.85
AICRP on LTFE	631.06	631.06
AINP on SBB	296.42	296.42
CRP on CA	242.36	242.36
Total	5761.92	5761.92

1.6 Resource Generation

S.No	Head of Account	Rs. In lakh
1	Sale of farm produce	19.26
2	Sale of publication, royalty and advertisement	0.04
3	Licence fee	5.37
4	Interest earned on loans & advances	12.13
5	Receipts from schemes	28.22
6	Analytical and testing fee	0.36
7	Diploma Charges /Leave Salary & Pension Contribution	13.06
8	Interest earned on short term deposits	7.83
9	Recovery of loans and advances	26.46
10	Miscellaneous Receipts	12.55
	Total	125.28

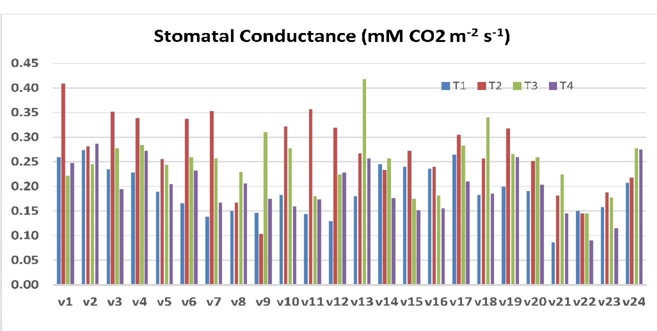
2. Research Achievements

Theme - I: Soil Health and Nutrient Use Efficiency

2.1 Improving Input Use Efficiency

2.1.1 Nutrient use efficiency (NUE) of selected wheat genotypes grown in nutrient sufficient and deficient environment

An experiment was conducted during the rabi season of 2021-2022 at ICAR IISS research farm and 24 selected varieties of wheat were evaluated for growth, yield and NUE traits. These genotypes were earlier selected from about 120 genotypes of wheat developed from India/ abroad based on the performance during last two years for N and P use efficiency and crop yield trials. These selected genotypes were evaluated under plots of nutrient gradient with low N, low P and general recommended dose (GRD) of fertilizer nutrient (120-60-40 kg h^{-1} of NPK) under field conditions. Great diversity in agro-morphology and yield attributing traits were observed among these wheat genotypes. The genotypes HI 8663, HI 1544, HI 1605, DBW 88 had high Pn and HI 1544, HI 1605, HI 1531, HI 8498, HI 1500, Narmada 14, DBW 88 and BWL 5233 exhibited higher stomatal conductance under low N supply. Similarly, lower transpiration rate was observed with HI 1531, HD 2687 under low N and HI 8663, HI 8713, HI 1605, HI 1531, GW 322 under low P conditions. The genotypes *viz*., HI 1563, HI 1605, HI 1531, HI 8498, Narmada 14 had lesser SPAD value but exhibited high grain yield indicating higher requirement for N. Higher biomass of >10t ha^{-1} and grain yield >4 t ha^{-1} was observed in genotypes HI 8737, HI 1563, HI 1605, HI 1531, HI 8498, and Narmada 14, which make them suitable for low N supply conditions. For low P conditions, genotypes HI 8713, HI 1544, HI 1605, HI 1531, GW 322, HI 1500 were found to be suitable based on biomass/grain yield (Fig. 2.1.1). In addition, the remaining 96 genotypes were also maintained for germplasm conservation.



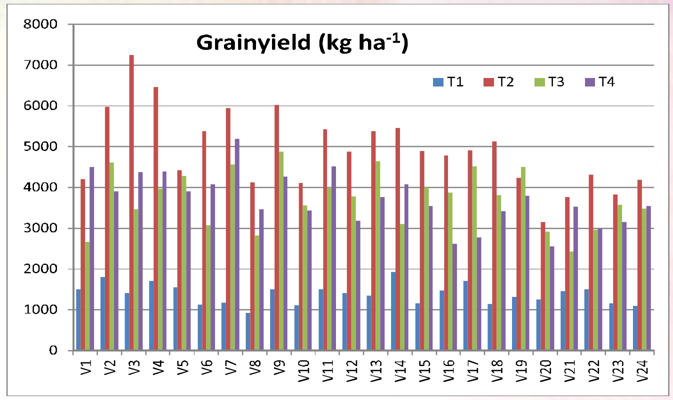


Fig. 2.1.1 Stomatal conductance and grain yield in selected wheat genotypes

2.1.2 Integrated nutrient management (INM) modules for crop growth, productivity and nutrient balance in Vertisol

A long-term field study was conducted to evaluate diverse INM modules in maize-chickpea cropping sequence. In this study, twelve INM modules of Soil Test Crop Response (STCR) based fertilizers, general recommended dose (GRD), farmyard manure (FYM), poultry manure (PM), urban compost (UC), maize residue (MR) and Glyricidia loppings (Gly) were investigated. Results indicated that growth parameters (plant height and dry matter accumulation), yield attributes (length and girth of cob, grains/cob and 1000-grains weight) and yields (grain and stover) of maize significantly ($p=0.05$) improved with STCR based INM module (75% NPK +5 t FYM) and increased 31.8 and 23.8% grain yield over the GRD and 100% NPK of STCR, respectively. In chickpea, higher plant height, DMA, number of pods/ plant and yields (grain and straw) were obtained with the residual fertility of FYM @ 25 t ha^{-1} every year followed by INM module (75%NPK +5 t FYM). However, residual fertility of PM and UC based INM modules also considerably improved the crop growth and yields of chickpea. Substantially higher system productivity was also noticed with 75% NPK +5 t FYM followed 75% NPK +1 t PM based INM modules which was 1.86 and 0.99 t ha^{-1} higher than GRD. Apparent nutrient balance was negative for N and K in all treatments except in case of higher level of FYM while P balance was positive under STCR based INM modules. However, there has been substantial build-up of N, P and K in plots receiving 25 t FYM every year. The additional supply of nutrient through integration of organic and inorganic fertilizers is essential for positive nutrient balance. Thus, balanced use of nutrients through STCR (75% NPK) with 25% organic manures (FYM and PM) sustained the crop yield while the addition of FYM (25 t ha^{-1}) is essential for positive balance of nutrients in the soil (Plate 2.1.2).

Plate 2.1.2 Field performance of maize and chickepea crop under INM

2.1.3 Effect of urease inhibitor (NBTPT) on yield of rice-wheat cropping system

A field experiment was conducted under rice-wheat cropping system. The experiment was laid out in a randomized complete block design with four replications. Basal application of P (60 kg ha^{-1}) and K (40 kg ha^{-1}) was applied at the time of sowing of crop. The rice hybrid (Arize-6444 gold) was transplanted in July 2022. No significant difference in yields were recorded between the different doses of neem coated urea (NCU) and agrotain incorporated urea (AIU). Yield of rice was significantly influenced by N application. In general, as the application rate increased, the grain yield of rice also increased. Highest grain yield of rice (5.8 t ha^{-1}) was recorded under 100%NCU, which was at par with 100% AIU.

2.1.4 Effect of biochar application on wheat crop in Vertisol

The experiment on biochar use under rice-wheat cropping system in vertisols of central India revealed that wood biochar application did not result in significant effect on wheat grain yield without manure or fertilizer addition. Further, FYM as well as fertilizer application resulted in significant improvement in wheat grain yield under all the three types of biochar studied. Application of wood biochar at the rate of 4 and 8 t ha^{-1} along with NPK+FYM resulted in only 5% higher wheat grain yield over no biochar +NPK+FYM. However, wood coconut husk biochar application at the rate of 8 t ha^{-1} along with NPK+FYM resulted in significant improvement (13%) in wheat grain yield over no biochar +NPK+FYM. Similarly, crop residue biochar application at the same rate of biochar addition along with NPK+FYM resulted in about 11% increase in wheat grain yield over no biochar +NPK+FYM. Similarly in case of rice crop, all the unfertilized treatments were found statistically at par with each other. FYM as well as fertilizer application resulted in significant improvement in rice grain yield (Fig. 2.1.4).

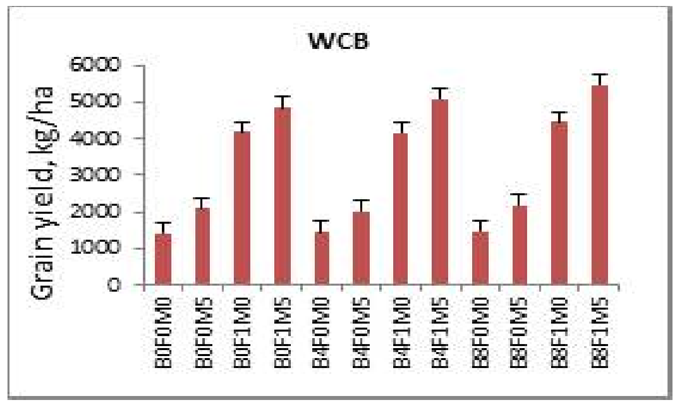


Fig. 2.1.4 Effect of biochar application on wheat yield

2.1.5 Effect of biochar on fruit yield of brinjal and okra in Inceptisols and Alfisols of Odisha

Pot studies on acidic and normal soils of Odisha with brinjal and okra were conducted in green house. Treatments included were absolute control, RDF, RDF as well as FYM and RDF and FYM with wood coconut husk biochar (WCB) and crop residue biochar (CRB) application. The study clearly showed significant improvement in fruit yield of brinjal. In soils of Belpada, there was significant response over fertilizer application alone. However, NPK+FYM application increased the fruit yield significantly but further significant yield could be achieved with CRB application at the rate of 4 g kg^{-1} biochar with FYM or 8g kg^{-1} with and without FYM application. In acidic soils of Nuapada, response of both types of biochar addition was significant over fertilizer application alone. WCB at the rate of 8 g kg^{-1} resulted in significant increase in fruit yield however, CRB showed a significant improvement in fruit yield at both the levels with and without FYM (Fig. 2.1.5).

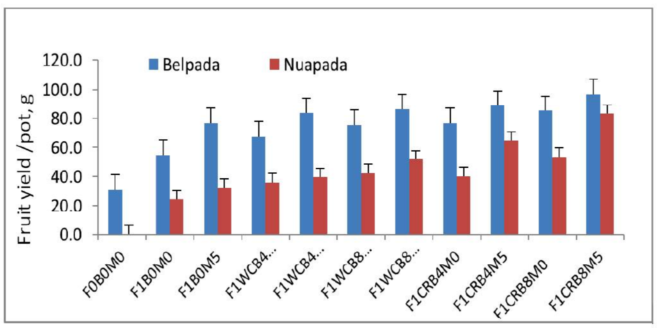


Fig. 2.1.5 Effect of biochar on okra productivity in Inceptisols and Alfisols

2.1.6 Assessment of SOC stock and produce quality in agri-horticultural system

Bulk density of soil was influenced by different fruit orchard and it gradually increase throughout the depth (0-45 cm) of the soil profile. Irrespective of the soil depth, the highest carbon stock was observed in aonla orchard (13.31 t ha^{-1}) followed by guava (12.27 t ha^{-1}). Inter crops *viz.*, wheat and gram have been sown during winter in the orchards and highest wheat yield was observed in mango orchard (0.44 kg m^{-2}) and gram in lime orchard (0.32 kg m^{-2}). Phenolic content in fruit crops is major constituent and it is highly correlated with stress. Its production was significantly influenced by mulching treatments. Black polythene mulch resulted in lowest whereas control (without mulch) resulted in highest phenolics as well as thickness of leaf. The leaf chlorophyll content was highest under black polythene mulch and lowest under white polythene treatment followed by control (Fig. 2.1.6 and Table 2.1.6).

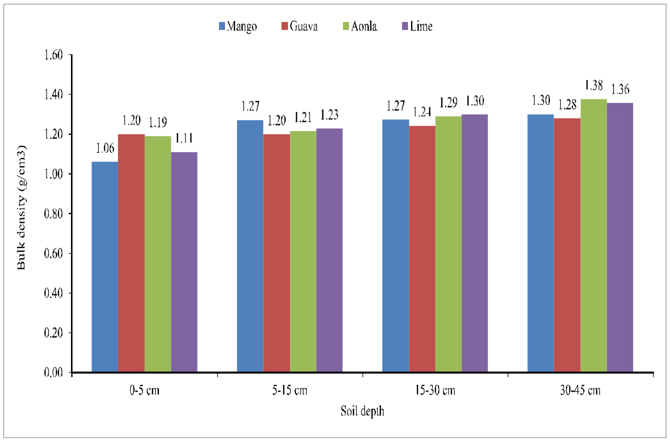


Fig. 2.1.6 Soil carbon stock in different orchard

Table 2.1.6 Effect of mulching in leaf characteristics in mango

Treatments	Total phenolics (mg GAE 100 g^{-1})	Chl_A (mg 100g^{-1})	Chl_B (mg 100g^{-1})	Total_Ch (mg 100g^{-1})	Leaf thickness (mm)
10 kg Wheat residue	1175	7.91	2.65	10.56	0.25
10 kg gram residue	1085	8.21	2.34	10.55	0.30
10 kg dry grass	787	6.63	2.07	8.70	0.22
Black polythene	332	12.28	3.56	15.83	0.25
White Polythene	997	6.19	1.82	8.00	0.22
Control	1268	6.63	2.03	8.65	0.32
CD (0.05)	54.89	0.422	0.151	0.421	0.019
CV	3.165	2.873	3.401	2.200	3.943

2.1.7 Identification and quantification of clay minerals in different benchmark Vertisols

Semi-quantitative estimate of the minerals in the fine clay fractions of all studied Vertisols are shown in table (Table 2.1.7). The X-ray intensity ratio of peak heights of 001 and 002 basal reflection of mica was greater than unity in soils of Kheri, Nabibagh, Jalawara and Sarol series whereas Panjari, Junagad, Wanirambhapur, Parabhani and Nimone series this ratio was close to unity indicated that the soils of Kheri, Nabibagh, Jalawara and Sarol series contain both muscovite and biotite. Whereas, the soils of Panjari, Junagad, Wanirambhapur, Parabhani and Nimone series are more muscovitic in character. The smectite was dioctahedral as evident from the 060 reflection around 1.50 Ao in soils of Kheri, Panjari, Parabhani and Junagad series (Fig. 2.1.7 a). Smectite was also low charge confirmed by the expansion of smectite beyond 1.4 nm after glycolation of K saturated and heated at 300^{o}C. The 060 reflection for the soils of Nabibagh, jalawara and Sarol series found around 1.50 Ao and 1.54 Ao indicated that the smectite present in these soils are both dioctahedral and trioctahedral (Fig. 2.1.7 b). The smectite present in soils of Jalawara and Wanirambhapur series was high charge smectite as confirmed by there was no expansion of smectite peak beyond 1.4 nm after glycolation of K saturated and heated at 300^{o}C.

Table 2.1.7 Semi-quantitative estimates of clay minerals in studied soil

Sampling sites	Minerals in %							Sm		001/002 Mica
	Sm	Vm	Chl	I	K	Q	F	B-N	Mt	
Kheri series	74.5	15.1	1.6	4.7	1.1	1.6	1.5	40.7	33.8	1.25
Nabibagh series	70.8	17.7	1.0	5.0	1.3	1.7	2.5	43.6	27.2	1.42
Jalwara series	60.7	24.1	0.9	10.1	1.7	1.1	1.2	40.7	19.9	1.69
Sarol series	63.9	12.2	2.7	11.8	5.8	1.7	1.9	38.0	25.9	1.38
Panjari Series	76.3	15.3	1.1	2.3	1.2	1.8	1.9	49.5	26.7	1
JAU Junagad	70.4	17.9	1.1	1.5	1.3	3.5	3.5	46.7	23.8	1
Wanirambhapur	69.7	10.4	4.1	4.2	3.0	4.6	4.1	44.7	25.0	1
Parbhani	76.2	12.0	2.6	2.9	1.4	2.4	2.6	49.5	26.7	1
Nimone	68.0	9.4	3.0	8.1	3.1	4.6	3.9	47.4	20.6	1

*Sm= Smectite, Vm=Vermiculite, Chl=Chlorite, I=Illite, K=Kaolinite, Q=Quartz, F=Feldspars, B-N=Beidellite-nontronite, Mt=Montmorillonite.

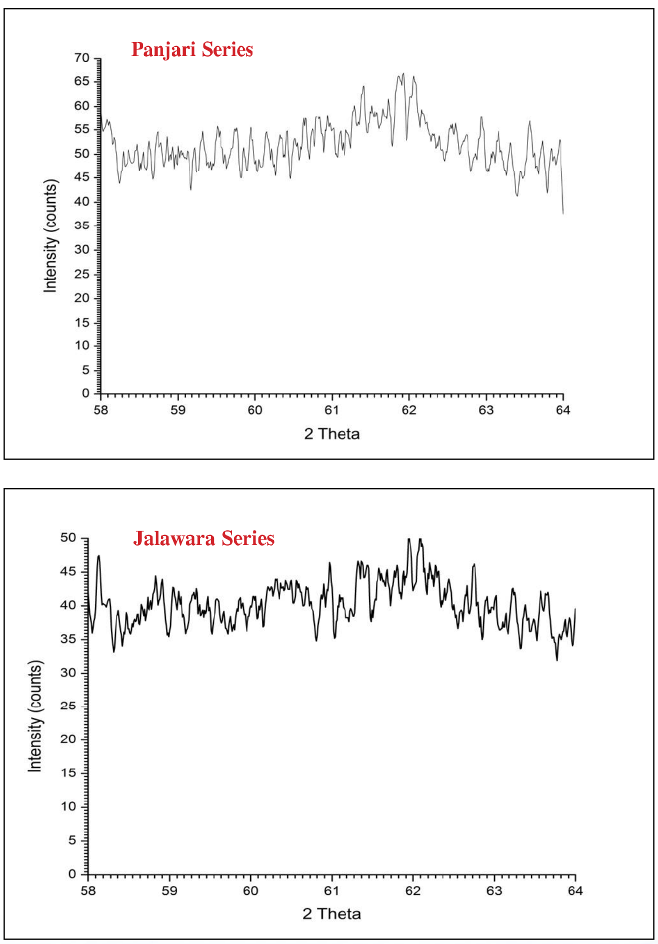


Fig. 2.1.7 a Representative X-ray diffraction of 060 reflection of fine clay fraction

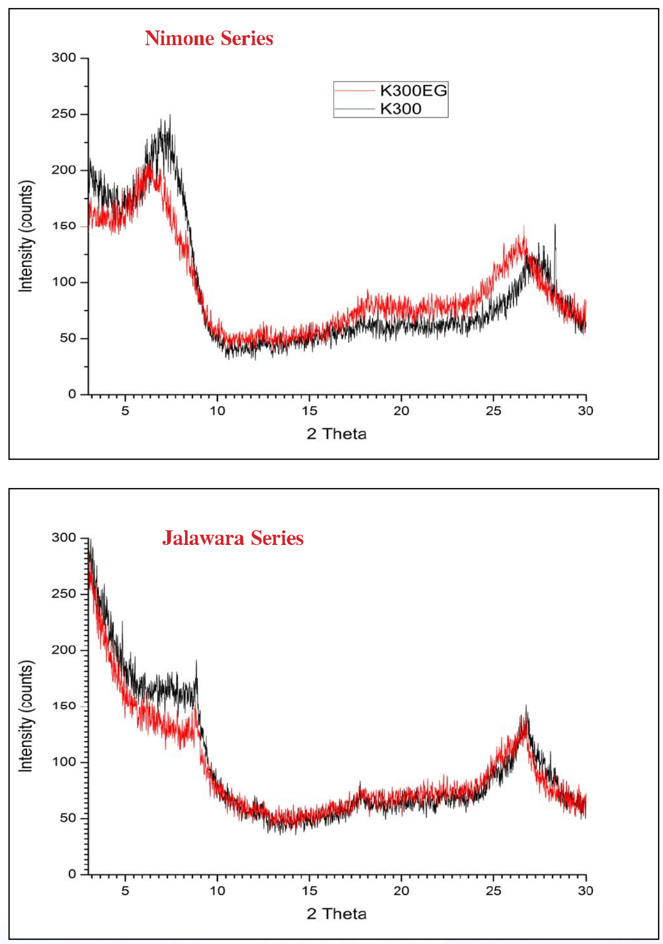
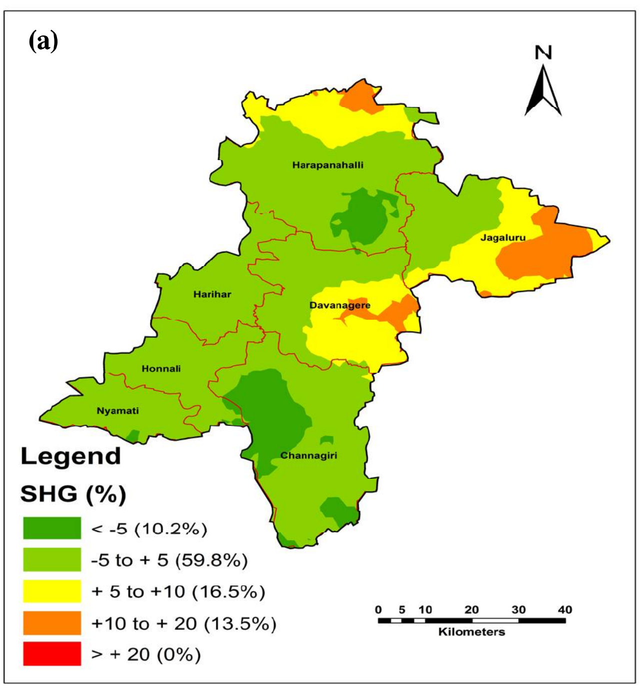


Fig. 2.1.7 b. Representative X-ray diffraction of smectite peak shifting after glycolation of K saturated

2.1.8 Impact of imbalanced nutrient management on soil quality under intensive cultivation

Effect of imbalanced nutrient management practices on soil and water quality was studied in four intensively cultivated districts of India. For the selection of study district, the 2016-17 fertilizer use statistics of the Fertilizer Association of India was used and a matrix involving the highest fertilizer consumption per hectare, total fertilizer use and cropping intensity was developed. Districts having higher matrix value were selected for the study. Accordingly, grid sampling was followed and the following districts were covered for the study: Davengere (Karnataka), US Nagar (Uttarakhand), West Godavari (AP) and Hoshangabad (MP), representing different cropping systems and soil variability and the fertilizer consumption (NPK in kg h^{-1}) of the selected four districts were 634, 545, 350 and 136, respectively. Soil quality index (SQI) was computed using Principal Component Analysis and soil function-based approaches. To quantify the change in soil health, the soil health gap (SHG) approach was developed and used. This approach compares the soil health of the selected point with the site under best management practice. In this case, negative values indicate improvement. A classification scheme was developed, where less than -5% refers to improvement in soil health; -5 to +5% indicate no change; 5 to 10% means slight depletion; 10 to 20% refers to depletion and >20% refers to severe depletion. Accordingly, the soil health status of the four study districts showed that the soil health has deteriorated in about 68% arable land in US Nagar, 69% in West Godavari, 48% in Hoshangabad and 30% in Davengere district (Fig. 2.1.8).



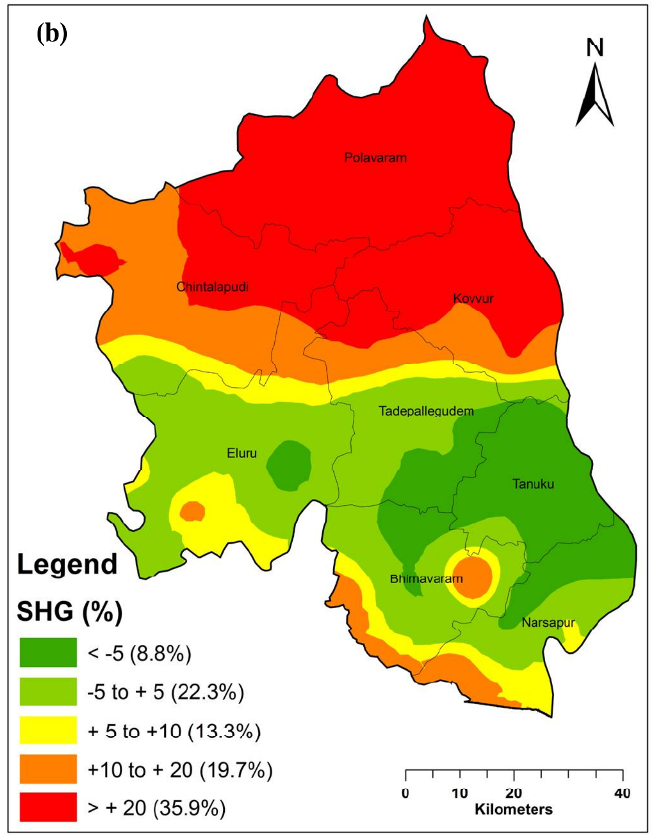


Fig. 2.1.8 SHG map of (a) Davengere and (b) West Godavari districts

In three districts (US Nagar, West Godavari and Davengere), ground water samples were also unsafe for drinking, which is possibly due to higher leaching caused by heavy N application coupled with poor soil retention due to poor soil quality. Irrigation water containing more than 10 ppm of NO_3-N can be a good source of N for crop plants. Four irrigations each of 5 cm depth in one hectare area can provide 20 kg of N if the water contains 10 ppm of N. In such cases, while computing the fertilizer requirement, the contribution of irrigation water and native soil need to be accounted for. On the contrary, in the four districts, 61-100% of the samples showed high P availability, which was due to high P application, thus calling for rationalization in P application. Most of the samples showed high P availability indicating a P saturation in the soil profile. High P availability in the surface soil should be considered for fertilizer application for the next cropping cycles. Most of the soil samples are below the BMP in terms of SQI value, whereas, NO_3-N content in ground water samples were above threshold in most cases. This gives two clear indications: (1) the soil quality is getting affected due to imbalanced nutrient management, (2) the fertilizer application is skewed to N and P fertilizers in the study districts.

2.1.9 Water quality analysis in the tribal inhabited areas of Balaghat District in Madhya Pradesh

Water quality analysis carried out by collecting samples from surface (ponds and streams) and ground water sources (open wells and tube wells) of the tribal villages, Kaweli, Kula and Sarra of Balaghat district in Madhya Pradesh showed that water from these resources has a pH in the range of 7.1-7.5. Temperature of ground water resources was in the range of 25-29^{0}C while that of surface water resources in the range of 26-30.8^{0}C. Total Dissolved Solids (TDS) in the surface water resources was $<$100 mgL^{-1} and in the ground water resources, it was in the range of 112-295 mg L^{-1}. Oxidation-reduction potential (ORP) of stream water was measured in the range of 112-122 mV. Nitrate content (measured as NO_3-N) in ground water particularly of bore well water was in the range of 1.0-10.3 mg L^{-1} and that of surface water was in the range of 0-0.25 mg L^{-1}. Phosphorus content was not detected in any of the water samples collected. Potassium in the surface water resources ranged between 1.20-5.30 mg L^{-1} and in ground water resources in the range 2.10-6.20 mg L^{-1}. Quantity of elements such as Al, Cd, Co, Cr, Fe, Pb, Zn, and Cu were negligible. However, Si content measured in water samples collected from wells and rivers is in the range of 144-262 mg L^{-1} and that of ponds is in the range of 1-65 mg L^{-1}. Nickel content measured in water samples from open wells, tube wells and rivers in the range of 0.05-0.15 mg L^{-1}. Biological analysis of water samples showed presence of fecal coliforms in water samples collected from open wells in the range of 120-1100 mpn per 100 mL. Surveys carried out earlier also showed seasonal and water related illness in the project location.

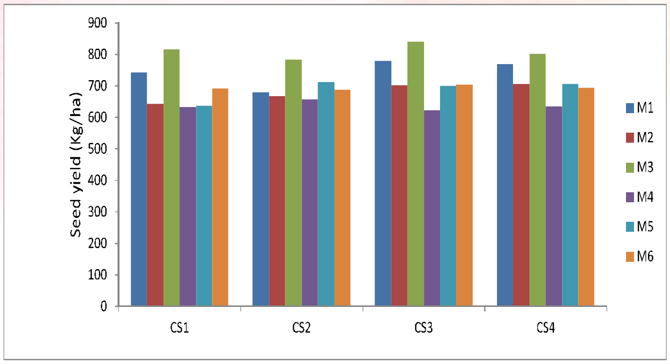
2.1.10 Evaluation-cum-demonstration of bio formulations in tribal farm fields of Madhya Pradesh

Livelihood and ITK surveys carried out among the tribal farmers of Betul district under the STC/TSP showed low crop yield from the rainfed crops *viz.,* soybean, maize and paddy, due to imbalanced use of nutrient inputs and other biotic stress factors. In an effort to resolve these issues, bio-formulations, liquid bio-fertilizers such as *Rhizobium*, PSB, KSB, ZSB, *Azotobacter, Acetobacter* and bio-formulations of *Trichoderma* and *Pseudomonas* were integrated with the farmers practices i.e., farmyard manure @ 5 t ha^{-1} and chemical fertilizers *viz.,* DAP @ 100 kg ha^{-1} for all the thee crops and Urea @ 125 kg ha^{-1} for maize and paddy crops. Additional cost requirement for executing intervention calculated as 4000 Rs ha^{-1}. Evaluation-cum-demonstration of the nutrient management interventions carried out during the Kharif 2022 season in 200 farm fields of Betul District in Madhya Pradesh in an area of 160 hectares (@ 2 acre per farm field). Crops covered under the field demonstration were soybean (37 fields), maize (131 fields) and paddy (32 fields). Average yield of crops under the nutrient management intervention and farmers practice were respectively 12.5 q ha^{-1} and 7.3 q ha^{-1}for soybean, 40.2 q ha^{-1} and 33.6 q ha^{-1} for maize and 43.1 q ha^{-1} and 37.3 q ha^{-1} for paddy (Plate 2.1.10).

Plate 2.1.10 Nutrient management intervention in maize crop in the tribal fields of Betul district

2.1.11 Evaluation of organic, inorganic and integrated crop management practices

Field experiments were conducted during kharif and rabi season 2022 at research farm of ICAR-IISS. The seed yield of soybean was significantly varied under different nutrient management systems. Soybean, wheat, mustard, chickpea and linseed yield was recorded to be highest in 50% organic + 50% inorganic treatment followed by 100% organic treatment, which were significantly higher than 100% inorganic treatment (Fig. 2.1.11).



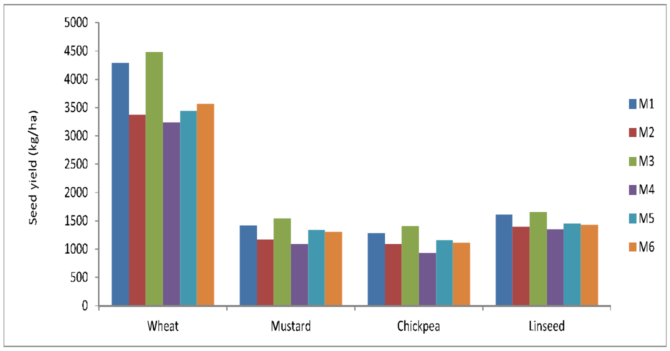


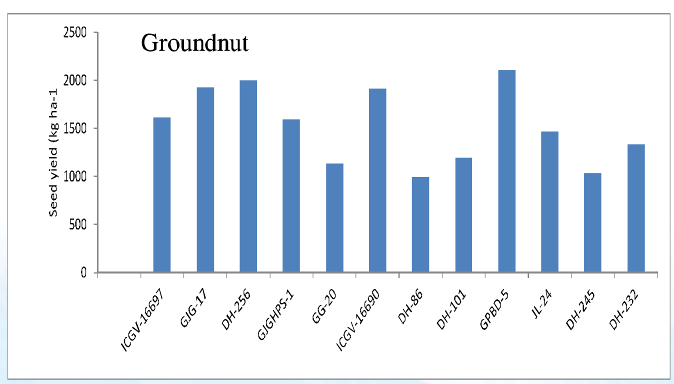
Fig. 2.1.11 Yield of crops under different nutrient management practices

Cropping systems: (CS1) Soybean-Wheat, (CS2) Soybean-Mustard, (CS3) Soybean-Chickpea (CS4) Soybean-Linseed
Management practice: (M1) 100% Organic (Organic manure equivalent to 100% N requirement of the system), (M2) 50 % organic (Organic manure equivalent to 75 % N requirement of the system) +Natural farming, (M3) 50 % Organic + 50 % inorganic, (M4) 25 % Organic + 25 % Inorganic + Natural Farming, (M5) 100% inorganic package, (M6) State recommendations

Plate 2.1.11 View of different crops under organic farming

2.1.12 Response of different varieties of groundnut and mustard crop under organic farming

Performance of different varieties of groundnut and mustard were evaluated for their yield response to screen out promising varieties for organic management practices for Central India. Twelve varieties of groundnut and mustard grown under organic nutrient management practices were tested at ICAR-IISS, Bhopal. Groundnut varieties were tested and found that GPBD-5 (2111 kg ha^{-1}) out performed followed by DH-256 (1997 kg ha^{-1}) and GJG-17 (1931 kg ha^{-1}). Among the different varieties of mustard, Aravali (1144 kg ha^{-1}) out performed in yield followed by CS-52 (1110 kg ha^{-1}) and DRMR-IJ – 31 (1098 kg ha^{-1}) (Fig. 2.1.12).



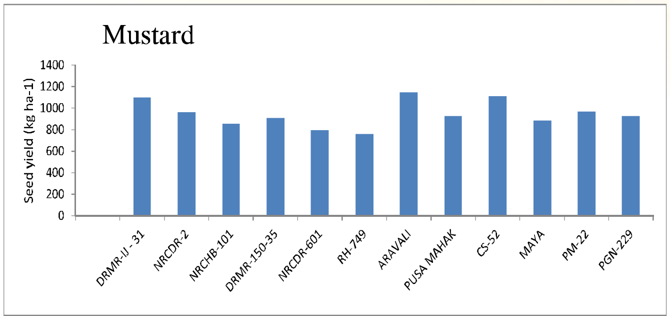


Fig. 2.1.12 Performance of different varieties of groundnut and mustard crops under organic practices

2.1.13 Assessment of soil biological properties under different nutrient management systems

Enzyme activity in terms of fluorescein diacetate (FDA), dehydrogenase activity (DHA) and alkaline phosphatase (ALP) were determined in soil as influenced by different nutrient management practices (Fig. 2.1.13). FDA was found to be highest under 100% organic plot which was closely similar to 50% organic+natural farming plot and 50% organic+50% inorganic plot as compared to 100% inorganic in wheat. Among the cropping systems, soybean-wheat recorded higher FDA followed by soybean-chickpea, soybean-linseed and soybean-mustard. DHA was recorded highest in organic management compared to inorganic and integrated management (Fig. 2.1.13). Similarly, ALP were recorded highest in 100% organic followed by to 50% organic+natural farming treatment indicating beneficial effect of organics on soil microorganisms. Long-term organic management produce favorable micro environment in soil which helps in higher enzymatic activties as compard to others.

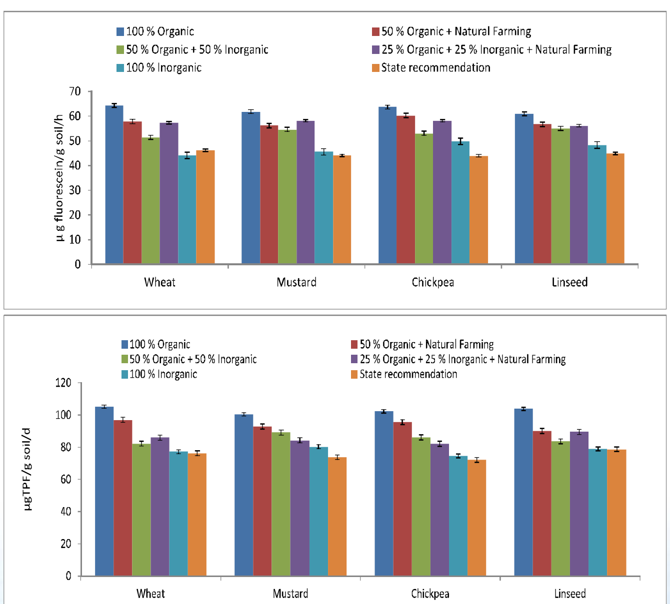


Fig. 2.1.13 FDA and DHA as affected by different nutrient sources

2.1.14 Labile carbon fractions under long-term organic and inorganic management practices

The results highlighted that 100% organic (M1) and treatment having nutrient from both inorganic and organic sources (M3) maintained the highest amount of $KMnO_4$-C and Dissolved Organic Carbon (DOC). Invariably, 100% inorganic (M5) and state recommendations (M6) obtained the lowest amount. Providing organic sources of nutrients for long term usually helps to maintain optimum physical and chemical condition in soil which in turn helps greater growth of crops. As the yield increases, so is the underground biomass. Repeated biomass addition as well as greater microbial activity helps to maintain a higher mineralization capacity of soil. Therefore, the labile or easily oxidizable C fractions were found to be higher in these treatments has inorganic sources (Fig. 2.1.14).

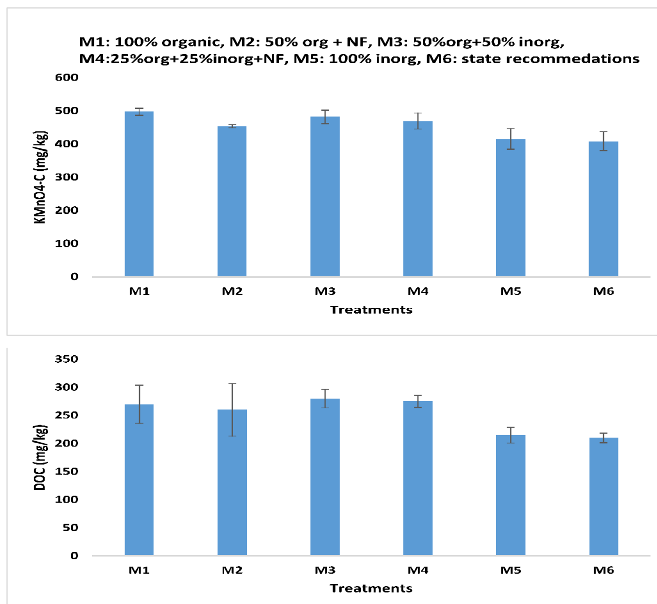


Fig. 2.1.14 Effects of long-term manurial treatments on $KMnO_4$-C and DOC

2.1.15 Evaluation of natural farming practices in different agro-ecology

Field experiment was conducted during rabi season 2021-22 at research farm of ICAR-IISS. Overall, highest grain yield of wheat was recorded in integrated crop management practices with chemical pesticide (ICMP), which was at par with integrated crop management practices with natural farming (ICMNF) and AI-NPOF package. Mustard was grown as an intercrop in natural farming experiment. Among the natural farming treatments, highest grain yield was recorded in the treatment whereall the components of natural farming was used as compared to others (Plate 2.1.15).

Plate 2.1.15 Wheat crop under natural farming

2.1.16 Development of nano sensor and its application for real time irrigation management

A non-contact nano sensor was developed for the estimation of soil moisture levels by measuring the humidity levels above the soil surface (at a distance of 20 cm from the soil surface) which is in equilibrium with the soil moisture levels in soil. The functionalised cellulose matrix with cobalt chloride without changing the morphology or the property of the cellulose matrix was developed. This functionalised cellulose matrix has been utilised to make strips (Plate 2.1.16a) for further studies using our developed prototype "MEGH" which indirectly determines moisture from a matrix (soil/cotton sample) by evaluating the relative humidity of the matrix (Plate 2.1.16b). With increase in moisture level, the colour of the developed sensor strip changes from blue to pink. The ratio of absorbance at 650 nm and 450 nm was taken as the instrumentation index and the calibration curve was obtained. Plate 2.1.16b shows the Bland-Altman analysis of the soil moisture values obtained from developed device and the conventional soil moisture sensor.

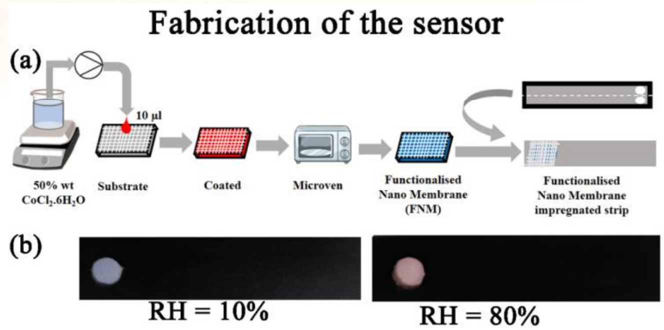


Plate 2.1.16a Schematic representation of synthesis of the functionalized nano membrane

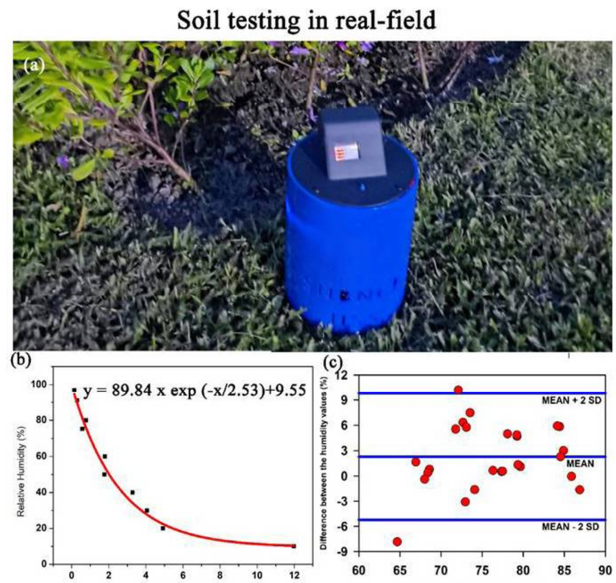


Plate 2.1.16b The development of the prototype "MEGH" (a), Calibration curve of the device in response to various humidity (b) and Bland Altman analysis (c)

2.2 AICRP on Long-Term Fertilizer Experiments to Study Changes in Soil Quality, Crop Productivity and Sustainability

2.2.1 Crop productivity

Balanced nutrient application is of prime importance for yield stability. The magnitude of response was observed in the order: Control <100% N < 50% NPK < FYM < 100% NP < 100% NPK < 150% NPK < NPK + FYM (Table 2.2.1). Application of 100% NPK + FYM recorded highest grain yield followed by 150% NPK. Imbalanced (N or NP) application of fertilizer resulted in significant decline in the yield and the lowest grain yield was recorded in the control. Therefore, either balanced nutrient application or INM is key for sustaining crop productivity.

Table 2.2.1 Grain yield (kg ha-1) of different crops at various locations of AICRP-LTFE

Location	Crops	Control	100% N	100% NP	100%`NPK	150% NPK	100% NPK + FYM
Akola	Sorghum	298	789	1412	2175	2805	3301
	Wheat	175	726	2051	2675	3205	3495
Jabalpur	Soybean	825	960	1488	1686	2010	2080
	Wheat	1460	1850	4170	5262	6038	6150
Junagadh	Groundnut	555	568	622	786	833	865
	Wheat	1916	2910	3596	3828	3931	4176
Raipur	Rice	4751	5656	7391	7600	8768	8675
	Wheat	1151	1557	2837	2998	3530	3489
Parbhani	Soybean	303	359	1263	1379	1466	1504
	Safflower	329	408	970	1050	1149	1169

2.2.2 Nutrient uptake

At Akola, the uptake of nutrients (N, P and K) by sorghum increase with an increase in amount of nutrient applied (Table 2.2.2). The difference in magnitude of nutrients uptake is depended on total biomass production. Highest uptake of N, P, K and S were recorded with the application of 100% NPK + FYM @ 5 t ha^{-1} followed by 150% NPK. Application of 100% NPK along with S @ 37.5 kg ha^{-1} and Zn @ 2.5 kg ha^{-1} increased the uptake of nutrients (N, P, K and S). The application of FYM @ 10 t ha^{-1} recorded lowest uptake of nutrients followed by 100% N and control. Similarly, significantly highest uptake of N, P, K and S by wheat was recorded with the application of 100% NPK + FYM @ 5 t ha^{-1}. Imbalanced (control, N or NP) application of fertilizers recorded significantly lowest uptake of nutrients as compared to balanced and integrated nutrient supply.

Table 2.2.2 Nutrient uptake as influenced by long-term nutrient management in sorghum and wheat in LTFE

Treatments	Nutrient uptake (kg ha^{-1})					
	Sorghum			Wheat		
	N	P	K	N	P	K
Control	8.89	2.07	8.45	4.25	1.32	3.79
100% N	31.3	8.01	31.2	18.2	5.17	14.5
100% NP	59.5	16.6	60.2	44.9	13.0	37.4
100% NPK	77.5	20.3	80.3	59.6	17.7	49.6
150% NPK	95.8	28.0	110.1	79.5	22.7	66.1
100% NPK (S free)	68.0	18.1	69.6	54.0	15.1	45.3
100% NPK + Zn @ 2.5 kg ha $^{-1}$	80.2	23.6	87.0	65.8	18.7	55.3
100% NPK + 37.5 kg S ha $^{-1}$	87.0	25.9	99.2	70.13	19.6	60.5
FYM only 10 Mg ha $^{-1}$	58.9	16.2	61.8	37.7	10.9	32.2
100% NPK + FYM @ 10 Mg ha $^{-1}$	109.6	36.2	128.9	96.	28.2	83.3
CD (0.05)	5.93	2.51	10.0	7.26	2.34	6.83

At Jabalpur, minimum uptake of nutrient was recorded in control while maximum was recorded in 100% NPK + FYM (Table 2.2.3). The uptake of nutrients in INM was superior over 100% NPK. This shows that FYM not only contributed nutrients to the soil but it also enhanced greater uptake. Application of N alone had resulted in greater uptake of nutrients as compared to control but application of N alone may not be good proposition. However, when P was also applied along with N the yield and nutrient uptake resulted in marked increase showing that in this cropping system P is an important input controlling the yield of the crops. Further inclusion of K with NP, however, resulted in marginal increase in uptake of nutrients.

Table 2.2.3 Nutrient uptake by soybean and wheat in LTFE at Jabalpur

Treatment	Nutrient uptake (kg ha^{-1})					
	Soybean			Wheat		
	N	P	K	N	P	K
Control	34.8	0.9	17.1	20.3	1.5	14.4
100% N	49.9	1.5	21.1	27.8	3.0	20.7
100% NP	81.6	4.4	35.5	96.7	11.9	56.0
100% NPK	98.5	6.4	60.1	138.7	20.4	99.3
150% NPK	134.3	8.3	76.5	163.5	24.5	135.7
100% NPK-S	84.9	5.0	48.6	111.5	14.8	75.2
100% NPK+Zn	95.0	6.0	57.6	137.4	19.2	94.3
100% NPK+FYM	147.2	9.3	82.9	169.5	26.2	146.4
CD (0.05)	16.3	1.07	10.4	19.4	3.06	15.6

At Junagadh, maximum N uptake by groundnut was recorded with 50% NPK + FYM and 100% NPK+Zn. However, N content in pod remain at par with 100% NPK. Similarly, P, K and S uptake were also highest in 50% NPK+FYM in groundnut and wheat at Junagadh (Table 2.2.4).

Table 2.2.4 Uptake of nutrients by groundnut and wheat in LTFE at Junagadh

Treatment	Nutrient uptake (kg ha^{-1})					
	Groundnut			Wheat		
	N	P	K	N	P	K
Control	21.5	1.96	3.97	22.0	3.69	6.90
100% N	17.1	2.12	3.96	16.3	3.35	7.19
100% NP	21.6	3.29	4.69	35.4	5.67	8.93
100% NPK	40.2	4.21	5.28	43.6	7.05	10.2
150% NPK	29.8	5.71	6.49	56.5	9.46	10.0
100% NPK+ Zn	37.6	4.71	5.79	42.6	6.73	10.4
100% NPK (P as SSP)	20.5	4.32	5.64	37.0	8.12	9.86
50% NPK+ FYM*	50.4	6.38	7.62	60.0	12.2	12.4
Only FYM 25 t ha^{-1}	46.8	6.17	8.01	58.5	13.0	13.1
50% NPK+Rhizobium +PSM**	24.5	4.01	5.57	46.8	6.28	9.33
CD (0.05)	12.9	0.81	1.15	9.39	1.40	1.74

*50% NPK+10 t ha^{-1} FYM to groundnut and 100% NPK to wheat; **Phosphate solubilizing bacteria

At Parbhani, N uptake was highest with 100% NPK+FYM @ 5 t ha^{-1} and was significantly superior over all other treatments except the treatments receiving 150% NPK and 100% NPK + Zn (Table 2.2.5). It was also observed that lowest N uptake was noticed in control followed by 100% N treatment. Highest P uptake was recorded with 100% NPK+FYM @ 5 t ha^{-1} followed by 150% NPK. The 100% NPK+FYM @ 5 t ha^{-1} was significantly superior over all other treatments. Similarly, the P and K uptake by soybean and safflower showed similar trend.

Table 2.2.5 Long-term effect of fertilizer, manure and their combinations on nutrient uptake by soybean and safflower in LTFE at Parbhani

Treatment	Nutrient uptake (kg ha^{-1})					
	Soybean			Safflower		
	N	P	K	N	P	K
Control	24.6	4.67	12.2	11.2	3.79	17.6
100% N	33.8	5.43	14.7	14.6	4.36	20.9
100% NP	90.0	17.7	39.5	37.2	13.8	50.8
100% NPK	93.5	17.1	41.1	46.3	15.3	62.2
150% NPK	110.2	22.9	48.6	54.9	21.8	72.1
100% NPK+Zn	104.6	20.5	46.2	49.5	18.5	67.8
100% NPK+FYM @ 5 t ha^{-1}	113.0	23.9	50.7	56.9	23.5	75.6
100% NPK-Sulphur	89.7	18.5	39.6	45.	16.6	64.1
Only FYM @ 10 t ha^{-1}	92.0	18.9	40.9	39.7	13.9	50.7
CD (0.05)	13.9	2.26	5.17	10.7	4.10	14.0

2.2.6 Sustainable yield index (SYI)

The SYI of different treatments was computed for major crops at different centers. Highest SYI was recorded in 100% NPK + FYM and 150% NPK (Table 2.2.6). Thus, balanced nutrient application gave better SYI values and INM (NPK+FYM) further improved the sustainability.

Table 2.2.6 Long-term effect of various treatments on sustainability yield index (SYI)

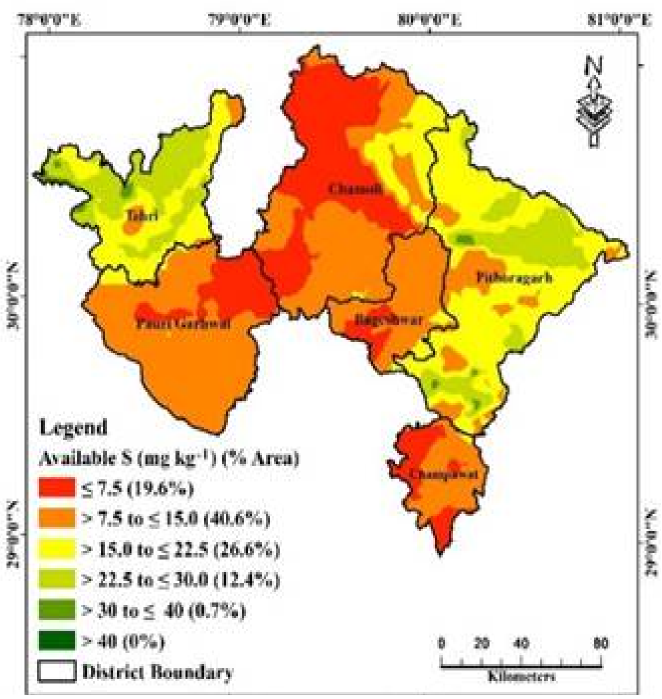
Location	Crops	Control	100% N	100% NP	100% NPK	150% NPK	100% NPK+ FYM
Akola	Sorghum	-0.004	0.22	0.35	0.47	0.62	0.65
	Wheat	0.43	0.59	0.62	0.53	0.61	0.58
Jabalpur	Soybean	0.12	0.14	0.24	0.30	0.32	0.34
	Wheat	0.14	0.15	0.49	0.56	0.59	0.61
Junagadh	Groundnut	0.22	0.20	0.22	0.28	0.32	0.33
	Wheat	0.36	0.35	0.49	0.65	0.71	0.85
Raipur	Rice	0.28	0.44	0.62	0.63	0.70	0.68
	Wheat	0.20	0.31	0.49	0.50	0.58	0.57
Parbhani	Soybean	0.077	0.185	0.627	0.726	0.769	0.775
	Safflower	0.066	0.176	0.636	0.708	0.744	0.771

2.3 AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (MSPE)

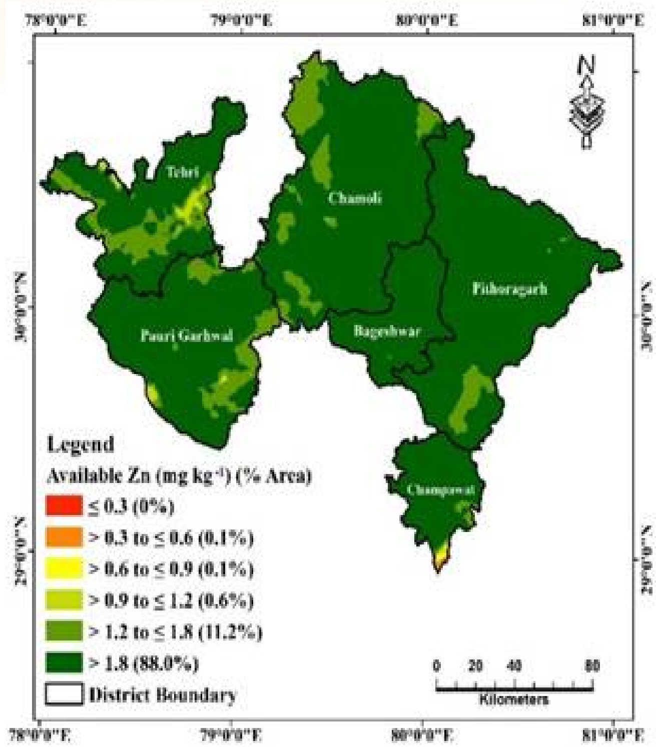
2.3.1 Variability of available sulphur and micronutrients in hilly region of northern India

The present study was carried out to assess and compare the status and spatial as well as temporal distribution pattern of available S (AS), available micronutrients, and soil organic carbon (SOC)] in cultivated soils of a hilly region of India, in 6 years (2015-2021). Altogether 2871 (1127 in 2015 and 1774 in 2021) georeferenced soil samples (0-15 cm depth) from cultivated areas of Uttarakhand were analysed. Soil properties, AS and available micronutrients exhibited moderate variability with coefficient of variation (CV) values ranging from 10 to 100%. The mean values of AS and available micronutrients in 2015 and 2021 differed significantly, as revealed by t-test. The mean concentrations of AS (13.2 mg kg^{-1}), available iron (AFe)

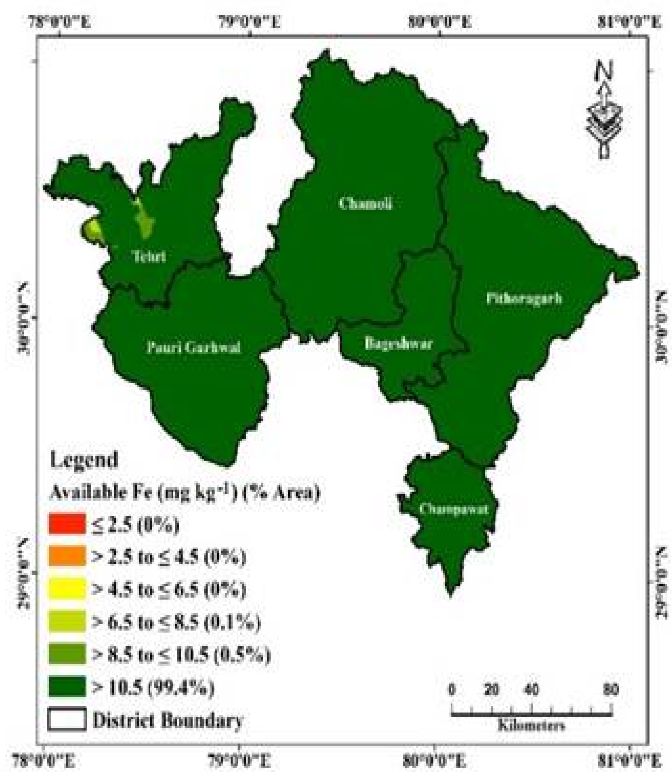
(36.5 mg kg^{-1}), available boron (AB) (0.92 mg kg^{-1}) and available molybdenum (AMo) (0.40 mg kg^{-1}) in 2021 were significantly lower than the concentrations of AS (44.7 mg kg^{-1}), AFe (42.8 mg kg^{-1}), AB (1.46 mg kg^{-1}), and Amo (0.94 mg kg^{-1}) in 2015. The AS concentration was positively and significantly correlated with soil pH and negatively and significantly correlated with SOC in both the years. There were positive and significant correlations of SOC with available zinc (AZn), available copper (ACu) and AB in 2015 and with AZn, AFe, ACu, available manganese (AMn) and AMo in 2021. The exponential model was found to be best fitted for all of soil parameters with lower MSE values (-0.007 to 0.006 in 2015 and -0.010 to 0.012 in 2021) in both the years of estimation. The nugget/sill ratios (varied from 0.32 to 0.74 in 2015 and from 0.29 to 0.57 in 2021) indicated the moderate spatial dependence for all the soil parameters except AFe (nugget/sill ratio 0.14, strong spatial dependence) in 2015 and EC (nugget/sill ratio 0.24, strong spatial dependence) in 2021.There were varied distribution patterns of soil properties, AS and available micronutrients in the study area for both the years of estimation. The distribution patterns of AS, AB and AMo changed to a greater extent over the period of time. Thus, the study highlighted the change in spatial variability of AS and available micronutrients in the study area over a period of 6 years (2.3.1).



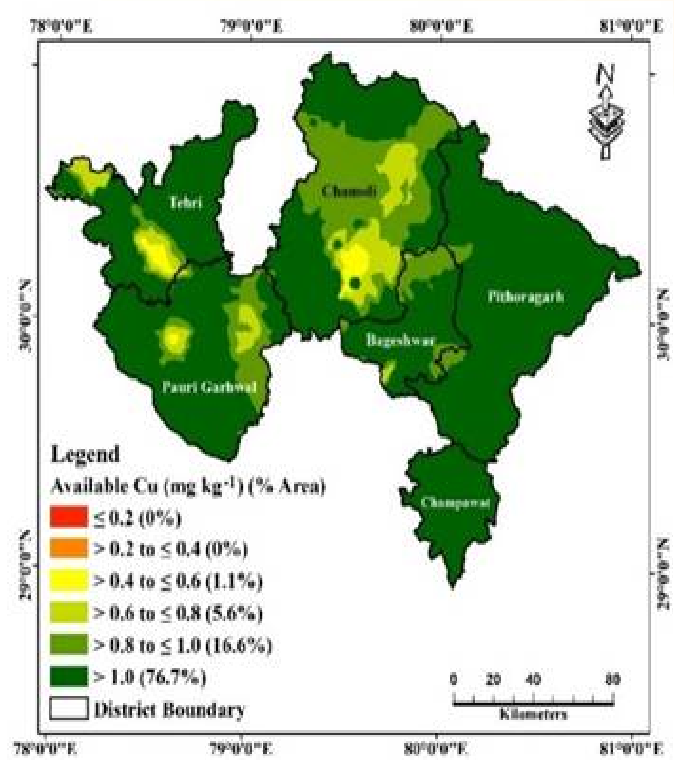
(a) AS in 2021



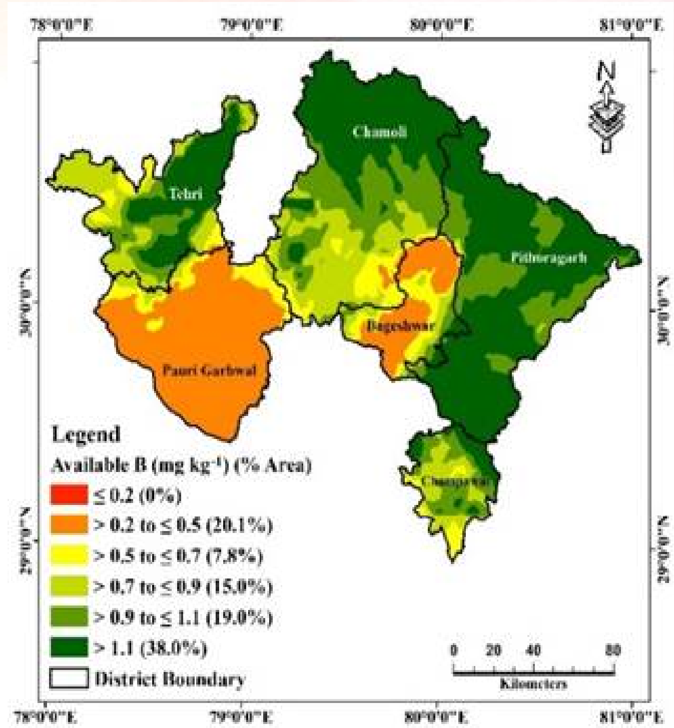
(b) AZn in 2021



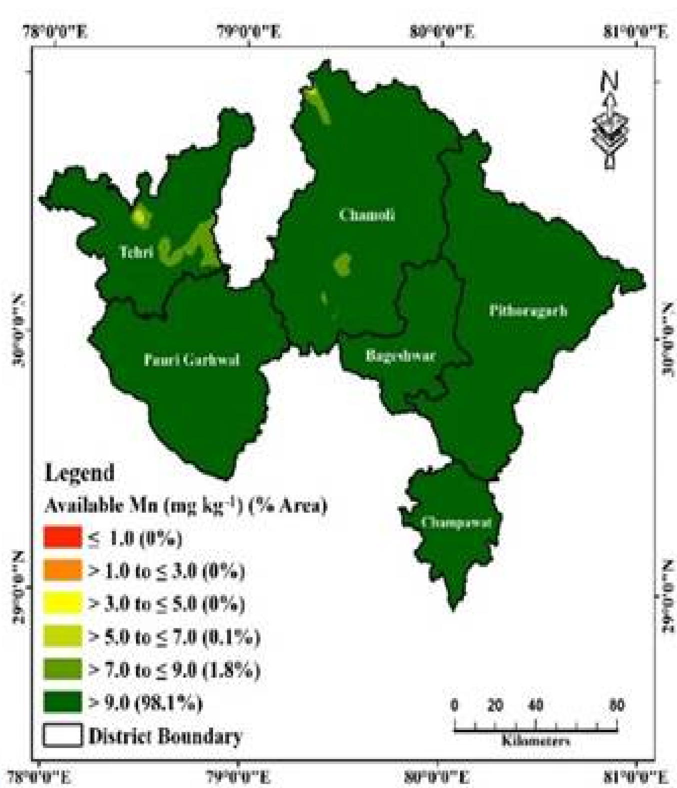
(c) AFe in 2021



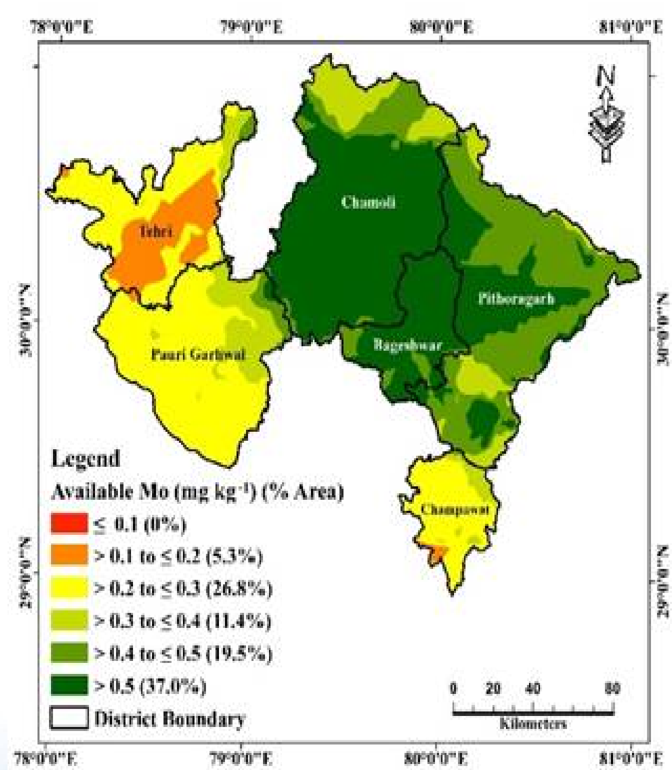
(d) ACu in 2021



(f) AB in 2021



(e) AMn in 2021



(g) AMo in 2021

Fig. 2.3.1 Distribution maps of available sulphur and micronutrients

2.3.2 Impact of boron addition to groundnut-cabbage system on yield and boron dynamics in Typic Haplustepts

A field experiment of 6-year duration was carried out at Anand Agricultural University, Gujarat, India to study the influence of long-term B fertilization in the groundnut-cabbage cropping system in different rates and frequencies on yield of crops and soil-B dynamics. The direct effect of B addition on groundnut yield and the residual effect on succeeding cabbage crop yield was evaluated. The treatments of the experiment encompassed various combinations of three frequencies and four rates of B application including one control (no B application). The application of B at different rates and frequencies significantly increased groundnut and cabbage yield in comparison to yield attained under the control. The addition of 1.0 kg B ha^{-1} in alternate years was found optimum for enhancing the yield of groundnut and cabbage crops grown on study soil. Boron application enhanced B content in groundnut pod, haulm, cabbage and available B in soil. Optimal available B content in soil was 1.25 mg kg^{-1} for both groundnut pod and cabbage head yield. The application of B with different rates and frequencies significantly enhanced B fractions in soil. The content of different fractions improved with the increase in rates of B application. The percentage contribution of various B fractions towards total B content followed the order: readily soluble B (0.43 to 0.55%) < specifically adsorbed B (0.74 to 0.98%) < organically bound B (0.70 to 1.55%) < oxide bound B (1.26 to 3.11%) < residual boron B (93 to 96.8%). Path analysis revealed the highest contribution of total boron towards groundnut-pod yield with a coefficient value of 4.30. Whereas oxide-bound boron fraction contributed to the maximum extent with a coefficient value of 0.91 towards cabbage-head yield. This information will be useful for B management in the groundnut-cabbage cropping system grown on studied soil.

2.3.3 Effect of Zn application in maize–wheat cropping on crop productivity and Zn use efficiency

A long-term field experiment was conducted during 2012 to 2018 at Anand Agricultural University, Anand (Gujarat), India, to find out the right Zn fertilizer dose and its frequency of application in maize–wheat cropping systems grown on typic haplustepts soil. The study comprised of three frequency levels, i.e., Zn application in the first year only, alternate year, and every year, with four different rates of Zn, i.e., 2.5, 5.0, 7.5, and 10.0 kg Zn ha^{-1} per year imposed in the maize–wheat cropping system in each kharif season for six years. Findings of the study revealed that Zn applications to maize at 7.5 and 10 kg ha^{-1} in alternate year and 5.0 to 10 kg ha^{-1} in every year significantly increased maize equivalent yield as compared to no-Zn treatment. Application of 10 kg Zn ha^{-1} per year produced higher grain size, straw, and total Zn concentrations compared to those observed under no-Zn application in maize and wheat crops. DTPA extractable Zn concentration in soil was higher in Zn treated plots which received Zn application at 5.0, 7.5, and 10.0 kg ha^{-1} in alternate years and 10 kg ha^{-1} in every year as compared to no-Zn application. Apparent Zn recovery efficiency varied from 0.17 to 1.46% for maize crop and 0.34 to 1.70% for wheat crop under different rates and frequencies of Zn application. The above results emphasize the importance of Zn retention capacity of soil regarding its response to different rates and frequencies of Zn application to maize and wheat crops.

2.4 AICRP on Soil Test and Crop Response Correlation (STCR)

2.4.1 Development of fertilizer prescription equations under integrated plant nutrient supply system

The different cooperating centers have generated technologies for integrated supply of plant nutrients involving fertilizers, organic manures and biofertilizers. In this technology, the fertilizer nutrient doses are adjusted not only to that contributed from soil but also from various organic sources like FYM, green manure, etc. The combined use of chemical fertilizers along with organics will help in sustaining the soil productivity and maintaining the soil health by way of improvement of soil physical, chemical and biological properties. The work done by various centers for development of IPNS targeted yield equations has been detailed in Table 2.4.1 and Plate 2.4.1.

Table 2.4.1 Basic data and targeted yield equation of different crop varieties developed by various centers of STCR

Crop (variety)	Basic Data					Targeted Yield Equations
	Nutrient	NR (kg q^{-1})	CS (%)	CF (%)	CO (%)	
PAU, Ludhiana						
Mustard	N	9.118	0.691	0.662	0.788	FN= 12.53T-1.04 SN-1.19 ON
(GSC-7)	P_2O_5	0.992	0.181	0.299	0.081	FP_2O_5= 2.96T-1.41 SP-0.60 OP
	K_2O	4.442	0.291	3.103	0.162	FK_2O=4.98T–0.09SK-0.0OK

IARI, New Delhi					
Late sown	N	2.24	33.8	50.04	6.84	FN=4.48 T – 0.68 SN – 0.14ON
Wheat	P_2O_5	0.45	62.75	29.37	11.12	FP_2O_5=1.55T– 2.10 SP–.038 OP
(HD 3059)	K_2O	1.89	35.35	118.3	2.77	FK_2O=1.60T- 0.30 SK– 0.02OK
DrRPCAU, Pusa					
Black niger	N	9.90	190.02	20.93	25.50	FN = 5.21T – 0.11 SN – 0.13ON
(Rajendra	P_2O_5	1.38	57.19	38.44	9.84	FP_2O_5=02.41T–0.67SP– 0.17OP
Shyama)	K_2O	5.09	190.32	36.23	33.64	FK_2O=.68T–0.19 SK- 0.18OK
PJNCARI, Karaikal, Pondicherry					
Cotton hybrid	N	3.49	10.82	47.90	38.45	FN=17.29 T – 0.23SN – 0.80ON
(RCH659 BG II)	P_2O_5	2.37	14.03	68.35	21.25	FP_2O_5=3.47T – 0.47SP – 0.71OP
	K_2O	4.22	10.88	98.20	26.04	FK_2O=4.30T– 0.13 SK– 0.32OK
GBPUAT, Pantnagar					
Groundnut	N	2.10	34.96	111.48	13.68	FN=1.89T-0.31SN-0.12ON
(Kailash)	P_2O_5	0.62	32.93	88.38	6.75	FP_2O_5=0.70T-0.85SP-0.17OP
	K_2O	1.77	22.71	60.77	12.38	FP_2O_5=2.91T-0.45SK-0.24OK
Wheat	N	2.58	49.34	36.20	16.26	FN=7.13T – 1.36 SN-0.44 ON
(HD-2967)	P_2O_5	0.295	46.59	32.47	7.04	FP_2O_5=2.08 T- 3.29 SP-0.497 OP
	K_2O	1.96	35.93	196.7	14.22	FK_2O=1.19 T- 0.22 SK- 0.08OK
CSKHPKV, Palampur					
Brinjal	N	0.30	16.71	40.91	7.64	FN = 0.74T – 0.41SN - 0.19ON
(Hisar Shymal)	P_2O_5	0.05	26.29	19.11	3.91	FP_2O_5=0.24T– 1.38SP–0.20OP
	K_2O	0.19	14.20	76.23	6.65	FK_2O =0.25 T - 0.19SK-0.09OK
IGKV, Raipur					
Maize-Cabbage-Okra cropping system					
Maize	N	1.63	40.39	21.92	8.30	FN = 4.03 T – 0.54 SN - 0.21ON
(NMH 8352)	P_2O_5	0.32	27.75	62.70	3.19	FP_2O_5=1.16T–2.26 SP - 0.11OP
	K_2O	2.11	108.96	20.75	8.50	FK_2O=1.93T – 0.19 SK- 0.08OK
Cabbage	N	0.23	39.58	23.70	8.21	FN = 0.59T – 0.60 SN - 0.21ON
(NS-22)	P_2O_5	0.03	21.33	45.80	2.23	FP_2O_5=0.16T– 2.15SP - 0.10OP
	K_2O	0.24	128.12	14.67	4.56	FK_2O=0.18T – 0.11 SK- 0.04OK
Hybrid Okra	N	0.74	35.10	13.78	5.65	FN = 2.12T – 0.39SN-0.16ON
(VNR-999)	P_2O_5	0.17	25.58	49.13	4.09	FP_2O_5=0.68T– 1.92 SP - 0.16OP
	K_2O	0.86	111.48	10.93	4.53	FK_2O=0.77T – 0.10SK- 0.04 OK
Sweet corn - Rice cropping system					
Sweet corn	N	0.26	25.30	11.09	11.20	FN = 1.03T – 0.44 SN - 0.44 ON
(Sugar-75)	P_2O_5	0.07	22.47	47.06	3.38	FP_2O_5= 0.31T– 2.09 SP-0.15OP
	K_2O	0.30	81.75	5.46	4.91	FK_2O=0.37T – 0.07 SK- 0.06OK
Hybrid Rice	N	1.62	34.98	27.45	8.90	FN=4.64T– 0.78SN- 0.25ON
(CG Hybrid -2)	P_2O_5	0.32	22.38	74.93	1.98	FP_2O_5=1.44T– 3.35SP - 0.09OP
	K_2O	2.11	158.61	14.23	4.01	FK_2O=1.33T– 0.09 SK- 0.03OK
SKRAU, Bikaner					

Pearl millet	N	7.03	39.94	157.6	181.5	FN=4.45T-0.25SN-1.15ON
(Super-82)	P_2O_5	0.90	25.66	22.62	43.85	FP_2O_5= 0.56T -1.13SP-1.93OP
	K_2O	5.18	17.11	109.7	168.8	FK_2O=4.71T-0.15SK-1.53OK
BCKV, Kalyani						
Garden pea	N	0.28	3.28	48.16	1.10	FN= 0.58T–0.07SN–0.02ON
(AP-3)	P_2O_5	0.07	7.52	13.38	0.28	FP_2O_5=0.49T–0.56SP–0.02OP
	K_2O	0.19	3.92	36.13	1.24	FK_2O=0.53T–0.11SK–0.03 OK
BHU, Varanasi, UP						
Garlic	N	2.04	17.82	20.74	4.60	FN=9.84T–0.86SN – 0.22ON
(Sweta)	P_2O_5	0.34	23.11	12.51	3.56	FP_2O_5=2.69T–1.85SP–0.28OP
	K_2O	1.57	17.74	37.91	7.18	FK_2O=4.15T–0.47SK–0.19OK
TNAU, Coimbatore						
Barnyard millet	N	2.58	23.33	32.69	22.32	FN=7.89T- 0.71SN- 0.71ON
(MDU 1)	P_2O_5	1.31	32.61	44.72	15.75	FP_2O_5=2.93T-1.67 SP-0.87OP
	K_2O	2.80	7.01	64.66	30.21	FK_2O=4.34T-0.13SK- 0.57OK
Bengalgram	N	3.93	42.02	63.17	24.24	FN=6.53T-0.39SN-0.68ON
(NBeG 49)	P_2O_5	1.78	89.01	39.34	16.06	FP_2O_5=3.37T-1.21SP-0.78 OP
	K_2O	2.53	8.35	66.51	15.07	FK_2O=5.03T-0.12SK-0.50OK
RAU, Pusa						
Linseed	N	3.16	7.40	68.01		FN = 4.65 T-0.11 SN
(Priyam)	P_2O_5	1.08	12.41	35.28		FP_2O_5= 3.06 T-0.35 SP
	K_2O	3.16	12.82	56.25		FK_2O = 25.62 T-0.23 SK
UAS, GKVK, Bangalore						
Sweet corn	N	6.07	29.53	42.25	0.87	FN=14.36T–0.69 SN – 0.87ON
(Sugar 75)	P_2O_5	2.10	17.70	55.63	0.80	FP_2O_5=3.76T– 0.31SP– 0.80OP
	K_2O	5.20	52.83	113.3	0.76	FK_2O=4.58T– 0.46SK– 0.76OK
AAU, Jorhat						
Rice	N	2.95	35.33	54.43	10.57	FN=6.80T–0.79SN-0.50 ON
(Ketekijoha)	P_2O_5	0.20	32.88	23.04	1.15	FP_2O_5=1.46T–1.40SP-0.15OP
	K_2O	2.67	49.87	64.13	22.40	FK_2O=5.20T–0.87SK-0.44OK
PJTSAU, Hyderabad						
Sesamum	N	8.12	12.12	40.18	24.1	FN=21.14T-0.40SN-0.58ON
(Swetha)	P_2O_5	1.62	20.14	38.32	7.12	FP=4.92T-0.50SP-0.18OP
	K_2O	3.21	4.72	72.14	34.7	FK=4.89T-0.04SK-0.18OK
OUAT, Bhubaneshwar						
Radish	N	0.26	30	54	16	FN = 0.49T- 0.56 SN-0.30 ON
(Ravi Tejas)	P_2O_5	0.1	36	24	17	FP_2O_5 = 0.42T - 1.5 SP-0.71OP
	K_2O	0.25	31	37	16	FK_2O = 0.68T- 0.84 SK-0.44 OK
MPKV, Rahuri						
Rajma bean	N	7.04	39.95	84.7	25.1	FN= 8.31 T – 0.47 SN – 1.48ON
(Phule Rajma)	P_2O_5	1.32	48.00	21.7	12.7	FP_2O_5 = 6.10T– 2.21SP–1.75 OP
	K_2O	3.11	6.66	78.5	27.3	FK_2O = 3.96T–0.08SK– 1.86OK

JNKVV, Jabalpur						
Chickpea	N	5.18	32.24	86.42	74.4	FN=5.99 T – 0.37 SN – 0.86ON
(JG-36)	P_2O_5	1.43	26.92	21.79	6.60	FP_2O_5=6.56 T–2.83SP– 0.69 OP
	K_2O	3.58	13.46	77.34	123.8	FK_2O=4.63T–0.21SK– 1.92 OK

Where, F = Fertilizer dose of N, P_2O_5 or K_2O in kg ha^{-1}; T = Yield target in q ha^{-1}; NR = Nutrient requirement of N, P_2O_5 or K_2O for 100 kg economic produce; CS = Contribution from soil nutrients in fraction; CF = Contribution from fertilizer nutrients in fraction; CO = Contribution from organic nutrients in fraction; SN, SP, SK = Soil available nutrients N, P_2O_5 or K_2O determined through standard soil testing protocols.

Plate 2.4.1 View of STCR Linseed experimental field at RPCAU, Pusa, Bihar

2.4.2 Assessing methods for estimating potentially mineralizable nitrogen (PMN) under organic production system

A field experiment was conducted at BCKV, Mohanpur, in an organically fertilized french bean crop after a 3-year crop cycle of aromatic rice-french bean-okra. Farmyard manure, vermicompost, mustard oil-cake, poultry manure and their different combinations equivalent to 120 kg N ha^{-1} were applied as sources of N. Chemically fertilized plots were also maintained as a check. PMN was derived using first-order kinetics, from the disappearance of organic-N at different growth stages of french bean using the methods involving 1/15 M phosphate buffer (PB), 0.01 M calcium chloride ($CaCl_2$), 0.01 M sodium bi-carbonate ($NaHCO_3$), and 0.1 M sodium hydroxide + 0.05 M EDTA extractants. The conventional alkaline permanganate method for N estimation was also used for comparison. PB derived significantly 22, 39 and 47% higher PMN than Basic EDTA, $NaHCO_3$ and $CaCl_2$ respectively. PMNs estimated by different methods were well correlated (r = 0.53** to 0.84**) among themselves while exhibited poor correlation with alkaline permanganate N (r = 0.30 to 0.41*). PB-derived PMN depicted the strongest linear relationship with pod yield (r = 0.89**, R2 = 0.80**) and N uptake (r = 0.81**, R2 = 0.66**). The reliability of PB as the most suitable method was further established by principal component analysis as PB explained the highest proportion (73%) of total PMN variation. Adopting PB to estimate PMN as an index of N availability will thus assist soil testing agencies to improve nutrient management advisory for organic farmers.

Theme II. Conservation Agriculture, Carbon Sequestration and Climate Change

2.5.1 Impact of crop residue and nutrient levels on crop productivity in soybean–wheat cropping system

The experiment was designed to study the effect of different levels of crop residue retention and economized doses of nutrient application in soybean-wheat cropping system. The treatments comprised of four levels of residue retention and economized doses of N, P and K application as compared to 100% nutrient application. The maximum yield in wheat and soybean crop was recorded in 90% residue retention treatment which was significantly superior to 60%, 30% and without residue retention and the lowest grain yield was observed in without residue. The effect of nutrient application was non-significant (Table 2.5.1).

Table 2.5.1 Effect of different levels of crop residue retention and nutrient doses on grain yield (kg ha^{-1}) on wheat crop

Residue retention	100% RDF (120:60:40)	75% N, 100% P, K	75% P, 100% N, K	75% K, 100% N, P
90% R	6600	5989	6029	6244
60% R	5733	5911	5777	5666
30% R	5500	5275	5277	5422
WR	5232	5077	5133	5188

2.5.2 Effect of crop residue and herbicide application on weed density and crop productivity in zero-till maize-chickpea cropping system

The effect of different levels of crop residue retention and herbicide application in maize-chickpea cropping system was studied. The treatments comprised of four levels of residue retention and four weed control treatments. The maximum weed density and weed biomass at 30 DAS and after harvest in case of both maize and chickpea crop was recorded in without residue retention treatment and was significantly higher over 30%, 60% and 90% crop residue retention treatment. The different herbicidal weed control treatments have significant influence on weed density and maximum weed density was observed in one hand weeding at 50 days after sowing and which was at par with post-emergence application of treatment Imazethapyr @ 25g a.i.ha^{-1} + Clodinafop @ 60g a.i.ha^{-1} and significantly higher weed density over Imazethapyr @ 50 g a.i. ha^{-1} as a pre-emergence followed by Imazethapyr @ 50 g a.i. ha^{-1} (as pre-em) one hand weeding at 50 days after sowing. The maximum grain yield in both the crops was recorded in 90% crop residue retention level and significantly superior over 60% and 30% crop residue retention and without residue retention treatment. The maximum grain yield was recorded under treatment post-emergence application of Tembotrione @ 120g a.i.ha^{-1} +Atrazine @ 625g a.i.ha^{-1} followed by one hand weeding at 50 days after sowing which was at par with post-emergence application of Tembotrione @ 180g a.i.ha^{-1}+Atrazine @ 1000g a.i.ha^{-1} and significantly superior over Tembotrione @ 120g a.i.ha^{-1}+Atrazine @ 1000g a.i.ha^{-1} as a pre-emergence @ 120g a.i.ha^{-1}+Atrazine @ 625g a.i.ha^{-1} without hand weeding (4856.88 kg ha^{-1}) (Plate 2.5.2).

Plate 2.5.2 Effect of crop residue and herbicidal weed control on crop growthin zero-till maize- chickpea cropping system

2.5.3 Impact of no till system with residue retention on macro-aggregate formation and aggregate associated carbon stabilization in a Vertisol

A trial site established on a Vertisol under sub-humid, dryland conditions to examine the impact of NT along with residue retention on soybean (*Glycine max* L.), wheat (*Triticum aestivum* L), maize (*Zea mays*) and chickpea (*Cicer aerietinum* L) production over 8 years. The study was initiated with the hypothesis that the soil under NT along with residue would improve water stable aggregates, mean weight diameter and aggregate associated carbon particularly in top layer (0-10 cm) in comparison to CT with no residue retention. In case of Soybean-wheat cropping system (0-10 cm) tillage and residue retention significantly affected soil total carbon. No till system without residue retention enhanced soil total carbon by 6% in comparison to CT, although the difference was insignificant. Retention of residue to the tune of 90% resulted in 47% improvement in soil total carbon in comparison to C. Similarly, retention of residue of previous crops (90%) resulted in 17% improvement in soil total nitrogen after completion of 8 years of soybean-wheat cropping system Tillage along with residue retention significantly ($P < 0.05$) influenced the distribution of aggregates in large macro-aggregates (>2 mm size) The proportion of large– (>2 mm) was significantly higher in the NT treatment than that in CT. In contrast, the proportion of small macro-aggregates (1-0.25 mm) was higher in the CT than that in NT. No significant impact of no till system with residue retention was observed on WSA. The effect of no till system along with residue retention significantly impacted soil MWD. There was 5.5-77% improvement in soil MWD in no till system with different levels of residue retention in comparison to CT system (Table 2.5.3).

Table 2.5.3 Size distribution of water-stable soil aggregates (%)

Treatments	Large macro-aggregates (>2 mm)	Small macro-aggregates (2–0.25 mm)	Macro- micro-aggregates (0.25–0.053 mm)	Silt+clay fraction (<0.053 mm)
CT	13.73b	56.68a	11.78a	17.6a
NTR0	13.83b	54.58a	11.63a	19.83a
NTR30	26.50ab	43.73a	8.54a	20.60a
NTR60	28.67ab	45.46a	6.53a	18.60a
NTR90	36.13a	45.06a	5.81a	12.57a

Note: Values followed by a letter not in common within a column, are significantly different based on Duncan's multiple range test at P = 0.05

2.5.4 Impact of crop residue and nutrient levels on crop productivity and soil health

Soybean yield was relatively higher under no tillage, which is on par with reduced tillage plus residue retention. However, nutrient doses had a significant effect on soybean yield. STCR-based fertilizer application recorded significantly higher yields compared to 100% RDF and 75% RDF (Table 2.5.4a). The maize yield was relatively higher under no tillage, which is on par with other tillage treatments. Results indicated that nutrient doses had a significant effect on maize yield (Plate 2.5.4). Among the different doses, STCR-based fertilizer application recorded significantly higher maize yield compared to 100% RDF and 75% RDF (Table 2.5.4a). Soil organic carbon data indicated that the surface layer recorded higher values, regardless of tillage practices. Among tillage practices, no-tillage and reduced tillage with crop residue retention recorded higher values compared to conventional tillage practices (Table 2.5.4b). It is concluded that after nine years of continuous practice of NT, crop rotation and residue retention are the sustainable soil management systems for enhancing soil health and crop productivity in the rainfed vertisols. Conservation tillage practices effect on crop yield after 11 crop cycles After the completion of 11 crop cycles, crop yields were recorded and converted into soybean grain equivalent yield (SGEY, q ha^{-1}) (Fig. 2.5.4). During Kharif season, tillage systems did not have a significant effect on crop yield, but cropping systems had a significant effect on crop yield. During Rabi season, tillage and cropping systems had a significant effect on wheat and gram yield after 11 crop cycles (Plate 2.5.4).

Table 2.5.4a Effect of different tillage and nutrient doses on yield of different crops during 2021-22

Treatment	Grain Yield			
	Soybean* (q ha^{-1})	Maize (q ha^{-1})	Wheat (q ha^{-1})	Gram (q ha^{-1})
Tillage				
T1 – NT with 30cm height residue	17.97	49.83	53.81	17.43
T2 – NT with 60cm height residue	19.12	48.90	53.69	17.53
T3 – RT with 30cm height residue	18.98	48.77	52.98	17.01
T4 – RT with 60cm height residue	17.61	48.57	55.62	17.13
T5 – CT (Conventional Tillage)	18.52	48.84	53.38	16.76
Mean	18.37	48.98	53.90	17.17
Nutrient levels				
N1- 75% RDF	16.32	43.83	48.11	14.49
N2-100% RDF	19.01	50.24	54.51	17.57
N3- STCR dose	19.96	52.87	59.07	19.45
Mean	18.37	48.98	53.90	17.17
C.D. (P< 0.05)				
Tillage System (TS)	0.806	NS	NS	NS
Nutrient Dose (ND)	0.839	0.856	0.647	1.357

Table 2.5.4b Effect of different tillage and nutrient doses on SOC in different depth

	SOC (%)		
Treatments	**0-10 cm**	**10-20 cm**	**20-30 cm**
T1	0.83	0.56	0.46
T2	0.86	0.57	0.49
T3	0.76	0.56	0.43
T4	0.80	0.59	0.46
T5	0.70	0.53	0.48
CD	0.024	NS	0.019
100 %	0.80	0.57	0.46
75%	0.74	0.51	0.45
STCR	0.83	0.61	0.48
CD	0.023	0.026	NS

Plate 2.5.4 Experimental plots under different tillage system

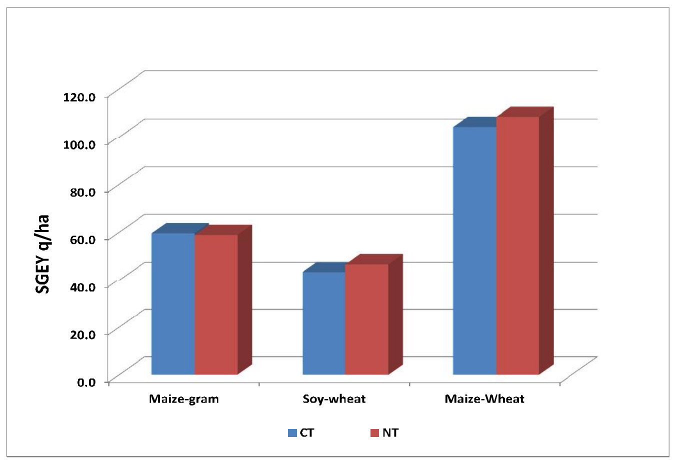


Fig. 2.5.4 Effect of conservation agricultural practices on SGEY

2.5.5 Effect of water, nutrient and tillage management on Soybean-Wheat cropping System

A perusal of the data showed that grain yield and straw yield of wheat did not vary significantly among the irrigation, tillage, and fertilizer treatments, but water use efficiency (WUE) was significantly higher under drip irrigation than sprinkler and flood irrigation. The WUE was lowest under flood irrigation, which was significantly lower than that under sprinkler irrigation (Table 2.5.5a & Plate 2.5.5a). Higher water productivity was attained in drip and sprinkler systems of irrigation compared to that in flood irrigation, where losses of water through surface evaporation and deep drainage were higher. Conservation agricultural system-maintained yield level on par with conventional agricultural practices with concomitant savings of time, labour and input costs and improvements in soil health parameters and sustainability of yield.

Table 2.5.5a Effect of tillage, nutrients and irrigation systems on wheat yield parameters and WUE

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (%)	Water Use efficiency (Grain kg ha^{-1} mm^{-1})	SMC (%)
Irrigation methods					
Flood	5256	5179	0.50	12.6	15.8
Sprinkler	5155	5230	0.50	14.4	20.7
Drip	4745	4923	0.49	16.3	21.0
LSD (0.05)	NS	NS	NS	2.034	
Tillage systems					
CT	4933	5059	0.49	14.2	18.4
RT	5058	5085	0.50	14.4	19.7
NT	5156	5188	0.50	14.8	19.3
LSD (0.05)	NS	NS	NS	NS	
Nutrients Doses					
100% RDF	5092	5106	0.50	14.4	18.8
75% RDF	4747	4902	0.49	13.6	19.2
STCR dose	5307	5358	0.50	15.2	18.9
LCC dose	5063	5076	0.50	14.5	19.6
LSD (0.05)	279.8	337.98	NS	NS	

Plate 2.5.5a Water management practices in CA

The field experiment was conducted on soybean crops in the kharif season. There were three levels of fertilizer treatments (F1 = 100% RDF, F2 = 75% RDF, and F3= STCR) and three levels of tillage treatments (CT = conventional tillage, RT = reduced tillage, and NT = no tillage) tested in the kharif season. The grain and straw yields of soybean were slightly higher under the reduced tillage system as compared to conventional tillage (Table 2.5.5b). The lowest grain and straw yields were recorded under no tillage, but all the tillage systems were significantly at par. Similarly, in the case of fertilizer treatments, the STCR dose recorder recorded a slightly higher grain yield of soybean, followed by 100% RDF, and a slightly lower yield of 75% RDF. However, all the fertilizer treatments were also significantly above par. The interaction effect of tillage systems and different nutrient doses was found to be non-significant (Table 2.5.5b). Conservation agricultural system-maintained yield level on par with conventional agricultural practises with concomitant savings of time, labour, and input costs and improvements in soil health parameters and sustainability of yield (Plate 2.5.5b).

Table 2.5.5b Effect of tillage systems and nutrients doses on grain and straw yield of soybean

	Soybean grain yield (kg ha^{-1})				Soybean Straw yield (kg ha^{-1})			
	F1	F2	F3	Mean	F1	F2	F3	Mean
CT	1085	1013	1056	1051	3130	3010	3160	3100
RT	1103	1055	1136	1098	3540	3030	3490	3350
NT	1011	1049	1048	1036	3030	3030	3130	3060
Mean	1067	1039	1080		3230	3020	3260	
	Tillage: NS, Nutrient Dose: NS Tillage x Fertilizer dose: NS				Tillage: NS, Nutrient Dose: NS Tillage x Fertilizer dose: NS			

Plate 2.5.5b View of soybean experiment in CA

2.5.6 Impacts of conservation agriculture on runoff and soil loss under different cropping systems in Vertisols

There were three types of tillage operations, namely conventional tillage, reduce tillage, and no tillage, along with 30 and 60 percent crop residues retention in combination with reduce and no tillage operations examined for run-off and soil loss under soybean-wheat and maize-chickpea cropping systems. However, conventional tillage treatment was imposed alone. These treatments were also studied for their impacts on the physical and chemical properties of soil as well as crop productivity. During the years 2022, a total of 1887 mm of rainfall was received, which was 37% higher than the average rainfall for the location. A total of 20 runoff events were recorded during the year. The maize-chickpea cropping system was observed to be comparatively more prone to soil loss (Table 2.5.6 & Plate 2.5.6) and runoff than the soybean-wheat system; however, conventional tillage under both cropping systems was recorded to have the highest soil loss and runoff over other treatments of conservation agriculture.

Table 2.5.6 Soil loss and Run off under soybean-wheat and maize-chickpea cropping system

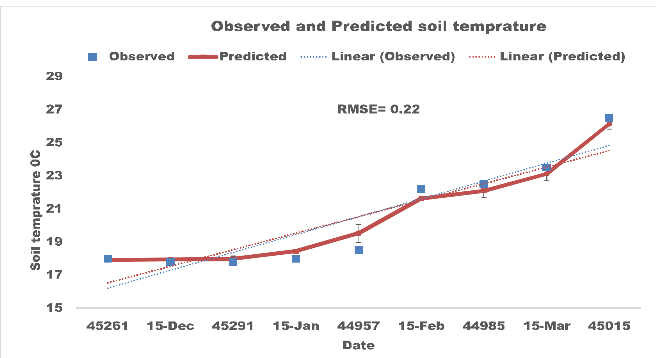
Treatments	Soil loss (t ha^{-1})	Runoff(%)	EC (µS cm^{-1})	pH
Soybean-Wheat cropping system				
Conventional Tillage	5.84	45.50	159.4	7.10
Reduce Tillage +30% crop residue	4.72	44.50	149.0	7.17
Reduce Tillage+ 60% crop residue	4.08	42.08	114.3	7.36
No Tillage+ 30% crop residue	4.02	41.70	119.4	7.44
NoTillage + 60% crop residue	3.66	40.26	120.6	7.54
Maize-Chickpea cropping system				
Conventional Tillage	8.95	47.07	134.2	7.04
Reduce Tillage +30% crop residue	8.04	46.48	149.6	7.19
Reduce Tillage+ 60% crop residue	7.42	45.76	153.4	7.38
No Tillage+ 30% crop residue	6.00	45.68	158.4	7.40
NoTillage + 60% crop residue	5.28	45.06	178.8	7.66

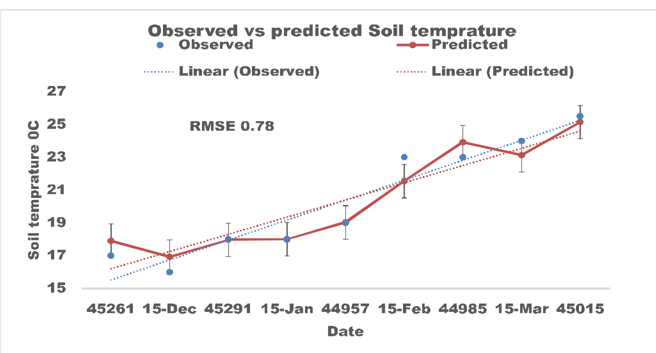
The lowest soil loss and runoff were associated with no tillage and 60% crop residue under both cropping systems. The nutrient losses in the form of total N, P, and K followed the same trend as in the case of soil loss and runoff; therefore, nutrient losses are higher with conventional tillage than with other treatments. Losses of major and micronutrients were recorded comparatively more with the maize-chickpea cropping system (Plate 2.5.6). There was a non-significant effect of different treatments observed on various soil properties like bulk density, mean weight diameter (MWD), water-stable aggregate (WSA), EC, and pH under both cropping systems. The plant growth parameters and yield attributes were no variation under various treatments.

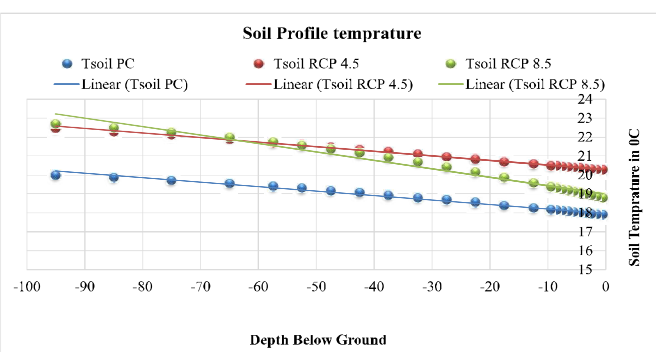
Plate 2.5.6 Crop field with multislot divisor

2.5.7 Impact of climate change on soil physical processes in maize based cropping systems

The evaluation of the field water cycle for a winter wheat-summer maize double cropping system in 4.5 and 8.5 future climatic scenarios in order to estimate field water dynamics and optimize agricultural water management strategies to mitigate climate change In this study, the agro-hydrological Soil-Water-Atmosphere-Plant (SWAP) model was used to evaluate the field water cycle. The model was first calibrated and validated using field experimental data, including soil water content and soil temperature. The root mean square error (RMSE) is 0.22 and 0.78 for soil temperature at 5 and 10 cm depth, respectively, and 0.53 for hydraulic conductivity. A model-based field water balance showed different climatic situations with reasonable accuracy. This study also indicates that the soil profile temperature will be 2-3^{0}C higher under RCP 4.5 and RCP 8.5 compared to the present scenario. The net water balance (Fig. 2.5.7) of -4.18 cm3/cm3 in RCP 8.5 is less than that of 1.57 cm3/cm3 in comparison to the present scenario during 2021–22.







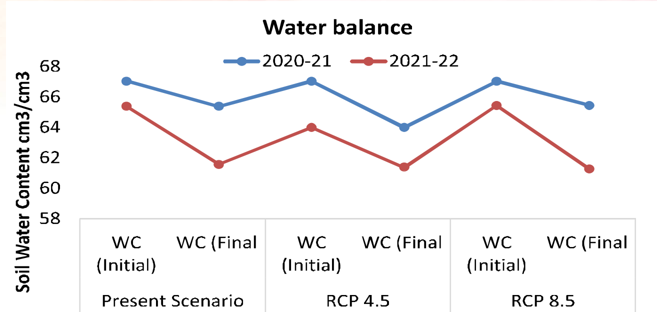
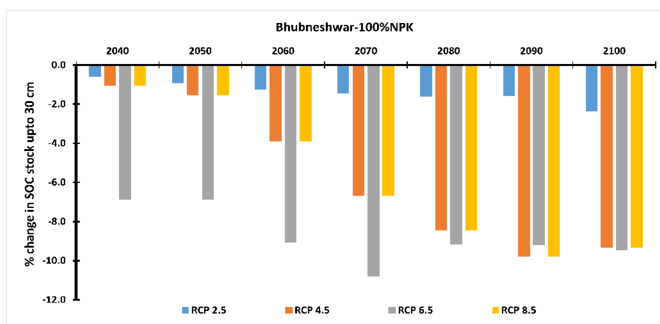
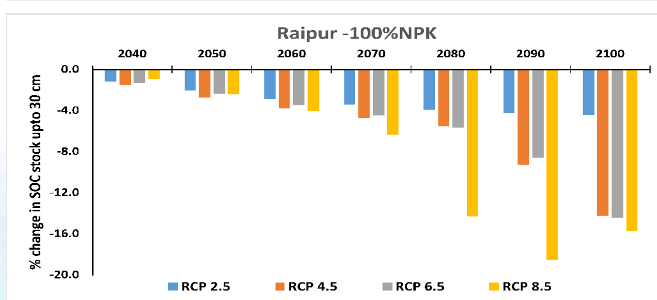


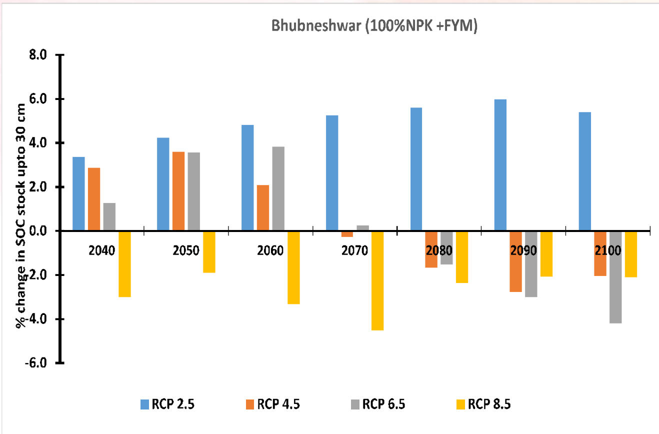
Fig. 2.5.7 Observed and predicted soil temperature and water balance under RCPs

2.5.8 Soil organic carbon (SOC) sequestration potential under the changing climatic scenarios

To simulate the long-term dynamics of SOC in rice-based cropping systems under different management practices, the RothC process-based model was utilized. The model accounted for soil, climate, and management practices (100% NPK and 100% NPK+FYM), and used data from the LTFE experiment. The RothC model was parameterized and validated to predict SOC stock. The validated model was then used to evaluate the impacts of different management practices on SOC dynamics under different climatic scenarios. The results demonstrated that management practices with FYM have great potential to increase SOC sequestration in the rice-based cropping system. The equilibrium SOC concentration is higher with an integrated application of N with FYM. Climate change decreases the rate of SOC sequestration in all the studied agroecosystems, with higher decreases (Fig 2.5.8) reported under RCP 8.5, followed by RCP 6.0, RCP 4.5, and RCP 2.6.







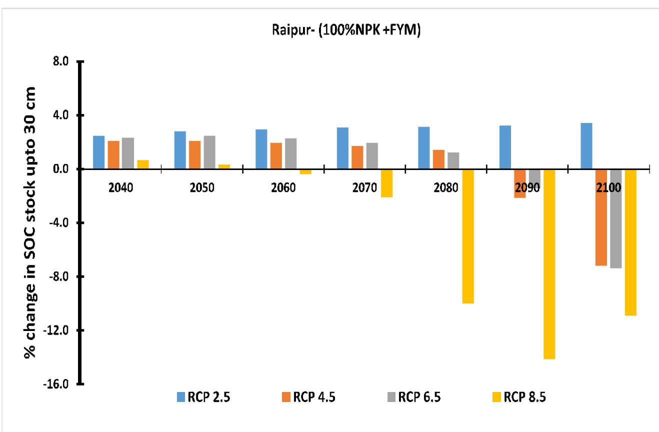


Fig. 2.5.8 Decadal changes of SOC stock over the base year (2020) at two location

2.5.9 Adaptive water management to improve pigeon pea yield using APSIM model

India accounts for approximately 22% of the world's production of pulses. Despite this fact, the yield of Pulses in India is much less than in the world. Pulses in India are grown mostly in a rainfed situation with less-than-ideal conditions, which may be the primary cause for the lower yield. Pigeon pea is an important pulse crop largely grown in Madhya Pradesh. However, Pigeon Pea productivity (1.133 t ha^{-1}) is relatively low compared (Fig 2.5.9) to a developed nation. To work out a suitable strategy to improve the productivity of Pigeon peas, it is imperative to assess the potential yield in the region of interest and the gap between the potential yield and actual yield obtained by the average farmers. This study employed a well-calibrated and validated APSIM crop model to assess the pigeon pea yield gap in Madhya Pradesh and identify suitable adaptive management practices to improve the pigeon pea yield in the state. Results indicate that one irrigation of 60 mm during the last week of November may improve pigeon pea yield by 300 kg ha^{-1} in central India.

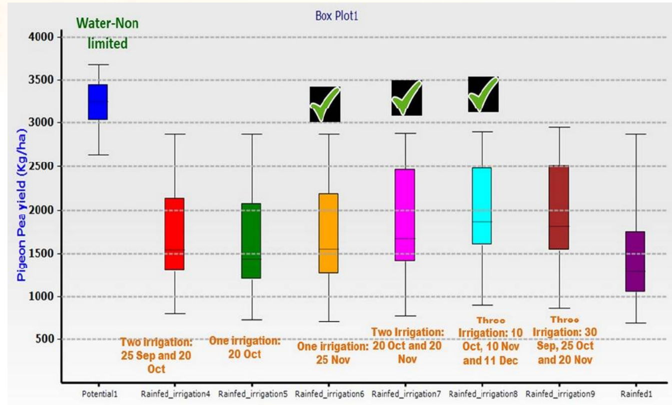
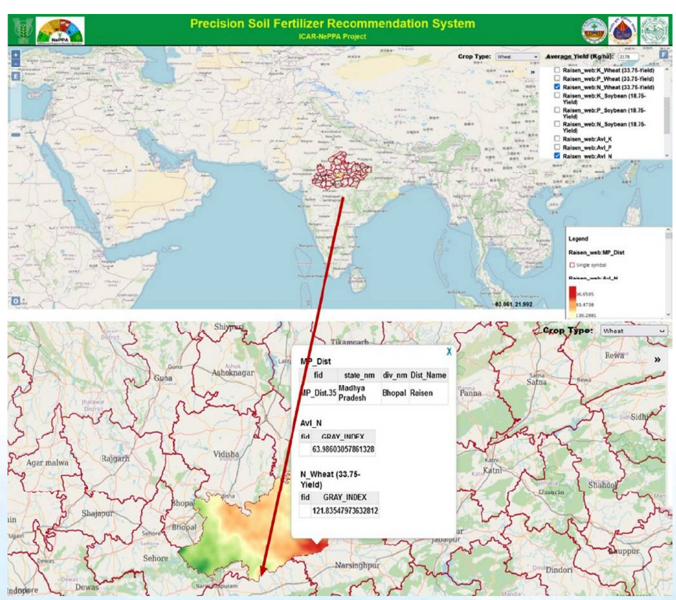


Fig. 2.5.9 Adaptive water management practices to improve pigeon pea yield

2.5.10 Development of a Web and Mobile based precision soil fertilizer recommendation system (PFRS)

The foundation of all crop production activities is soil, making it the most valuable resource. The decrease in soil fertility is a crucial factor that directly impacts crop productivity. Blanket crop production technologies, including fertilizer application, have accelerated the situation over the decades. Due to blanket fertilizer recommendations, the application of nutrients is often not well matched to the requirements of the soil and crop. Also, excessive, non-judicious, and imbalanced use of chemical fertilizers can result in the deterioration of soil health. This is becoming a cause for concern for Indian agriculture. The solution lies in part in having a precise, site-specific nutrient management approach that will build a sustainable and profitable agriculture sector. To address this, a decision support system (Plate 2.5.10) is developed, integrating digital soil maps, geospatial tools, and target-based fertilizer recommendations.



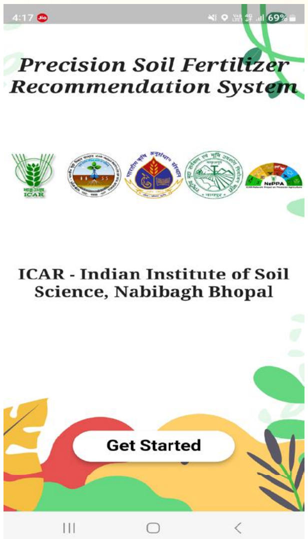
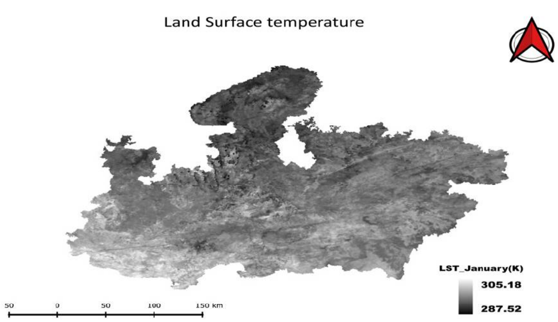
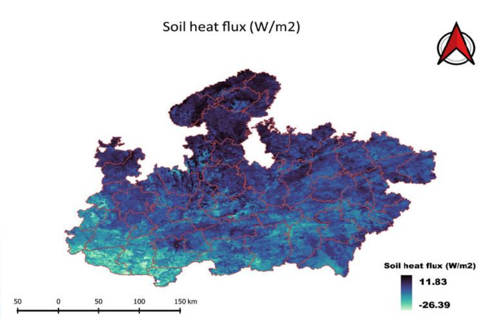


Plate 2.5.10 Web and Mobile based precision soil fertilizer recommendation system

2.5.11 Spatial and temporal analysis of land surface temperature of Madhya Pradesh

Land Surface temperature (LST) changes was analyzed in the Madhya Pradesh region using the MODIS monthly data. The LST of January showed temperature variation between 287 K to 305 K over Madhya Pradesh (Plate 2.5.11). The western part of the state is relatively warmer than the rest of Madhya Pradesh during January. However, during May, the LST of Madhya Pradesh exceeded 310 K. Further, using the LST, soil heat flux was derived for Madhya Pradesh.





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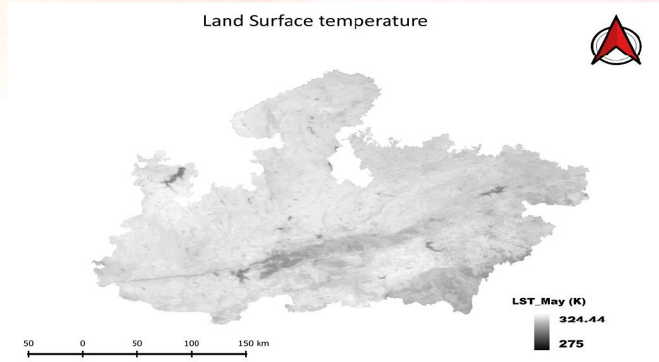

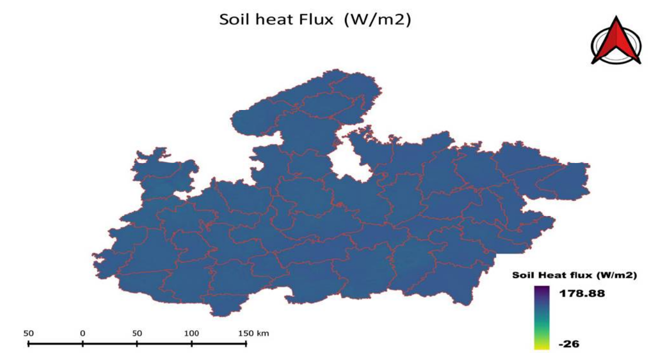

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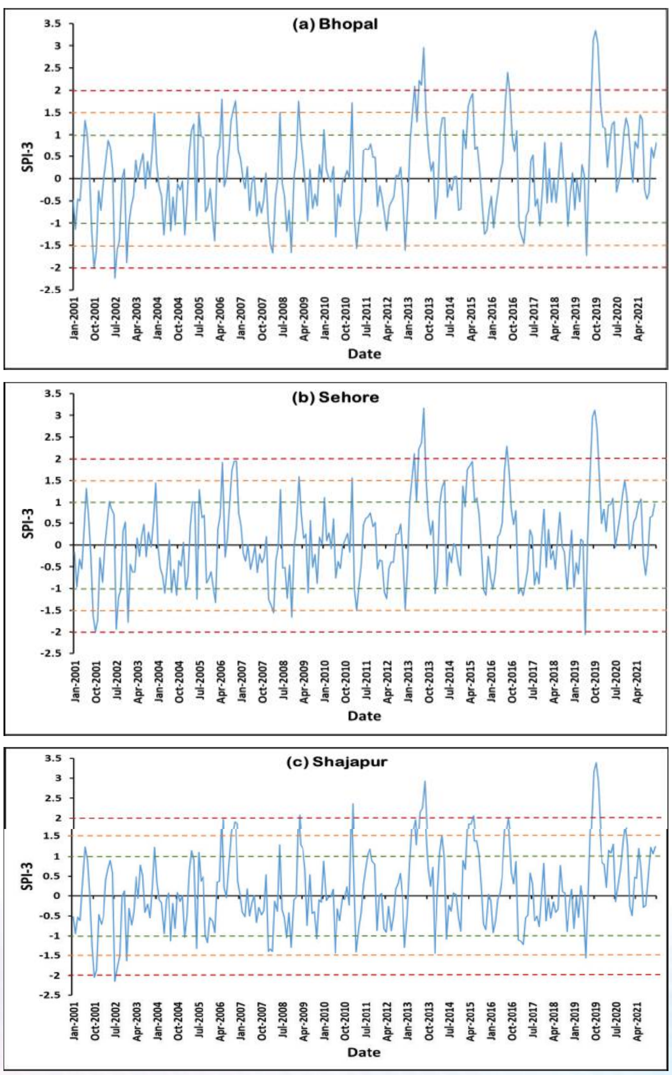
Plate 2.5.11 Spatial and temporal variation of Land surface temperature and soil heat flux

2.5.12 Indices for monitoring agricultural drought episodes in three districts of Madhya Pradesh

In this study, two widely used drought indices was computed, i.e., Standardised Precipitation Index at a three-month time period (SPI-3) and the Standardised Vegetation Index (SVI), from the satellite data, and their applicability was evaluated for Bhopal, Sehore, and Shajapur districts of Madhya Pradesh for characterizing agricultural drought. These indices were computed for the period of 2001 to 2021 at a 16-day interval and 1 km spatial resolution. These indices were classified for drought severity. The negative values of SPI-3 denote drier (SPI-3 $<$ -1) conditions, while positive values denote wetter (SPI-3 $>$ 1) than normal conditions. The temporal variation of SPI-3 in Bhopal, Sehore and Shajapur districts of Madhya Pradesh is depicted in figure (Fig 2.5.12) The green line represents the normal category, the orange line represents the moderately dry or wet category and the red line represents the severely dry or wet category. According to SPI-3, extreme and severe droughts were found in the kharif season mainly during the years 2001 and 2002 in the study region. SPI-3 reported moderate drought in the study region during the kharif season, mainly during the years 2004, 2005, 2008, 2009, 2018, and 2019. Moderate and severe droughts were found in the rabi season mainly during the years 2001, 2008, 2012, and 2017 in the study region, as per SPI-3. The SVI depicts drought based on the vegetation condition. The positive value of SVI represents good crop condition, while the negative value represents poor crop condition with respect to the long-term average. The temporal variation of SVI in Bhopal, Sehore, and Shajapur districts of Madhya Pradesh is depicted in figure 2, where green, yellow, orange, and red lines represent the no, mild, moderate, and severe drought classes, respectively. SVI reported agricultural drought during the kharif season mainly during the years 2001, 2002, 2006, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2018, and 2019 in the majority of the study region. As per SVI, agricultural drought was found in the rabi season mainly during the years 2001, 2002, 2003, 2005, 2006, 2007, 2008, 2009, 2016, and 2018. Shajapur district was found to be more affected by drought, followed by Sehore and Bhopal, respectively. The behaviour of both SPI-3 and SVI for characterizing agricultural drought is different, as SPI-3 is sensitive to rainfall whereas SVI is sensitive to vegetation conditions.



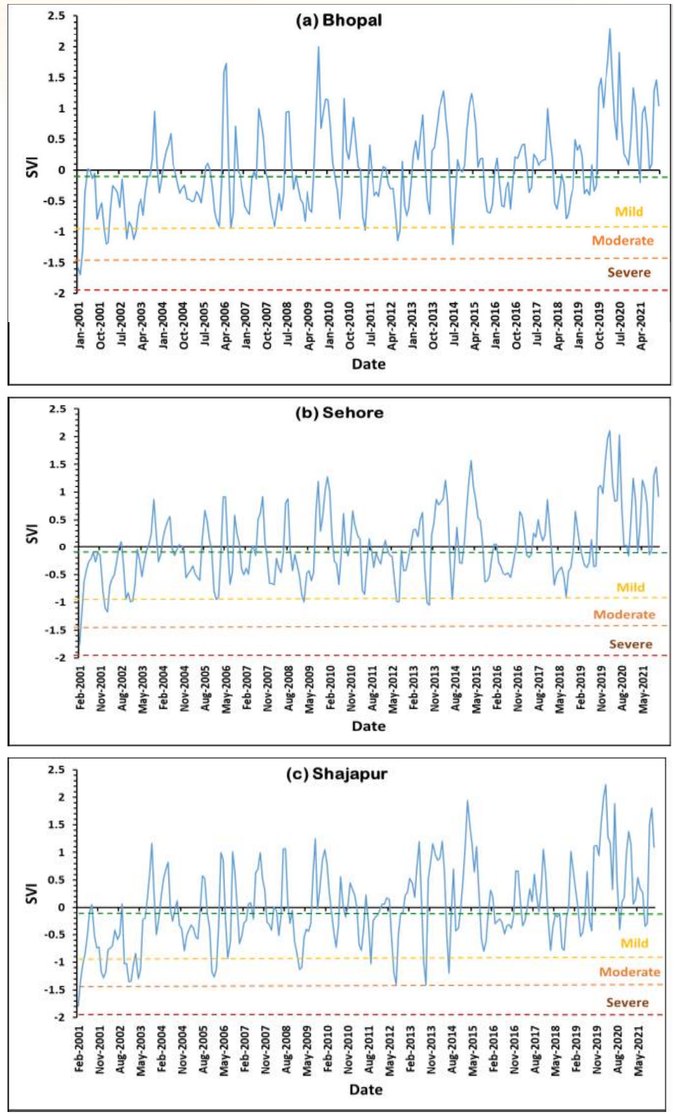


Fig. 2.5.12 Temporal variation of SPI-3 and SVI in (a) Bhopal, (b) Sehore, and (c) Shajapur

2.5.13 Trends in potassium fractions under conservation agriculture in Vertisol of Central India

Potassium fractions under conservation agriculture in the soils of ICAR-IISS Bhopal were studied in the mazie-chickpea cropping system after the harvest of Maize in October 2022. The influence of different levels of residue at three depths was estimated, and results indicated that in conventional plots and CA plots without the application of crop residue, all the pools of K (water-soluble K, available K, and non-exchangeable K) were significantly lower than in CA plots with residue addition. The addition of crop residue significantly added K to the soil, and the increase was prominent in all the pools of K. However, the effect was restricted to the upper 0–10 am of soil, signifying that the effect of CA is mostly confined to the upper 0–10 cm of soil depth. (0-10 cm). The absolute values of K fractions showed high stratification (Fig. 2.5.13) between 0–10 and 10–20 cm, and less difference was noted between 10–20 and 20–30 cm soil depth.

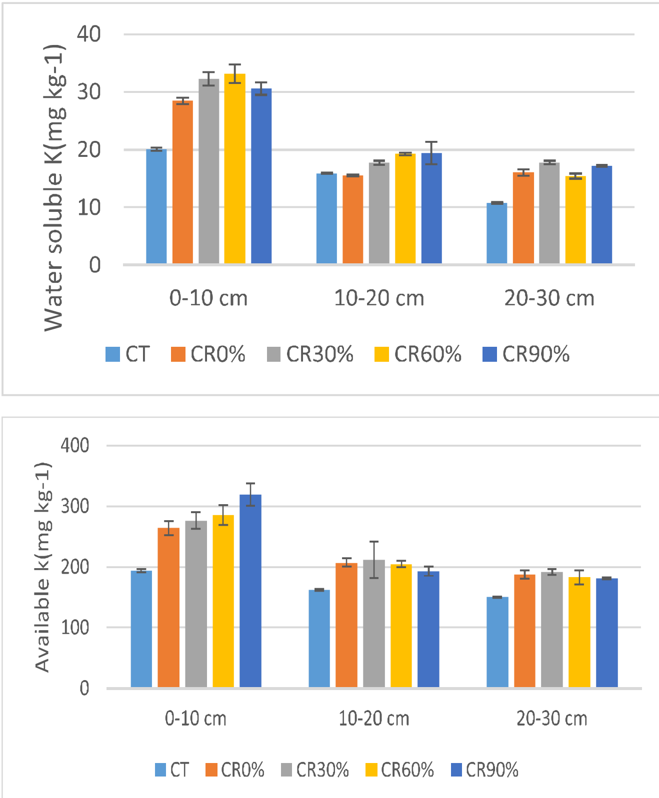
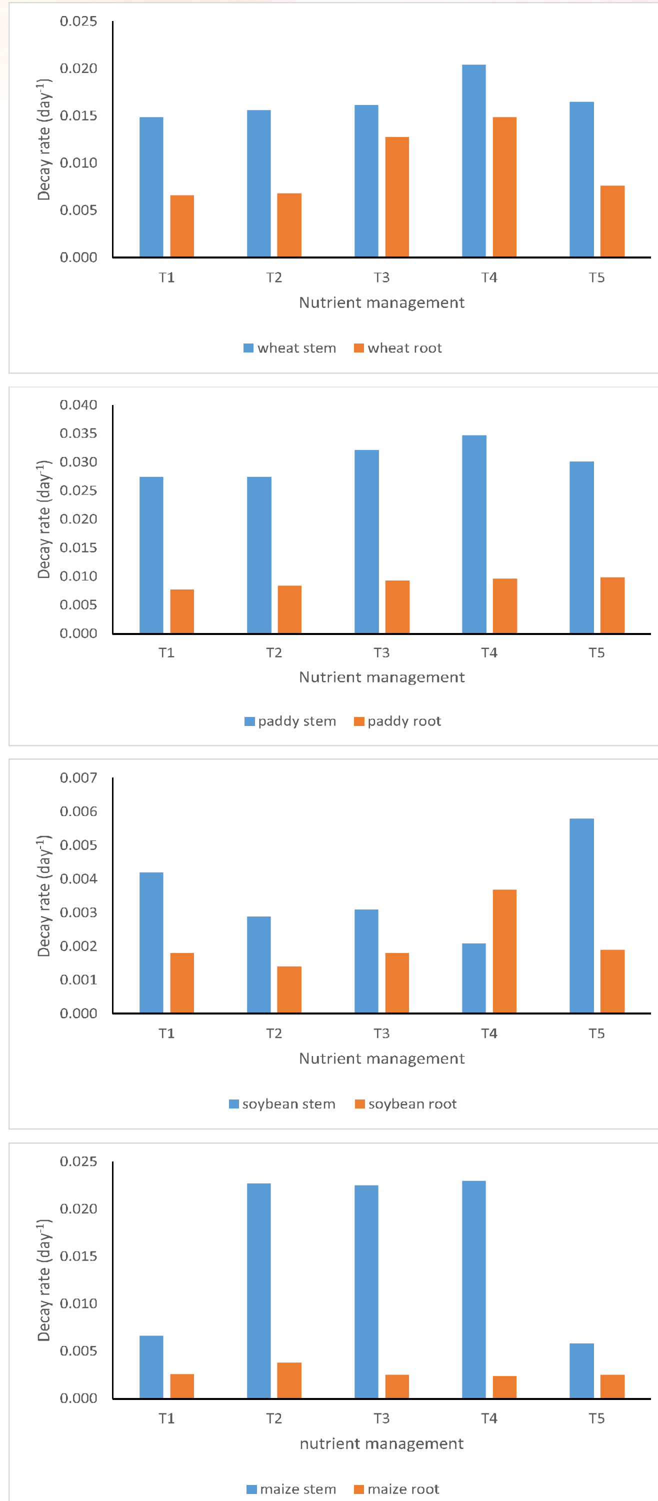


Fig. 2.5.13 Different fractions of K under conservation agriculture in Vertisol of Central India

2.5.14 Decomposition kinetics of different crop residues under different nutrient management

An 18 month in situ decomposition experiment in a soybean-wheat and maize-chickpea cropping system was conducted to investigate the potential mechanisms governing the decomposition of incorporated litter. The results showed that in soybean-wheat cropping system, the wheat stem and roots' mean decay rate was 3.6 and 4.7 times higher than the stem and root of soybean, respectively across nutrient management (Fig. 2.5.14). However, in the maize-chickpea cropping system, the maize stem's decomposition rate was less than 0.7 times compared with the chickpea stem. The decomposition of maize root was more than 1.7 times compared with the chickpea root. Further, the results demonstrated that across the cropping system, integrated use of nutrients (N100PK + FYM @ 5t ha^{-1}) resulted in a higher decomposition rate of residue stem and root compared with N0PK. The decomposition rate of above-ground straw was significantly higher than that of below-ground roots across residue types and nutrient management.



T1:Fallow; T2: N0PK; T3:N100PK; T4:N100PK+FYM @5t ha^{-1}; T5:N150PK

Fig. 2.5.14 Effect of nutrient management on decay rate of different crop residues

2.5.15 Methane flux influenced by crop residue and nutrient management under long-term conservation tillage

A mesocosm experiment was conducted to evaluate the impact of different crop residues (wheat, rice, soybean, and maize) on methane (CH_4) emissions in response to soil moisture and nutrient management from long-term conservation till soils. The results indicated a significant ($p<0.001$) interaction effect of residue type, nutrient, and soil moisture on methane emission and consumption (Fig. 2.5.15). Across crop residue and nutrient levels, reducing soil moisture from 80% field capacity to 60% field capacity increased methane consumption. The average methane fluxes at the two soil moistures were 2.72 and -6.97 μg-C kg^{-1} soil, respectively. The incorporation of rice and maize straw increased methane consumption by eight times compared with soybean and wheat across all nutrient and moisture management. Nutrient application (inorganic and integrated) increased methane emission compared with minus nutrient in control and residue amended soil.

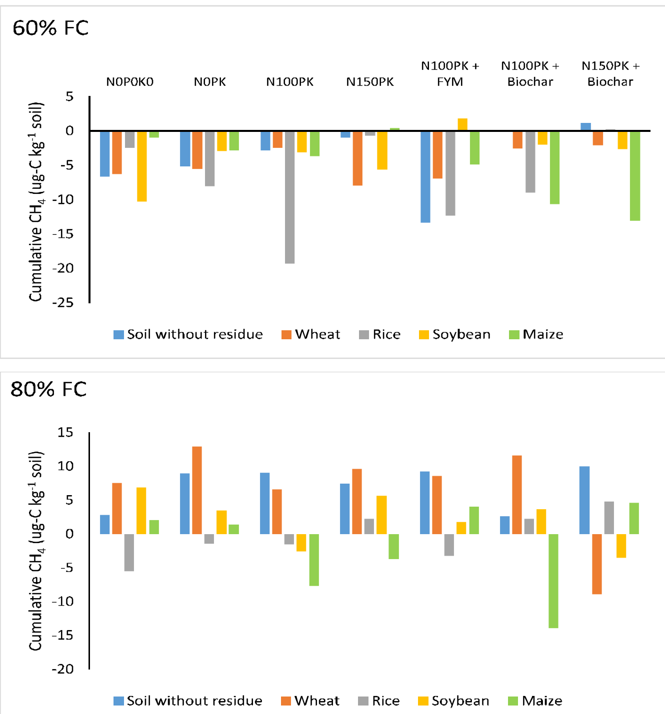


Fig. 2.5.15 Methane flux as influenced by crop residue and nutrient management

Theme -III: Microbial Diversity and Genomics

2.6.1 Plant growth promoting attribute of endophytic and rhizoplane colonizing bacteria in Mustard

From rhizoplane and endorhizosphere of Mustard (cv Pusa Mehak) grown in three different soils *viz.*, Vertisol, Inceptisol and Alfisol, the total 37 isolates were obtained. Nineteen isolates from these could grow on nitrogen free medium, 6 isolate solubilized P from tricalcium phosphate, 2 isolate solubilized potassium from glauconite, 2 possessed siderophore production ability and 8 had zinc solubilizing ability with the highest zinc solubilization index of 3.84 by isolate BVR-7 (Plate 2.6.1a and b).

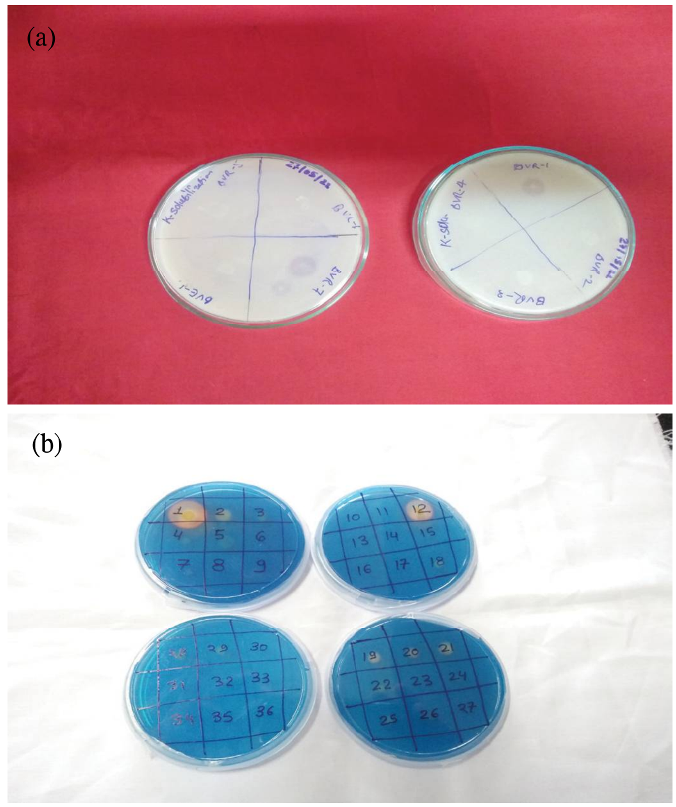


Plate 2.6.1 K-Solubilization from glauconite (a) and (b) siderophore production by mustard root endophyte

2.6.2 Plant growth promoting effect of endophytic fungal isolates

The inoculation effect of endophytic fungal isolates on maize and wheat plant growth and biomass weight was examined and also to what extent endophytic fungal strains influences the host plant growth were compared with control group. The inoculation experiment revealed that, presence of selected fungal isolates had no pathogenic effect on maize and wheat crop growth or even in its presence promotes the plant growth. Furthermore, presence of heavy metals in the soil also has no effect on the root and shoots length and significantly increased in plant growth in all inoculated pots of maize and wheat. Moreover, significant differences were observed when compared to control pot. The fungal isolates belong to genera; *Fusarium* and *Curvularia* sp. showed wide range of heavy metal tolerance and grew well in the presence of Pb, Cd, Cr and Hg heavy metals (Plate 2.6.2).

Plate 2.6.2 Effect of endophytic fungal isolates on maize in metal contaminated soil

2.6.3 Alleviation of UV radiation driven abiotic stress using Methylotroph bacteria

Experiment was undertaken to evaluate the role of phyllosphere methylobacteria and its metabolite in the alleviation of abiotic stress rendered by ultraviolet (UV) radiation. A potential pink pigmenting methylotroph bacterium was isolated from the phylloplane of the rice plant (*Oryza sativa*). The 16SrRNA gene sequence of the bacterium was homologous to the *Methylobacter radiotolerans*. The isolate referred as *Methylobacter radiotolerans* N39, produced β carotene at a rate (μg mL^{-1} d^{-1}) of 0.45 to 3.09. Biosynthesis of β carotene was stimulated by brief exposure to UV for 10 min per 2 days. The carotenoid extract of N39 protected the *E. coli* from UV radiation by declining its death rate from 14.67% min-1 to 4.30 % min^{-1} under UV radiation. Application of N39 cells and carotenoid extract also protected rhizobium (*Bradyrhizobium japonicum*) cells from UV radiation. Scanning electron microscopy indicated that the carotenoid extracts protected *E. coli* cells from UV radiation. Foliar application of either 39 cells or carotenoid extract enhanced the plant's (Pigeon pea) resistance to UV irradiation.

2.6.4 Bioconversion of atmospheric GHGs and volatiles to plant metabolites through phyllosphere methylotroph

Two variety of wheat HI 8759 Pusa Tejas (PT) and HI 1605 Pusa Ujala (PU) are raised in white plastic pots containing 1.5 kg vertisol soil. Five replicates of each treatment were maintained. The soil moisture stress was maintained as 20% and 60% in both wheat varieties. Experiments conducted to understand methylotrophs in the seeds and its partitioning to root and shoot. Seeds of wheat (variety HI 8759 Pusa Tejas and HI 1605 Pusa Ujala), rice (variety PB1 and Kranti) and maize (variety 1144 and PC (35002)) were surface sterilized crushed extract from seeds were pooled and a dilution series was prepared using sterile normal saline. After 48 h of incubation the Colony Forming Units (CFU) were counted manually shown in Table 2.6.4a and 2.6.4b.

Table 2.6.4a Plant variety and methylotrophs abundance (CFU) recovered from seeds

Crop	Plant variety	Methylotrophs (CFU/mL ± SD)
Wheat	HI 1605 Pusa Ujala	210 x 10^3 ± 10
	HI 8759 Pusa Tejas	150 x 10^3 ± 14
Maize	1144	100 x 10^3 ± 13
	PC35002 hybrid	155 x 10^2 ± 12
Rice	PB1	101 x 10^2 ± 13
	Kranti	260 x 10^2 ± 11

Methylotroph abundance varied in the root and shoot system. Both white and pink colonies were recovered from root and shoot samples. Shoots have higher number of methylotrophs than root (Table 2.6.4b). Ten pink pigmented colonies were observed in shoot whereas eight colonies were observed in root samples. Out of 28 isolates, 12 morphologically different isolates were screened for further analysis. Methanol dehydrogenase gene (*mxa*)[1] was PCR-amplified.

Table 2.6.4b Methylotrophs abundance in maize plant at different source point

Crop	Source	Methylotrophs abundance (CFU/ g of sample)±SD
Maize	Seeds	1.1 x 10^5±0.5
	Root	1.7 x 10^6±0.4
	Stem	3.3 x 10^4±0.12
	Leaf	6.7 x 10^4±0.21

2.6.5 Soil ecological indicator under LTFEs (Inceptisol, Alfisol and Vertisol) of India

Geometric mean of soil enzyme activities (GMea), an integrated index of soil quality, has been appeared as a crucial soil ecological indicator in all the three LTFE centres. In the present study, GMea values followed a similar trend to that of individual enzyme, however, it differentiated the treatments more explicitly than the individual enzyme in all the LTFE soils. Moreover, the lower temporal variability of GMea as compared to the individual enzyme makes it more promising to indicate a real-time scenario (Fig. 2.6.5a).

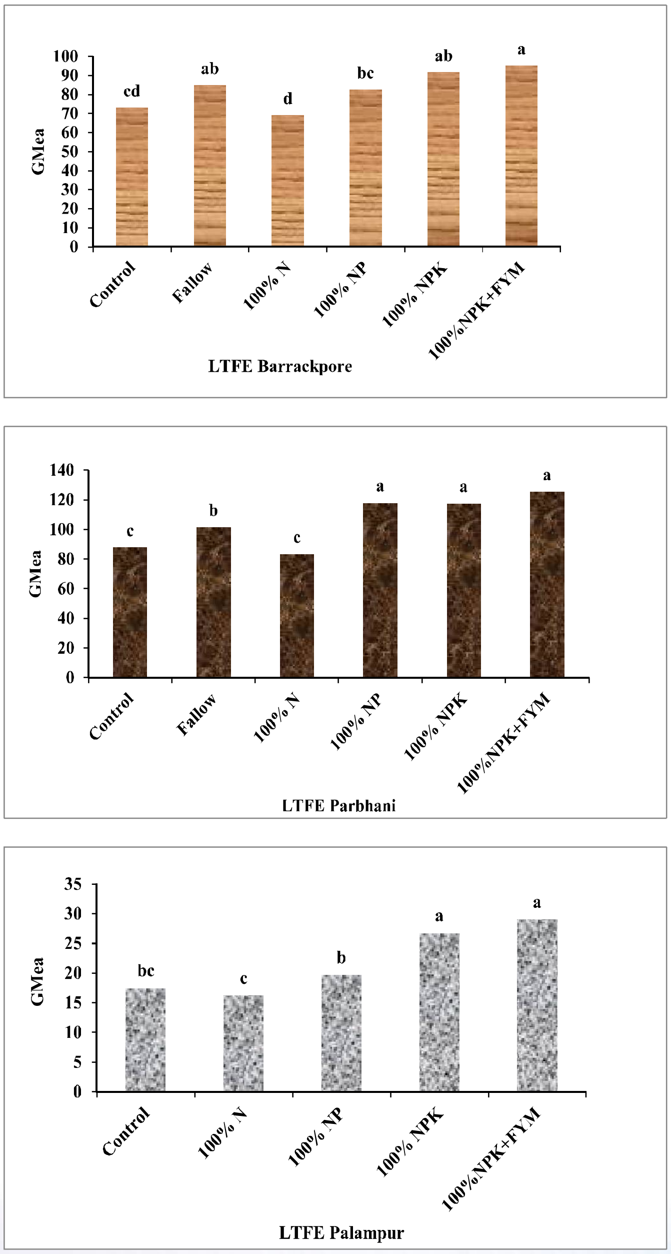
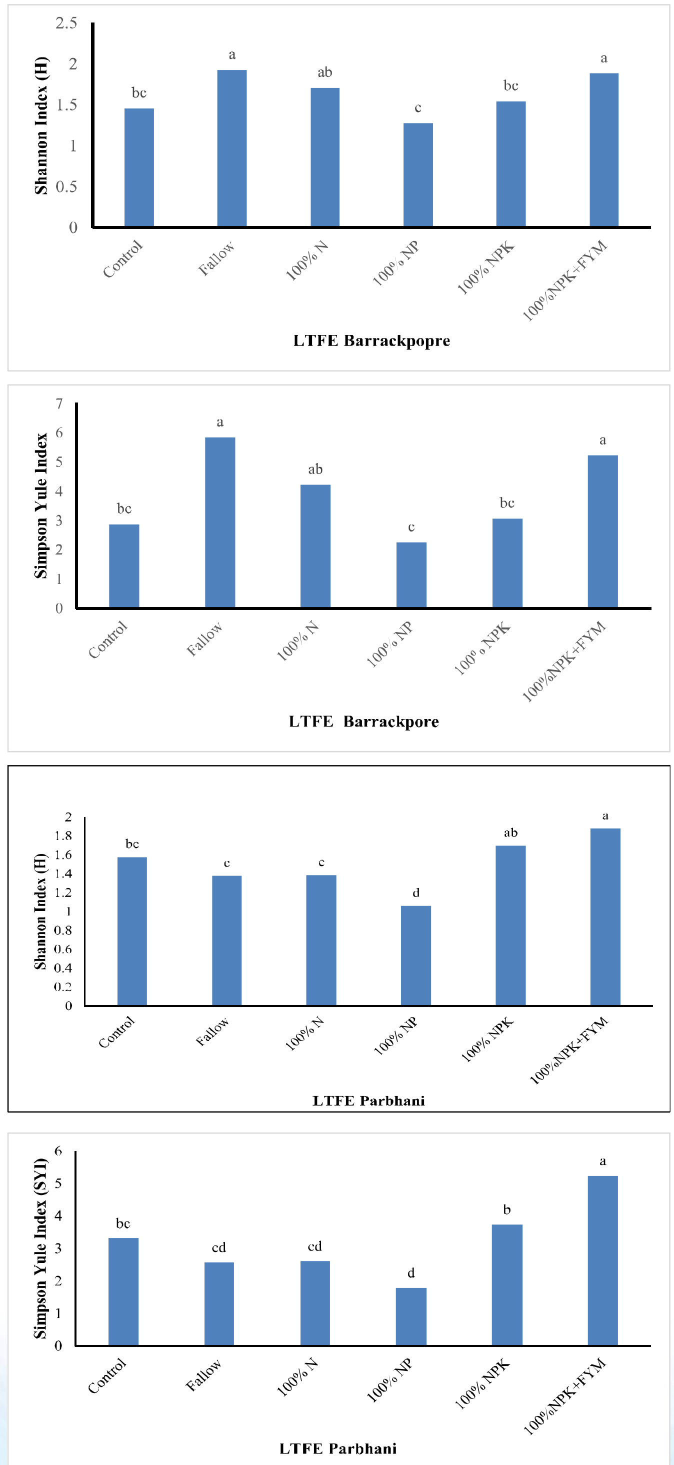


Fig. 2.6.5a GMea of LTFE treatments under different locations

Soil functional diversity has been enumerated through different enzymatic diversity indices. In this regard, Shannon diversity index (H) and Simpson Yule index (SYI) have been quantified (Fig. 2.6.5b). The highest H and SYI have been noticed in 100% NPK+FYM treatment in LTFE Barrackpore and LTFE Parbhani, however, the highest H, SYI was noticed in 100% NPK in LTFE Palampur, though it was statistically similar with 100% NPK+FYM treatment.



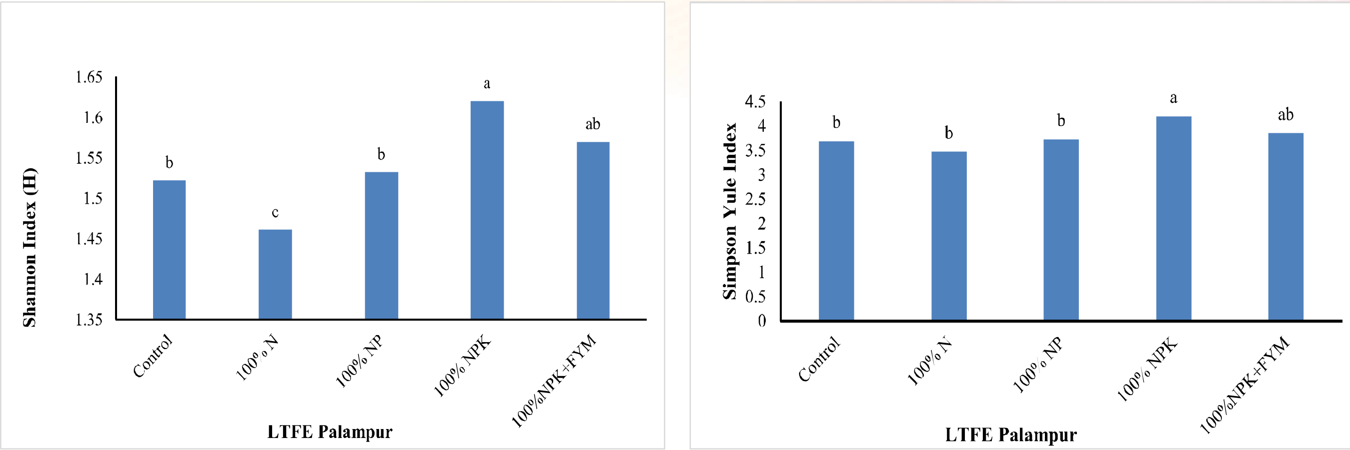


Fig. 2.6.5b H and SYI of LTFE treatments under different locations

2.6.6 Deciphering thermophiles from hot springs for rapid decomposition of crop residues

In total 101 thermophiles were isolated from three hot springs CA, BA and TA of Central India (Table 2.6.6a). Apart from bacterial isolates, from TA soil sample one fungi and from water sample one actinomycetes has been also isolated. The number of positive isolates for thermozyme production were shown in Fig. 2.6.6 Pure cultures of microbial isolates were individually spotted on CBM agar plates. After 5 days of incubation at 40°C, the plates were flooded with Gram's Iodine solution. Clear zones that appeared around microbial colonies indicated cellulose hydrolysis. The intense zone on the plate medium was measured and calculated as a potency index (Plate 2.6.6, Table 2.6.6b).

Table 2.6.6a Total number of thermophiles isolated from hot springs of Central India

HS	In Water sample	In Mat sample	In Soil sample	Total
CA	5	13	6	24
BA	11	21	19	51
TA	6	18	2	26
Total	22	52	27	101

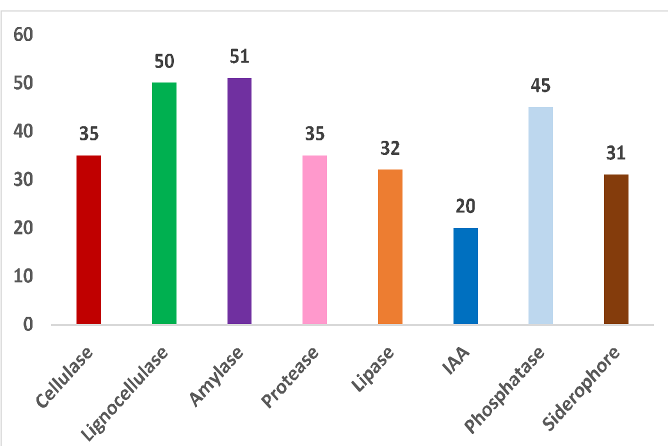


Fig. 2.6.6 Number of positive isolates for thermozyme production

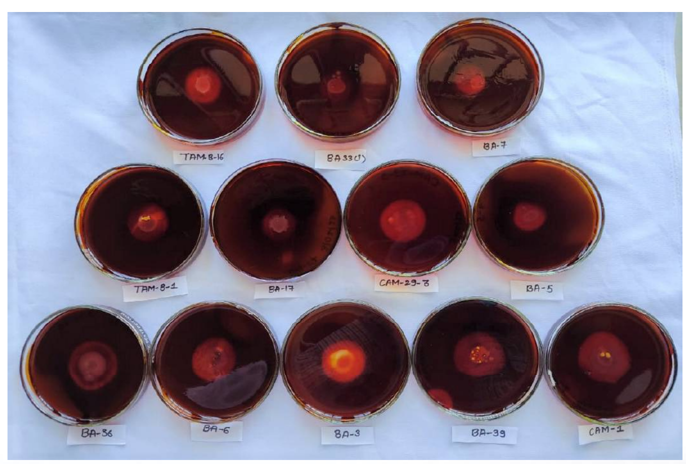


Plate 2.6.6 The ability of isolated microorganisms to degrade cellulose

Table 2.6.6b Potency index of different thermophiles

S.No.		Potency Index	
		CMC (Congo red)	CMC (Gram's Iodine)
1	CAM-1	1.081	1.917
2	CAM-29-3	1.000	1.750
3	BA 33 (1)	1.182	1.960
4	BA 36	0.956	1.625
5	BA-5	1.133	2.087
6	TAM-B-23	1.258	2.440
7	TAM-B-16	1.074	2.286
8	TAM -B-5	1.023	2.276
9	CAS-5	1.129	1.483
10	BA- 3	0.811	1.800
11	TAW-B-10	1.120	0.000
12	BA 7	1.000	2.048
13	BA-11	0.931	1.370
14	BA-6	0.943	1.862
15	TAM -B-1	0.931	2.000
16	ACA-4	1.045	1.238
17	BA 17	1.111	2.087
18	BA 39	1.069	2.833
19	BA 33(2)	1.000	1.095
20	TAS -F-1	1.037	1.000

2.6.7 On-farm evaluation of ECOWELL organic products under soybean-wheat cropping system

Field experiments were conducted to assess the efficacy of ECOWELL Organic Manure (OM), ECOWELL Phosphate Rich Organic Manure (PROM), and ECOWELL Plant Growth Promoter (E-OMPGP). No significant differences were observed in soybean crop whereas in wheat crop RDF performed better than the organic treatments.

2.6.8 Evaluation of Bio.Soilz on soil nutrient availability and microbial activity

A field experiment was conducted at ICAR-IISS farm with wheat crop (Variety: HD 1544) to evaluate the effect of Bio. Soilz on available soil nutrients, changes in soil microbial activity and crop performance (Plate 2.6.8). Variation in wheat growth was observed across the different treatments having Bio.Soilz application with and without recommended dose of fertilizer (RDF). The soil chemical properties such as pH, EC and available NPK and biological properties like dehydrogenase, β-glucosidase were measured. The soil chemical properties did not change and soil biological properties in terms of soil enzymatic activities did not show any specific trend. However, the plant agronomic parameters recorded numerically higher values with application of Bio. soilz along with recommended fertilizer application.

Plate 2.6.8 Experimental trial of Bio.Soilz products in IISS, Bhopal

2.7 AINP on Soil Biodiversity and Biofertilizer

2.7.1 Effect of silicon on rice productivity in Vertisols of Central India

A field experiment was carried out to find out the effectiveness of P and Si in plant growth and yield of rice-wheat cropping system. Seven treatments including control, phosphorus, silicon and their combination applications with three replications were carried out under this study. In the PB-1 rice crop, T4 (P + Si priming) produced the highest yield, while the control treatment resulted in the lowest yield compared to the other treatments (Plate 2.7.1). The yield increased over the control was observed as follows: T4, P+ Si priming (50%) >T6, P + Si priming + Si foliar (35%) ≥ T5, P + Si foliar (35%)> T1, P (33%)> T2, Si priming (31%)> T3, Si foliar (5%). While in wheat (HI 1605), the yield increased over the control was observed as follows: T4, P + Si priming (91%) > T5, P+ Si foliar (78%) > T6, P+ Si priming + Si foliar (69%)> T1, P (67%)> T3, Si foliar (10%)≥ T2, Si priming (10%).The study indicates that using Si as seed priming, along with P fertilizer, could have a significant impact on rice-wheat cropping system in the Vertisols of Central India.

Plate 2.7.1 Treatment wise comparison at harvest of rice (PB-1) and wheat (HI 1605)

2.7.2 Bio efficiency of mechanized seed coat biofertilizer technology

AINP SBB centre located at TNAU Coimbatore developed a seed coat biofertilizer technology which involves coating of seeds with biofertilizers using a mechanized protocol. This technology is fast, economic and farmers friendly compared to traditional biofertilizer technologies. However, the effectiveness of mechanized seed coating needs to be verified with the traditional inoculation technique. Two bioformulations for NPK and NPKZn were prepared using *Azospirillum* (Sp7), phosphobacteria (Pb1), potash bacteria (KRB9) and zinc solubilizing bacteria (ZSB15). Both consortia were prepared with 5% HPMC (binding agent) and 1% dextrin (nutrient source) and dye (colouring agent). Maize seeds of variety CoH(M)8 was used in the experiment. Seeds were treated manually or coated by mechanical approach having a population of 9.73 and 12.52 log CFU//seed respectively. Experiment laid out with following treatments T1- Uninoculated control; T2- Seed treatment of NPK biofertilizer consortia; T3- Seed treatment of NPKZn biofertilizer consortia; T4- Seed coating with NPK biofertilizer consortia; T5- Seed coating with NPKZn biofertilizer consortia. Results highlighted that seed coating with NPK and NPKZn consortia increased plant height by 21% and 18% respectively than uninoculated control. Similarly, coating enhanced root length by 25% and 20.7%. The mechanized coating increased soil organic carbon, microbial biomass carbon and labile carbon content in both rhizosphere and non- rhizosphere soil samples (Table 2.7.2a).

Table 2.7.2a Effect of mechanized seed coating of biofertilizer on soil organic carbon pools

Treatments	Soil organic carbon (mg g^{-1} soil)		Microbial biomass carbon (µg g^{-1} soil h^{-1})		Soil labile carbon (µg g^{-1}soil)	
	RS	BS	RS	BS	RS	BS
T1	17.69	17.09	34.84	33.91	970.41	961.43
T2	18.53	17.87	36.87	35.48	990.78	984.73
T3	18.80	18.29	37.12	36.29	1002.68	994.20
T4	19.75	19.18	39.58	38.65	1035.05	1021.34
T5	20.11	19.47	40.52	39.33	1073.45	1055.84

RS – Rhizosphere soil; BS – Bulk soil

Soil enzyme activities also increased in mechanized coating of seeds than traditional biofertilizer treatment. Dehydrogenase, acid and alkaline phosphatase activities were stimulated by seed coating of bioformulations (Table 2.7.2b).

Table 2.7.2b Effect of mechanized seed coating of biofertilizers on enzymatic activities

Treatments	Dehydrogenase (µg g^{-1} soil h^{-1})		Alkaline phosphatase (µg g^{-1} soil h^{-1})		Acid phosphatase (µg g^{-1} soil h^{-1})	
	RS	BS	RS	BS	RS	BS
T1	0.76	0.61	39.00	36.48	9.91	7.90
T2	0.87	0.72	43.24	39.79	10.98	9.00
T3	0.79	0.66	41.99	38.93	11.85	9.96
T4	0.93	0.76	48.33	45.30	13.42	11.45
T5	0.90	0.74	45.97	42.30	12.31	10.31

RS – Rhizosphere soil; BS – Bulk soil

The soil available nitrogen, phosphorus, potassium, and zinc, and nutrient uptake by maize were quantified (Table 2.7.2c). An increased level of soil available nutrient including nitrogen, phosphorus, potassium and zinc was recorded in mechanized seed coating treatments. Of the two seed coating formulations, NPKZn resulted higher nutrient status in soil than NPK alone. Seed coating increased the nutrient status (N, P, K & Zn) of maize by increasing 35.3% N, 13.8% P, 12.9% K and 32% Zn over treated plants.

Table 2.7.2c Effect of mechanized seed coating on available nutrients and nutrient uptake in maize

Treatments	Soil available nutrient				Plant nutrient content				Plant nutrient uptake			
	N	P	K	Zn	N	P	K	Zn	N	P	K	Zn
	(kg ha^{-1})			(ppm)	(kg ha^{-1})			(ppm)	(kg ha^{-1})			(ppm)
T1	189.1	20.0	762.5	0.14	9.2	0.59	8.20	7.54	73.1	4.7	65.2	59.9
T2	203.7	20.8	780.2	0.16	10.5	0.65	9.33	9.70	107.3	6.6	95.4	99.1
T3	219.9	20.9	803.8	0.17	13.6	0.80	10.02	12.41	145.2	8.5	107.0	132.5
T4	252.3	22.1	827.1	0.17	14.7	0.88	10.54	12.63	176.0	10.5	126.2	151.2
T5	275.2	22.6	847.0	0.20	17.9	0.77	11.31	16.56	237.0	10.2	149.7	219.3

2.7.3 Influence of Mesorhizobium strains on root nodule morphology and function in chickpea

Inoculation effect of three mesorhizobial strains namely *Mesorhizobium ciceri*, *Mesorhizobium mediterraneum* and *Mesorhizobium* sp. were evaluated in chickpea genotypes (BG 372 and BG 3022). Genotype BG 3022 showed profused root growth over BG 372 with mesorhizobial inoculation. A pot experiment was conducted using sterilized sand and vermiculite as a growth medium and observations on root nodule development and plant growth in chickpea were recorded. In-planta acetylene reduction activity of chickpea root nodules showed higher activity with *Mesorhizobium* sp. with BG-372 genotype (1003.33 nmoles of C_2H_4 /mg fresh weight nodule / hr) and *M. ciceri* with BG-3022 genotype (958.47 nmoles of C_2H_4 /mg fresh weight nodule / hr^{-1}) at flower initiation stage. Light microscopy of chickpea root nodules confirmed that *Mesorhizobium* entry may be through root hair curling. V shaped bacteroids were observed in nodule thin sections (Plate 2.7.3). N uptake in chickpea genotypes were significantly improved with mesorhizobial inoculation. The study clearly indicated that the differential symbiotic potential of chickpea was influenced by genotype X *Mesorhizobium* interaction.

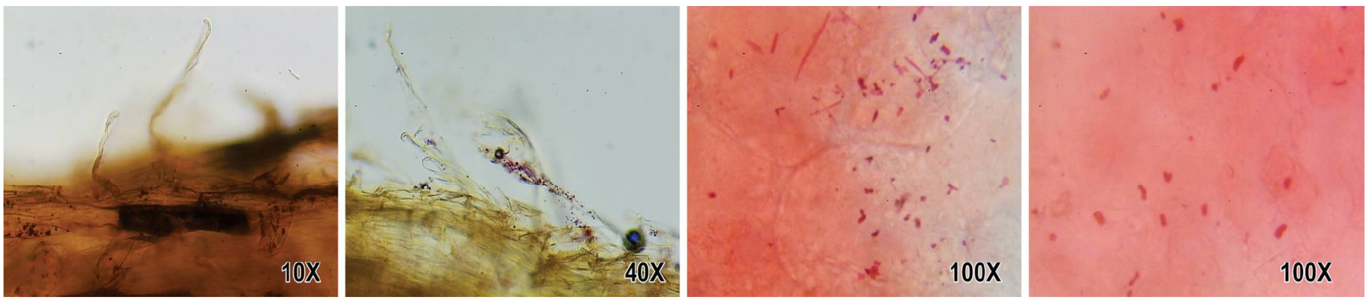


Plate 2.7.3 Chickpea nodules infected with *Mesorhizobium* showing bacteroid differentiation

2.7.4. SCAR marker technology

AINP SBB center located at TNAU have developed a molecular tool to authenticate the strain present in the biofertilizer packages. This independent technique is helpful to identify the strain present in biofertilizer formulations using inherent genetic variability. Sequence characterized amplified regions (SCAR) marker is a genomic DNA present in a specific location of an organism that can be identified by polymerase chain reaction amplification using specific primer known as star Primers. SCAR markers can be developed for any strain of our interest whose genome need not to be known. SCAR markers for four strains of *Azospirillum lipoferum* (Az204), *Azospirillum* brasilience (SP7), Phospho bacteria (Pb1) and *Azotobacter chrococum* (Ac1) was developed (Table 2.7.4). Technique of SCAR marker-based strain detection involved PCR amplification using SCAR primers and detection in gel electrophoresis (Plate 2.7.4).

Table 2.7.4 Primers designed for SCAR markers for different strains of bacteria

Primer Sets	Sequence	Target biofertilizer (strain)	AT (◦C)	Amplicon Size (bp)
SCAR-Az204-2	F:5'GATTCACTCCAACATGAGCCGC3" R:5'GCGCAACAAGTCAGGTGAGA3'	*Azospirillum lipoferum* (Az204)	60	464
SCAR-Sp7-1	F:5'TTCGTACCGCCTGACACTTC3' R:5'GGACAGCCCGTGAACATACA3'	*Azospirillum brasil-iense* (Sp7)	65	299
SCAR-Pb-1	F:5'ACCTGCGTAACAGCGGTAAA3' R:5'CAGAGACGCGCAGCTCATAA3'	*Bacillus mageterium* (Pb1)	68	375
SCAR-Ac-3	F:ATGATCTTCGATTACGCGTGTTAAA3' R:5'GGCTCGCTCGAGGTTCATC3'	*Azotobacter Chroococ-cum* (Ac1)	72	584

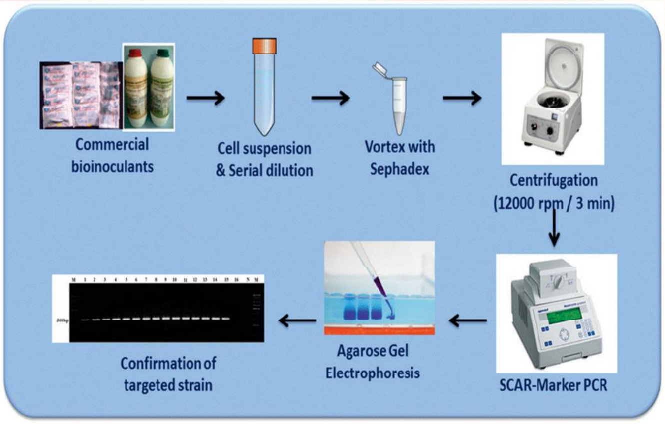


Plate 2.7.4 Technique of SCAR marker-based strain detection

Theme – IV: Soil Pollution, Remediation and Environmental security

2.8.1 Crop response, quality and changes in soil properties due to fly ash application

Field experiments were conducted under wheat-soybean cropping system at ICAR-IISS, Bhopal to investigate crop responses due to application of pond ash supplied by NTPC Ltd. The pond ash application on black soil significantly increased wheat grain yield and plant growth parameters. Higher rates of ash application (@ 200 and 400 t ha^{-1}) significantly increased straw (10.7 and 15.8%, respectively) and grain yields (10.7 and 16.1%, respectively) of wheat crop (Fig. 2.8.1). In case of soybean crop (kharif season), high rainfall during the growth period affected plant growth considerably due to water stagnation. However, in plots receiving high rates of pond ash (200 t ha^{-1} or more), such adverse effect of water stagnation on crop growth was not observed (Plate 2.8.1). Soybean seed yields and straw yields increased significantly (13-17% and 15%, respectively) with application of >200 t ha^{-1} ash respectively (Fig. 2.8.1). The FYM application significantly improved soybean seed yield in ash treated soil. Ash application decreased bulk density of top soil (0-15 cm) significantly particularly at its higher rate of application (>200 t/ha). It also increased availability of essential plant nutrients like P, K, S, Fe and B in soil. Fly ash application had no significant effect on concentration of other micronutrients (Zn, Cu, Fe, Mn and Si) and heavy metals (Cd, Co, Cr, Ni and Pb) in grains of soybean and wheat. Results thus indicated that the improvement in crop yields might be due to considerable improvement in soil physical properties that facilitate root growth as well as improvement in availability of some essential plant nutrients in soil.

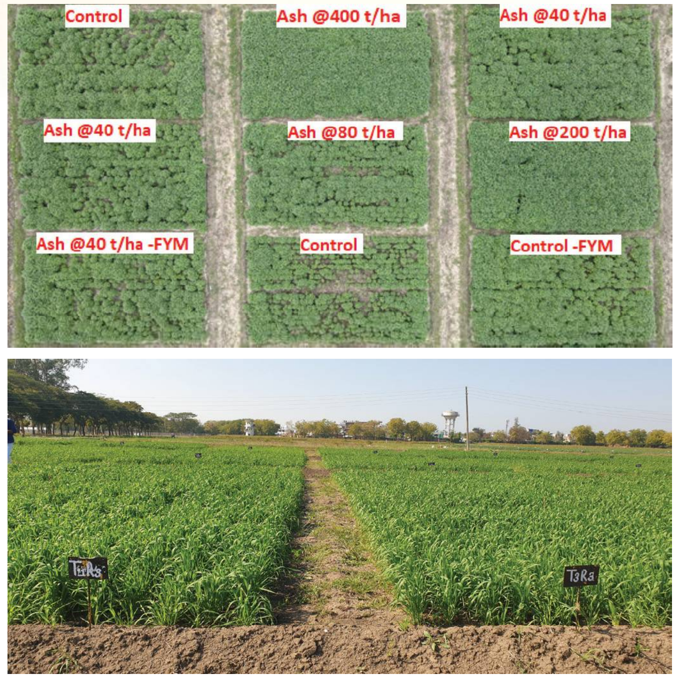


Plate 2.8.1 Performance of soybean and wheat crop

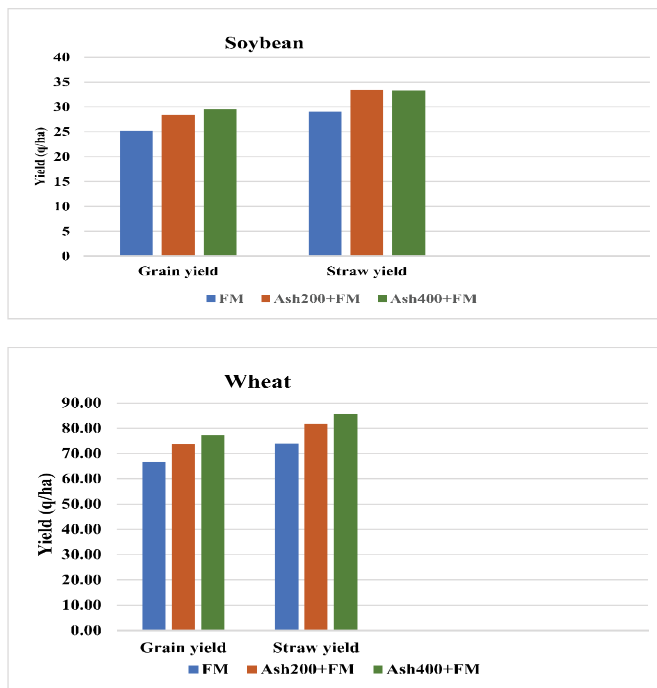


Fig. 2.8.1 Effect of fly ash on biomass yield of soybean and wheat

2.8.2 Comparative evaluation of various amendment combinations on cadmium and lead stabilization in a contaminated soil

An incubation study was conducted to evaluate the impact of various amendments (press mud, steel slag, fly ash and

FYM) and its application rates (1, 2.5 and 5%) on heavy metal (Cd and Pb) stabilization of contaminated soil (spiked with Cd and Pb). The soil samples were spiked with 100 mg Cd kg^{-1} soil and 1200 mg Pb kg^{-1} soil. After incubation period of 30 days, soil amendments (press mud, steel slag, fly ash and FYM) used in the present study had positive effects on the soil chemical properties like soil pH, EC and SOC content. Among the amendments used to remediate Cd contaminated soil, application of steel slag was proven to be significantly better in reducing DTPA extractable Cd content as compared to other amendments (Fig. 2.8.2). On the other hand, application of press mud was significantly better in reducing DTPA extractable Pb content as compared to other amendments. The study from the incubation clearly implicates that the application of phosphorus and organic carbon rich soil amendments like press mud/ FYM/ press mud + FYM in combination has greater potential in reducing the mobility of Pb in soil contaminated with Pb (Fig. 2.8.2). Similarly, silica and alkaline rich amendment like steel slag application either alone or in combination with FYM has greater potential in reducing the mobility of Cd in soil contaminated with Cd. Therefore, press mud and steel slag either alone or in combination with FYM was proven to be a better management option for sustainable crop yield and simultaneously reducing the transfer of potentially toxic heavy metal (Cd and Pb) to edible plant parts (leaf) in a Cd and Pb contaminated soil.

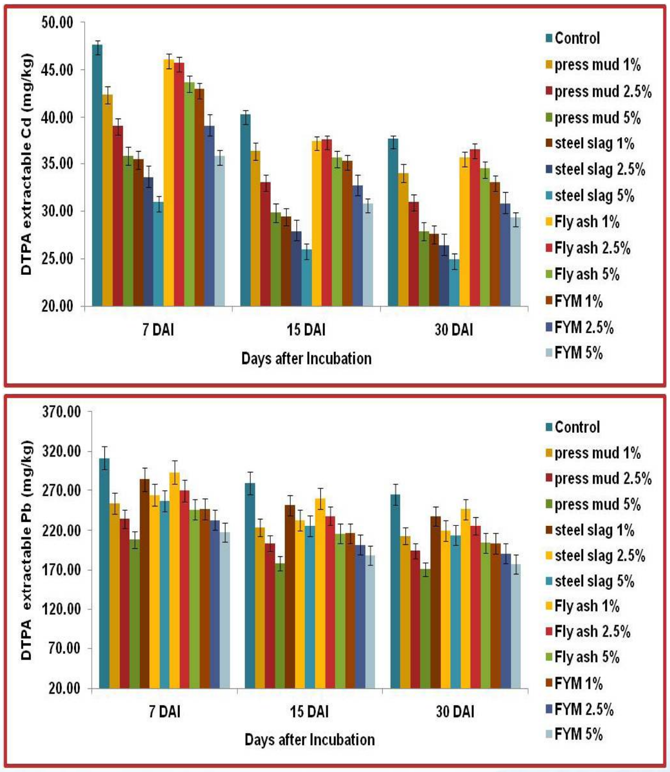
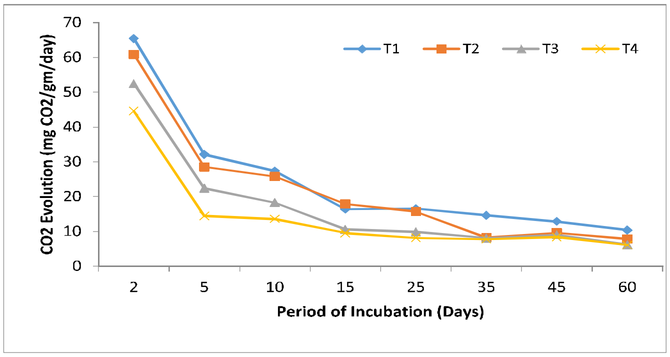


Fig. 2.8.2 Effect of different amendments on DTPA extractable Cd and Pb content in soil

2.8.3 Evaluation of various additives for co-composting with municipal solid waste (MSW) on compost quality and maturity

A laboratory study was conducted to evaluate the effect of heavy metals on CO_2 evolution from contaminated and uncontaminated MSW compost. The CO_2 evolution was done by alkali trap method. The treatment details include 8 levels of 4 heavy metal doses (Cd/Pb/Cr/Ni) individually and 4 levels of heavy metal mixture (Cd+Pb+Cr+Ni) doses along with which an absolute control (uncontaminated MSW). The study was conducted for a period of 60 days under controlled laboratory condition at 30°C and 70% WHC. The cumulative CO_2 evolution varied from 144 to 197, 163 to 198, 170 to 197 and 140 to 192 mg CO_2 g^{-1} of MSW in a Cd, Pb, Ni and Cr contaminated MSW, respectively. The CO_2 evolution was significantly reduced with increase in levels of heavy metals in MSW. The CO_2 evolution was significantly reduced at 40 and 50 ppm of Cd level; 1000 and 1500 ppm of Pb level; 300 and 500 ppm of Ni level; and 400, 600 and 800 ppm of Cr level of contaminated MSW over uncontaminated MSW (control). Lowest CO_2 evolution (144, 163, 170, and 140 mg CO_2 g^{-1} of MSW) was observed in the MSW contaminated with the highest level of Cd (50ppm), Pb(1500ppm), Cr(800ppm) and Ni (500ppm) contaminated MSW, respectively. On the other hand, the highest cumulative CO_2 evolution was observed in the soil amended with lowest level of Cd, Pb, Cr and Ni contaminated MSW at the end of 60 days.



T1 (0 ppm Cd+ Pb+ Cr + Ni), T2 (5 ppm Cd+ 100ppm Pb+ 100 ppm Cr + 25 ppm Ni), T3 (20 ppm Cd+ 500ppm Pb+ 300 ppm Cr + 100 ppm Ni) and T4 (50 ppm Cd+ 1500ppm Pb+ 800 ppm Cr + 500 ppm Ni)

Fig. 2.8.3 Effect of heavy metal contaminated MSW on CO_2 evolution

The result obtained from this study showed that the potential toxic elements present in the MSW exert negative effect on microbial activity. Further, the result from the laboratory study indicated that the % reduction in cumulative CO_2 evolution was to the extent of 28, 18, 28 and 14% at the highest level of Cd (50ppm), Pb (1500 ppm), Cr

(800ppm) and Ni (500 ppm) contamination in MSW over uncontaminated MSW (Fig. 2.8.3). However, about 42% reduction on cumulative CO_2 evolution was observed in multi heavy metal contaminated (Cd + Pb +Cr + Ni) MSW.

2.8.4 Effect of treated sewage water (TSW) application on soil GHG emissions and spinach yield

A pot experiment was conducted to study the effect of TSW (cf. freshwater; FW) with the co-application of inorganic fertilizers, vermicompost (VC), biochar, and fly ash on spinach leaf yield and greenhouse gas emission. There were nine treatments T1: FW+100% RDF (100:50:50); T2: FW+50% RDF + Biochar @ 10 t ha^{-1}; T3: FW+50% RDF + Fly ash @ 20 t ha^{-1}; T4: FW + 50% RDF + Fly ash @ 40 t ha^{-1}, T5: FW + 50% RDF + VC @ 5 t ha^{-1}; T6: TSW + 50% RDF + Biochar @ 10 t ha^{-1}; T7: TSW + 50% RDF + Fly ash @ 20 t ha^{-1}; T8: TSW + 50% RDF + Fly ash @ 40 t ha^{-1}; T9: TSW + 50% RDF + VC @ 5 t ha^{-1}). Results showed that T5 significantly enhanced the spinach fresh leaf weight by 95% over 100% FW irrigated soils at 100% RDF (100:50:50).

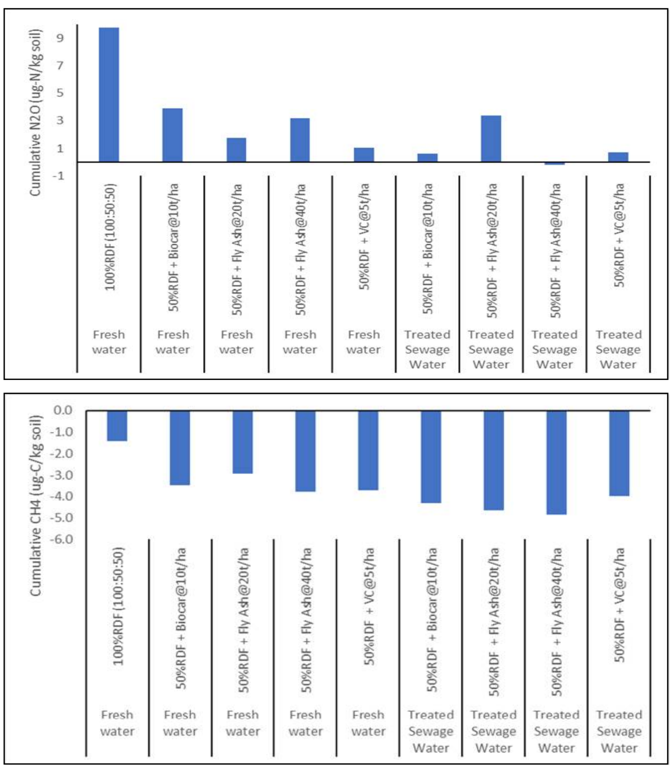


Fig. 2.8.4 Effect of TSW on GHGs emission under different nutrient and soil amendments

Across irrigation, a significant positive effect of Fly ash @ 20 and 40 t ha^{-1} plus 50% RDF was observed over 100% RDF on spinach leaf yield. Positive effects of biochar in enhancing spinach leaf yield were observed in TSW-irrigated soils with 50% RDF. In addition, TSW (cf. FW) irrigation significantly reduced the soil GHGs emissions (N_2O and CH_4) with 50% RDF (cf. 100% RDF). The co-application of biochar/fly ash/vermicompost with 50% RDF reduced N_2O emission by 88% compared with 100% RDF in TSW-irrigated soils and by 75% in FW-irrigated soils. Similarly, CH_4 emissions were negative, indicating consumption in co-application of biochar/fly ash/vermicompost with 50% RDF (cf. 100% RDF). The CH_4 consumption was 3.2 times higher in 50% RDF plus biochar/fly ash/vermicompost in TSW-irrigated soils compared with 100% RDF + FW (Fig. 2.8.4).

2.8.5 Leachate quality in microcosm experiment with dry and fresh sludge

The microcosm experiment was conducted with dry- and fresh- sludge at varying doses (0, 20 and 40 t ha^{-1}) with amendment like biochar (0, 5 and 10 t ha^{-1}) and lime (0 and 800 kg ha^{-1}). Spinach (*Spinacia oleracea*) was grown as the test crop in microcosm columns with 15 cm diameter and 45 cm height (effective soil depth). Except fertilizer application, general package of practices was followed, and leachate was collected at 30 and 60 days after sowing (DAS).

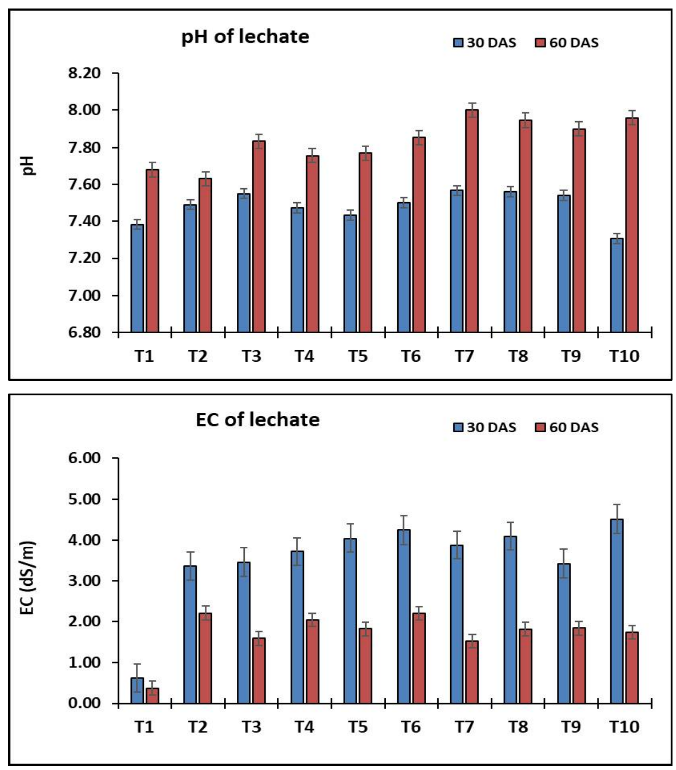


Fig. 2.8.5 pH and EC of leachates at 30 and 60 DAS

The pH of the leachate collected at 30 DAS ranged 7.31-7.57; whereas, it ranges 7.63-8.0 during 60 DAS. Overall, pH recorded during 60 DAS was significantly higher than the pH recorded at 30 DAS (Fig. 2.8.5). Our results revealed that leachates collected during 30 and 60 DAS have positive oxidation-reduction potential (ORP) values. This value ranged between 144.8 and 159.6 mV ORP at 30 DAS; whereas, ORP values decreased and ranged between 117.7 and 125.8 at 60 DAS. Expect the treatment devoid of any sludge, EC of the leachate collected during 30 DAS were more than 3 dS m^{-1}; however, EC value was significantly decreased at 60 DAS (ranging from 1.52 to 2.21 dS m^{-1}) (Fig. 2.8.5). During both the days of leachate collections it was quite clear that application of biochar reduced the TDS of leachate, higher doses even recorded lower TDS.

2.8.6 Soil and water qualities in Amlai coal mine affected areas

Amlai coal mine area water was found to be medium to very strongly alkaline and EC ranged between 100-4000 μS cm^{-1}. Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in coal mine area water were within safe limit; Cd was below detection level. In nearby agricultural areas Co, Cr, Cu, Fe (except Kelauhri and Bargaon village hand pump), Mn (except Kelauhri village hand pump), Ni, Pb and Zn in water were within safe limit and Cd was below detection level. The soils of coal mine area was slightly to strongly acidic and EC varied from 105-210 μS cm^{-1}. The soils were high in organic carbon, low to medium in available P and medium in available K and nearby village area soil were high in organic carbon, low in available P and medium to high in available K (Table 2.8.6). Total heavy metal concentrations are in the following ranges Fe: 0.3-0.7mg kg^{-1}, Mn: 39-520 mg kg^{-1}, Zn: 18-67 mg kg^{-1}, Cu: 7.8-56 mg kg^{-1}, Cd: 0.2-0.6 mg kg^{-1}, Cr: 31-120 mg kg^{-1}, Pb: 8-15 mg kg^{-1}, Ni: 27-51 mg kg^{-1}.

Table 2.8.6 Organic C, available phosphorus and potassium content of Amlai coal mine areas

Places	Parameters	Organic C (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})
Amlai mine site	Min	2.15	12.60	86.62
	Max	2.58	16.90	115.16
	Mean	2.37	14.61	101.69
	Median	2.39	13.90	104.04
	SD	0.17	1.77	9.60
	Variance	0.03	3.12	92.22
	CV	7.21	12.08	9.44
Nearby agricultural soils	Min	0.85	8.30	104.52
	Max	1.27	12.70	201.26
	Mean	1.08	10.25	127.74
	Median	1.07	9.60	121.45
	SD	0.15	1.54	26.45
	Variance	0.02	2.37	699.65
	CV	13.91	15.02	20.71
Reference point	Mean	0.49	19.1	171.75

2.8.7 Influence of pyrene contamination on enzymatic activities in contrasting soils of India

An incubation experiment was conducted to study the effect of pyrene, PAHs toxicity on enzymatic activities in major soils of India. Soil samples were collected from Vertisol (Bhopal), Alfisol (Betul), and Inceptisol (Kanpur). For the incubation study, these soils were spiked with pyrene at a different level of 0, 1, 12.5, 25, 50, 100, and 200 mg kg^{-1}. The soil enzymes viz., dehydrogenase activity (DHA) and alkaline phosphatase activities were measured at the time intervals of 7 & 45 days after incubation (DAI). It was observed that increasing the pyrene concentration from 0 to 200 mg kg^{-1} resulted in the reduction of dehydrogenase activities in Vertisol, Alfisol, and Inceptisol to the extent of 61, 65, and 57% respectively (Fig. 2.8.7). Similarly, the application of pyrene also negatively influenced soil alkaline phosphatase activities. It was shown that raising the pyrene concentration caused an alkaline phosphatase activity decrease in these soils of between 60 and 67%. The study suggested that long-term exposure to pyrene toxicity negatively affected the enzymatic activities, which may adversely affect nutrient transformation in the soil and deterioration of soil health.

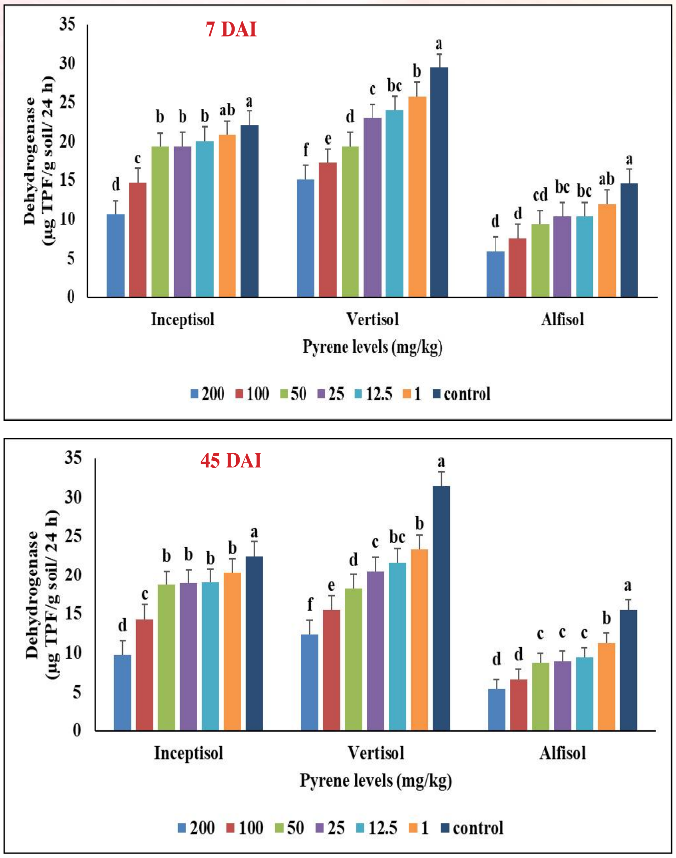


Fig. 2.8.7 Effect of pyrene contamination on DHA activities after (a) 7 and (b) 45 DAI

2.8.8 Analyzing spatial variability of Cr, Cd, Pb and Zn in Jajmau industrial area, Kanpur

Spatial variability of total Cr, Cd, Pb and Zn of highly contaminated Jajmau industrial area, Kanpur was assessed (Fig. 2.8.8). A total of 120 georeferenced soil samples (0-25 cm) were collected grid wise at an interval of 250 m. After normalization, data were interpolated by Ordinary Kriging (Spherical, Exponential and Gaussian). The sensitivity analysis was evaluated using Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and Goodness of prediction (G) obtained through cross validation and QQ plot. Semivariogram model and parameters like nugget, sill and range were obtained for each parameter through geostatistical analysis. Spatial variability maps for different heavy metals revealed high concentration of metals near tannery zones. The best model selected based on low MAE, low RMSE and highest G percentage. The results showed that Spherical Model was best for Cr and Zn (RMSE value 582.65 and 57.12) whereas Guassian Model was best fitted for Pb and Cd (RMSE value 13.79 and 2.86). Geostatistical analysis with Ordinary kriging interpolation method revealed strong spatial dependency for Cr (N:S ratio 21.6%) and moderate spatial dependency for Pb, Cd and Zn (N:S ratio 52.9, 51.5 and 28.7%, respectively).

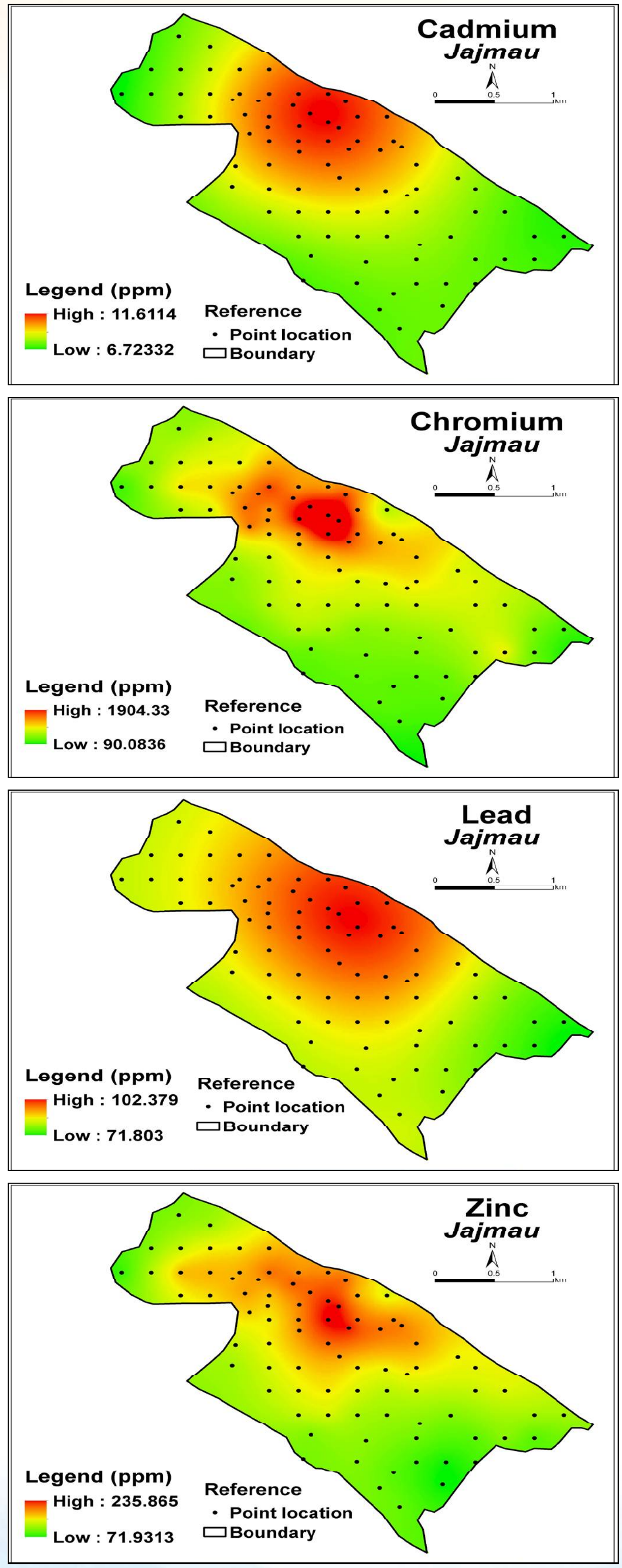


Fig. 2.8.8 Spatial variability maps of Cr, Cd, Pb and Zn in Jajmau Industrial Area, Kanpur

2.8.9 Quantification of clean index (CI) of composts

Sixteen compost samples were collected from farmer's composting unit and analysis revealed that CI varied from 2.33 to 5.0 (Fig. 2.8.9) which was within permissible limit of government of India. The compost sample exhibited 'Clean index' values that adhered to the regulatory standards set by various countries. These values are as follows: 3.9 (Austria: Class A+), 3.2 (Belgium), 3.7 (Germany: Class I), 3.6 (Ireland: Class I), 3.9 (Netherlands: compost), 4.1 (Netherlands: very clean compost), 3.6 (Sweden), 3.4 (Switzerland), 3.9 (UK), and 2.3 (India). Therefore, compost prepared at farmer field was suitable for application in agricultural land.

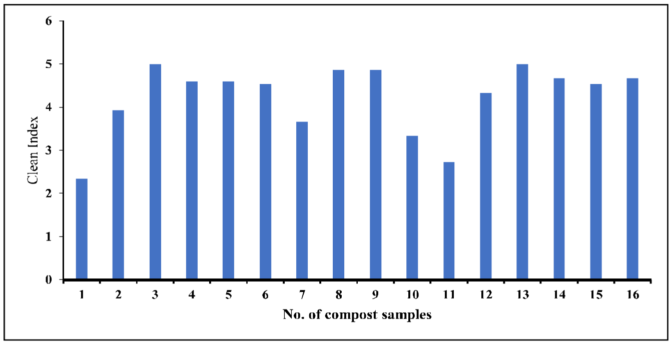


Fig. 2.8.9 CI value of compost samples collected from farmer's field

2.8.10 Effect of Plastic mulch on maize yield

A field experiment (Plate 2.8.10) was conducted at ICAR-IISS, Bhopal farm with the treatments *viz.,* control (No film), conventional (UK), conventional (India), biodegradable (UK) to assess the impact of plastic mulch on crop yield. Poly-mulching in field experiment recorded two-fold increase in maize yield (Fig. 2.8.10).

Plate 2.8.10 Plastic mulch in field trial

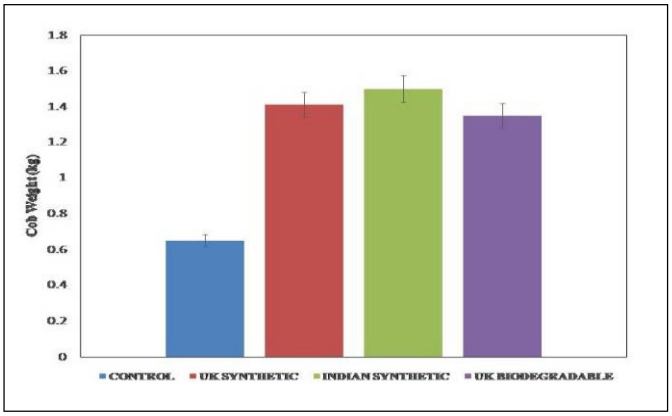


Fig. 2.8.10 Effect of plastic mulch on maize yield

3. Transfer of Technology

3.1 Capacity Building Programmme

3.1.1 Farmer Scientist interaction and field visit

Diagnostic visit and survey for introduction of climate smart technologies

A diagnostic visit and survey were conducted in Momanpur village, Bhopal on July 21, 2022 under NICRA project where 35 household farmers were surveyed about current agricultural practices such as the crops grown during the kharif and rabi seasons, as well as fertiliser management practices. Based on the survey, different technological interventions will be implemented to reduce GHGs from farmer's fields.

IPR workshop on awareness programme

The Institute Technology Management Unit (ITMU) of ICAR-IISS Bhopal and Krishi Vigyan Kendra (KVK), Raisen jointly organized an IPR workshop "Protecting Farmers Rights in areas of Farm Innovations, Breeding and Protection of Varieties" for the farmers of Raisen district of Madhya Pradesh at KVK Raisen on 17 May, 2022.

Household survey for usage of plastics in agriculture

A household survey was conducted based on a questionnaire with the farmers to understand their views about plastic use for the cultivation of their crops under UKRI project. The project team collected data regarding poly-mulching and micro-plastic pollution in surrounding villages in districts such as, Bhopal, Sehore, Raisen and Hosanghabad. A total of 250 surveys (questionnaire based and upload in KOBO tool Box Software) were completed.

Awareness campaign on recycling wastewater and water harvesting for agriculture and horticulture

One day awareness campaign on "Recycling wastewater and water harvesting for Agriculture and Horticulture" was organized under "Swacchta Karya Yojna" at Kanera on 21 December 2022. About 40 participants including children and women attended the program.

A field and farmer day was organized on role of "Conservation agriculture to combat climate change" on 20 September 2022 under NePPA project.

Training Program under the Swachhta Campaign

Various training program were organized under the Swachhta Campaign in different villages by the institute involving farming community and members of the civil society. Farmers were made aware to eliminate open defecation and encouraged to adopt efficient crop residue management practices without burning. Regular follow up programs were organized at beneficiary farmer's field. Various training program were organized as detailed below:

S. No	Name of Village/ Event	No. of participants	Date
1.	Khamkheda	80	23.04.2022
2.	Beenapur	30	14.06.2022
3.	Rasuliya Pathar	25	18.06.2022
4.	Beenapur	25	07.07.2022
5.	Ratibad	16	22.07.2022
6.	Rasuliya Pathar	20	02.08.2022
7.	Khajuri	15	14.08.2022
8.	Khamkheda	20	28.07.2022
9.	Beenapur	40	03.09.2022
10.	Rasuliya Pathar	20	27.09.2022
11.	Ratibad	15	28.09.2022
12.	Beenapur	20	29.09.2022
13.	Khajuri	15	30.09.2022
14.	Rasuliya Pathar	40	03.10.2022
15.	Ratibad	20	04.10.2022
16.	Beenapur	20	06.10.2022
17.	Hinoti Sadak	20	07.10.2022
18.	Swachhta Pledge	60	10.10.2022
19.	Bhairopur	15	11.10.2022
20.	Sagoni	20	12.10.2022
21.	Bandikhedi	15	13.10.2022
22.	Sevaniya	25	14.10.2022
23.	At institute	100	17.10.2022
24.	Khachiwarkhada	15	18.10.2022
25.	Khamkheda	20	19.10.2022
26.	Kalyanpur	15	20.10.2022
27.	Shahpur	20	21.10.2022
28.	Tarasevaniya	20	25.10.2022
29.	Bhagoniya	10	26.10.2022
30.	Swachhta Cam-paign at Institute	15	27.10.2022
31.	Swachhta Cam-paign Institute	20	28.10.2022
32.	Kothar	20	31.10.2022
33.	Soil Health Awareness Week	190	01.12.2022
34.	Soil Health Awareness Week	200	06.12.2022
35.	Swachhta Pakhavada	30	16.12.2022
36.	ICAR-IISS	10	17.12.2022
37.	Rasuliya Pathar	15	18.12.2022
38.	ICAR-IISS	15	19.12.2022
39.	ICAR-IISS	20	20.12.2022
40.	Shahpur	30	21.12.2022
41.	ICAR-IISS	40	22.12.2022
42.	Rasuliya Pathar	190	23.12.2022
43.	Ratibad	30	24.12.2022
44.	Khajuri	20	25.12.2022
45.	At ICAR-IISS Bhopal	50	26.12.2022
46.	ICAR-IISS	30	27.12.2022
47.	ICAR-IISS	20	28.12.2022
48.	Khajuri	15	29.12.2022
49.	Beenapur	15	30.12.2022


ग्राम - रसुलिया पठार


स्वच्छ भारत:
विशेष अभियान 2.0
2-31 अक्टूबर, 2022


SWACHHTA ACTION PLAN
ICAR- INDIAN INSTITUTE OF SOIL SCIENCE
BHOPAL, MADHYA PRADESH

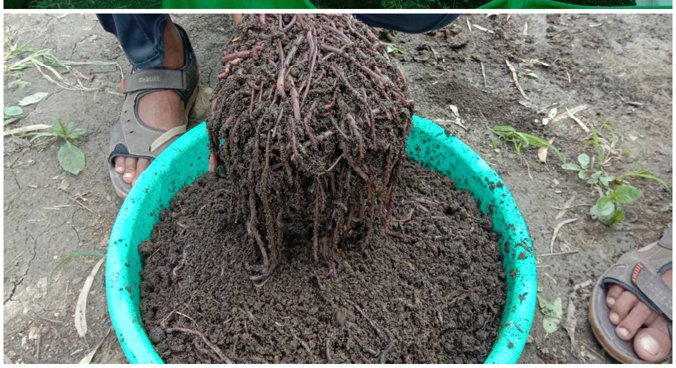

SWACHHTA ACTION PLAN

3.2 Demonstation/FLDs

3.2.1 ICAR-IISS, Bhopal

Mass multiplication of worm mother culture and its distribution

Mass worm mother culture multiplication (110 kg) was done at worm mother culture unit of ICAR-IISS, Bhopal during the year 2022 and distributed to the beneficiary farmers under the SAP project.Worm mother culture was also provided to the farmers for establishment of vermicomposting units.



S. N.	Name of Village	No. of Ver -mibed	Worm Mother Culture (Kg)	Date
1.	Beenapur, Khajuri	5	10	10.04.2022
2.	Beenapur, Khajuri		10	18.04.2022
3.	Rasuliya Pathar, Ratibad	5	10	22.04.2022
4.	Rasuliya Pathar		12	11.05.2022
5.	Rasuliya, Pathar		5	10.08.2022
6.	Beenapur, Khajuri,		5	24.08.2022
7.	Beenapur, Khajuri	15	16	02.09.2022
8.	Rasuliya, Pathar, Ratibad		5	12.10.2022
9.	Ratibad		4	03.11.2022
10.	Rasuliya, Pathar Ratibad	10	20	23.12.2022

Mass multiplication and demonstration of IISS-Ekcel decomposer under Swachhata Action Plan (SAP)

The microbial cultures were multiplied on large scale in laboratory, for preparation of IISS-Ekcel decomposer capsules. In-situ crop residue decomposition using these capsules was demonstrated in four farmer's field after harvesting of wheat crop during Rabi, 2022 at Mohammednagar, Sattikheda, Jhapadia and Kalyanpur village of Bhopal district under SAP.

Technology Assemble, Application and Feedback under Farmer FIRST programme

Crop based Module- Kharif season 2022-23

Conservation agriculture based 80 participatory demonstrations were conducted during Kharif season 2022-23 (70 Soybean and 10 Rice). Soybean productivity ranged between 13.60 to 19.50 q ha^{-1} in different villages with an average of 15.64 q ha^{-1}. Similarly, Rice crop also recorded seed yield varied between 36.20 to 41.60 q ha^{-1} with an average of 38.20 q ha^{-1} under farmers field condition in the selected villages.

Intervention	Villages covered	Name of crop	Number of House-holds covered	Area covered (ha)	Yield (q ha^{-1})
Conservation agriculture based low cost, energy saving sustainable management for improving crop productivity and improving soil health.	Bhairopur	Rice	02	0.80	36.80
		Soybean	14	5.67	15.40
	Kanchbavli	Rice	---	---	
		Soybean	03	1.21	13.60
	Khamkheda	Rice	07	2.84	41.60
		Soybean	49	19.84	19.50
	Kalyanpur	Rice	01	0.40	36.20
		Soybean	04	1.62	14.04
Total/Average		Rice	10	4.04	38.20
		Soybean	70	28.34	15.64

Soybean crop performance under Zero Tillage

Rice crop in farmer's field under demonstrations

Horticulture based module

Under horticulture-based modules, improved package of practices for better vegetables yield is demonstrated in forty farmer's field. In summer season, the vegetables of Tomato, Brinjal, Chilli and Okra were grown under the demonstration trial. The balanced nutrient application and need based pesticide was applied for better growth and production of vegetable. Due to balanced nutrient application, control of weed and insect-pest, the crop yield was increased under demonstrations as compared to farmer's practices. Tomato, Brinjal, Chilli and Okra productivity ranged between 35.70 to 43.50 t ha^{-1}, 34.85 to 44.60 t ha^{-1}, 18.84 to 26.50 t ha^{-1}, 10.05 to 17.44 t ha^{-1} in different villages with an average of 39.80 t ha^{-1}, 38.50 t ha^{-1}, 22.55 t ha^{-1} and 13.20 t ha^{-1} respectively.

Plantation/ Orchards

Guava plantation started bearing fruits and the yield and economic indicators were recorded.

(A) Performance indicators

a.	Technical Observation	Farmers practice	Intervention
	Yield (q ha^{-1})	145	190
b.	Economic indicators		
i.	Cost of cultivation (Rs. ha^{-1})	98500	115000
ii.	Net income (Rs. ha^{-1})	119500	170000
iii.	B:C ratio	2.20	2.45

Impact of NRM based activities

(A) Performance indicators, Wheat- HI- 1544

A.	Technical Observation	Farmers practice	Intervention
i.	Yield (q ha^{-1})		
a	Grain (q ha^{-1})	46.55	50.17
b	Straw (q ha^{-1})	76.80	87.79
B.	Economic indicators		
i.	Cost of cultivation (Rs. ha^{-1})	45500	40200
ii.	Net income (Rs. ha^{-1})	53418.75	66411.25
iii.	B:C ratio	2.17	2.65

(B) Performance indicators, Gram- RVG-202

A.	Technical Observation	Farmers practice	Intervention
i.	Yield (q ha^{-1})		
a	Grain (q ha^{-1})	15.27	17.28
b	Straw (q ha^{-1})	22.14	26.95
B.	Economic indicators		
i.	Cost of cultivation (Rs. ha^{-1})	30800	25750
ii.	Net income (Rs. ha^{-1})	45550	60650
iii.	B:C ratio	2.47	3.35

Livestock based module

Name of animal/bird:

ii) Technical indicators

a.	Technical Observation	Farmers practice	Intervention
i	Average body weight (kg)	1.25	1.35
ii	Average egg production / month	9	12
b.	Economic indicators		
i.	Cost of cultivation (Rs. ha^{-1})	6500	8500
ii.	Net income (Rs. ha^{-1})	12952	23420
iii.	B:C ratio	2.99	3.75

On-farm demonstration of resource conservation technology (RCT)

To popularize resource conservation technologies among farmers, different packages of RCTs *viz.,* (a) Reduced tillage (RT) + Broad Bed furrow (BBF) + Maize-chickpea; (b) No-tillage (NT) + BBF + Maize-chickpea; (c) RT + BBF + Soybean-Wheat; (d) NT + BBF + Soybean-Wheat; (e) RT + BBF + soybean-chickpea (intercropping, 3:2) and (t) NT + BBF + soybean-chickpea (intercropping, 3:2) were demonstrated. After the nine year of continuous treatment impositions, 15% in chickpea yield and 10% in wheat yield improvement were observed under NT than RT on the BBF system.

Radio Talk/TV Programme

Dr AB Singh gave radio talk on "Jaivik Kheti Aur Mrida Swasthya" on March 01, 2022 at Doordarshan Bhopal.

Dr AB Singh gave radio talk on "Kharif Fasalo me Jaivik Khad Ki Upyogita" in Krishi Darshan Programmme on August 17, 2022.

Dr AB Singh gave radio talk on "Mrida Swasthya" in Krishi Darshan Programmme on December 05, 2022.

3.3. Tribal Sub-Plan/Scheduled Tribe Component

3.3.1 ICAR-IISS, Bhopal

Kisan Mela cum Input distribution to tribal farmers of Rajnandgaon, Chhattisgarh

Kishan Mela cum interactive training programme was jointly organized by ICAR-IISS, Bhopal and AICRP on MULLaRP, Raipur at KVK Rajnandgaon with about 400 tribal farmers on 08 March 2022. A series of lectures were delivered by Drs R Elanchezhian, P. Tripathi, MV Coumar and Narayan Lal of ICAR-IISS, Bhopal and scientists of AICRP on MULLaRP, Raipur, KVK, Rajnandgaon and Officers from State departments of Rajnandgaon. On this occasion 8.0 quintal seeds of Summer Mung (IPM 410-3) and 30 quintal seeds of paddy (Var. DRR42 and IR-64) were distributed among tribal farmers. On 09 March, 2022 the team of ICAR-IISS, Bhopal visited fields of tribal farmers at village Kodikasa in Ambagarh chowki block of Rajnandgaon to review ongoing demonstrations. Water samples were collected from various sources i.e., hand pump, open well, tap water supply, ponds and tube well for their analysis of various contaminants.

Training cum workshop on soil health management and crop productivity

Training cum workshop on Soil Health Management and Crop Productivity was jointly organized by ICAR-IISS, Bhopal and KVK, Rajnandgaon at Agricultural College and research Institute, Surgi, Rajnandgaon with about 300 tribal farmers on 03 May, 2022. Shri Santosh Pandey, Hon'ble MP Rajandgaon was the Chief Guest and the event was presided over by Padmashri Smt. Phoolbasan Bai Yadav of Maa Bamleshwari Janhit Kare Samiti, a NGO working for the upliftment of women in Chhattisgarh. The farmers were sensitized to safeguard the soil resources, to recycle organic residues and to use organic biofertilizer. On the occasion, 5 quintal seeds of Arhar (Rajiv Lochan) and 27 quintal seeds of Paddy (var. MTU1010) were distributed among the beneficiary tribal farmers.

Training on natural farming at Rajnandgaon, Chhattisgarh during 16-17 December, 2022

ICAR- IISS, Bhopal (M.P.) organised a Krishi Mela cum Krishak Sangosthi on Natural Farming during 16-17 December, 2022 at KVK Surgi, Rajnandgaon district, Chhattisgarh. Padmashri Smt. Phoolbasan Bai Yadav, President of the Maa Bamleshwari Janhit Karya Samiti emphasised on importance of organic and natural farming practices for crop and soil health improvement. During this occasion 30 quintals of HYVs of rice and 10 quintals of summer green gram seeds were distributed to tribal farmers to improve crop productivity and soil health.The Krishak Sangosthi on Natural Farming was addressed by Drs R Elanchezhian, P Tripathi, MV Coumar, Narayan Lal and DK Yadav and officials of IGKV and state dept of agriculure. Altogether 300 tribal farmers attended the Mela and Sangosthi. On 17 December, 2022 seedlings of horticultural fruit crops such as, mango, guava, jack fruit and dragon fruit were also distributed among the tribal beneficiary farmers at Horticultural nursery, Kekti Tola, Ambagarh Chowki block, Rajnandgaon. Around 100 farmers were sensitized about the importance of fruit crops in enhancing farm income. Soil samples were collected in the district to prepare a GIS based map for fertilizer optimization.

On field demonstration on HYVs of rice, arhar and soil health management at Rajnandgaon

During Kharif season of 2022, 27 quintals of HYVs of rice (MTU 1010) and 5 quintals of arhar (Rajiv Lochan) seeds were distributed and demonstrated at 100 tribal farmers to improve crop productivity and soil health.

Training -cum –farmer's visit programme on soil health and management at Barwani District

The training -cum –farmer's visit programme on soil health and management was organized by IISS, Bhopal at KVK Barwani on March 11, 2022 under TSP project. About 125 tribal farmers participated in one day training programme from different villages of Barwani district and made aware about improved agriculture techniques and practices.

Training -cum –agricultural input distribution programme

The training -cum–agricultural input distribution programme organized with jointly by IISS, Bhopal at KVK, Barwani on June 10-11, 2022 under TSP project. About 35 tribal farmers participated in two days training programme.

Agricultural input distribution programme on soil health management programme

The agricultural inputs distribution on soil health management programme was organized at KVK, Barwani with jointly by IISS, Bhopal on November 12, 2022 under TSP project. About 45 tribal farmers participated in this training programme.

Farmer scientist interface meeting and input distribution

Under the project 'Enhancing the productivity of major crops through improving the natural resource base of tribal inhabited areas of Madhya Pradesh' Farmer-Scientist meeting-cum field visit was conducted on November 9, 2022 in the project area. Scientists explained the available eco-friendly management practices to control rice pests, and also demonstrated how to use bio-agents like Trichocards (*Trichogramma* spp.) and Braconcards (*Braconhebetor*) to manage the stem borer and other lepidopteron pests of rice crop.

Vermibeds were distributed to the 200 beneficiary farmers of the project in Betul district during February-March, 2022 along with demonstration of the composting method using portable vermibeds. Besides, liquid bio-formulations *viz.*, *Rhizobium*, *Pseudomonas*, *Trichoderma*, and *Beauvaria bassiana* were distributed to the beneficiary tribal farmers during December 30-31, 2022.

Farmer field school

Farmer field school on "Soil health improvement through in-situ composting of paddy residue using IISS-EKCEL decomposer capsules" was organized for the tribal farmers of Kaweli, Kulpa and Sarra villages of Balaghat District of Madhya Pradesh during November 9-10, 2022. Scientists of institute demonstrated preparation of the microbial solution using the decomposer capsules for composting farm waste and field application for in-situ stubble management.

FLDs under TSP project in Barwani District

The FLDs were conducted in different tribal farmer's field to observe the effect of improved practices over farmers' practices. The crop yield was increased under improved practices over farmers practice and its range is from 26.3 % to 43.6%.

Name of crops	No of Field Trials	Average crop yield under Improved practices (IP)	Average crop yield under Farmers Practices (FP)	Change in yield (%) over FP
Soybean	50	1350 kg ha^{-1}	940 kg ha^{-1}	43.6 %
Chilli	30	42.10 t ha^{-1}	31.0 t ha^{-1}	34.2 %
Tomato	50	120.2 t ha^{-1}	95.2 t ha^{-1}	26.3 %
Wheat	50	3760 kg ha^{-1}	2680 kg ha^{-1}	40.2 %
Chickpea	66	1334 kg ha^{-1}	970 kg ha^{-1}	37.5 %

Capacity building activities under SCSP

Input distribution

Item	Quantity	Amount spent during 2022-23	No. of beneficiaries
Seeds	Soybean 60q, Wheat 250q Gram 60q	2172000	757
Fertilizer	NPK 568 bags, Urea 490 bags	971634	99

Material distributed during Jan to June 2022 in different villages

Input	Raipur	Kanera	Karond khurd	Khinchita
Mango	76	20	4	1
Guava	35	45		20
Kathal	38	20	3	
Nimbu	42	4	4	
Anola		50		
Soybean (Bags of 30 kg)	31	13	5	
Shovel (Nos)	136	26	6	1
Axe (Nos)	136	26	6	1
Growmore (Bags of 50 kg)	32	17	6	2
Urea (Bags of 45 kg)	82	16	1	1

Effect of technology introduced in the farmer's field

In the assessment of technology implemented by the farmers under the SCSP project from 2020 to the end of rabi season 2022. It was found that with the introduction of these technologies, they got 10% more yield of wheat and chickpeas, while their soil quality also improved than earlier due to integrated nutrient management and balanced use of fertilisers. Distribution of vermicompost and training helped maintain soil health and also generated income through it.

Trainings organized under SCSP

S.	Topic	No. of participants	Date
1	Biofortification, nutrient grooming and crop diversification	31	28/04/22
2	Efficient and balanced use of fertilizers (including nano fertilizers)	67	21/06/22
3	Integrated and balanced nutrient management in rabi crops	51	03/11/22
4	Balanced nutrient management in wheat and gram	50	10/11/22
5	Importance of vermicomposting in rabi crops	48	7/11/22
6	Balanced nutrient management in rabi crops	36	15/11/22
7	INM for sustainable soil health management	68	7/12/22
8	Soil health management for sustainable productivity	70	12/12/22

FLD on integrated nutrient management (INM) under SCSP

FLD was conducted on INM in soybean, maize and wheat crops at Sahapur village of Bhopal. In this trial, balance fertilization, INM and farmer practices were evaluated in different crops for improving crop productivity and sustaining soil health at farmer's fields under the SC sub plan.

Demonstration of nutrient management technology in the farmer's field

Total 17 demonstrations on balanced use of fertilizers and INM were under taken during rabi season from October 2021 to April 2022. Twelve demonstrations were on wheat crop and five were on chickpea under SCSP at farmer's field of Raipur, Kanera, Khichital and Karondkhurd village.

MGMG activities

Under MGMG, various team members visited adopted villages periodically and interacted with the farmers and discussed about their agricultural activities and related problems.

Adopted Villages under MGMG by the Institute

Group	Members	Name of five villages adopted by Group Leader
1	Dr. AK Patra, Director, ICAR-IISS Dr. AB Singh, PS, & Nodal Officer, MGMG Dr. AO Shirale, Scientist, SC&F Dr. Sudeshna Bhattacharjya, Scientist, SBD Dr. Narayan Lal, Scientist, SC&F	Dobra, Khejra, Perwalia Sadak, Badarkha Sadak, Mubarakpur
2	Dr. P Tripathi PS & Co-Nodal officer Dr. NK Sinha, Scientist, SPD Dr. Dolamani Amat, Scientist, SBD Mr. Abinash Das, Scientist, SBD	Acharpura, Parewa Kheda, Arwali, Hazampura and Parewalia Sahani
3	Dr. SR Mohanty, PS & I/c BNF Dr. RH Wanjari, PS, LTFE Dr. K Bharati, PS, SBD Mrs. Seema Bhardwaj, Scientist, SPD (Study leave) Dr. Dhiraj Kumar, Scientist, PC (LTFE)	Choupdakala, Ghatkheri, Sayyaid Semara, Emaliya Chopra and Amoniw
4	Dr. JK Saha, HOD, ESS Dr. Hiranmoy Das, Scientist (STCR) Dr. Madhumounti Saha, Scientist, ESS Dr. Dinesh Kumar Yadav, Scientist, ESS Dr. Khushboo Rani, Scientist, SCF	Islam Nagar, Dewalkhedi, Bharonpura, Kalyanpura, Puraman Bhavan

5	Dr. KM Hati, PS, SPD Dr. Sanjay Srivastava, PS, SC &F Dr. Sanjib Kumar Behera, SS, MSN Dr. KC Shinogi, Scientist, ITMU Dr. Gurav Priya Pandurang, Scientist SC & F	Bankhedi, Baroda, Sojna, Amaravadi and Kuravadi
6	Dr. AK Shukla, PC, MSN Dr. R Elanchezhian, PS, SC&F Dr. RK Singh, PS, SPD Dr. JK Thakur, Scientist, SBD Dr. Nisha Sahu, Scientist, ESS	Sagoni, Munirgarh, Gudawal, Chhattarpura, Chiklodkhurd
7	Dr. AK Biswas, HOD, SC&F Dr. Brij Lal Lakaria, PS, SC&F Dr. Asha Sahu, Scientist, SBD Dr. Bharat P Meena, Scientist, SC&F Ms Alka Rani, Scientist, SPD	Golkhedi, Binapur, Kanchbavli, Khamkheda and Raslakhedi
8	Dr. RS Choudhary, HOD, SPD Dr. P Jha, PS, SC&F Dr. AK Vishwakarma, PS, SPD Dr. K Bharati, PS, SBD Dr. Abhijit Sarkar, Scientist, ESS	Raipur, Kanera, Momanpur, Kadhaiya and Karodkhurd
9	Dr. P Dey, PC, STCR Dr. NK Lenka, PS, SC&F Dr. M Mohanty, PS, SPD Dr. M Vassanda Coumar, SS, ESS Dr. Immanuel Chongboi Haokip, Scientist, STCR	Ratibad, Rasuliya Pathar, Mugaliahat, Ratanpur Sadak, Chandukhedi
10	Dr. AK Tripathi, PS, SBD Dr. J Somasundaram, PS, SPD Dr. Asit Mandal, Scientist, SBD Mr. Rahul Mishra, Scientist, ESS Dr. Mayanglambam Homeshwari Devi, Scientist, SBB	Dobra Jagir, KoluaKhurd, Sagoni Kalan, ChorSagoni, Adampur Chhawni
11	Dr. Ajay, PS, ESS Dr. Tapan Adhikari, PS, ESS Dr. Sangeeta Lenka, SS, ESS Dr. Jitendra Kumar, Scientist, SPD	Shahpur, Devpur, Kasi Barkeda, Sagoni, and Barkedi Hajam

Some of activities under MGMG are given below:

In-situ crop residue decomposition technology demonstration in MGMG village

In-situ crop residue decomposition technology developed by the ICAR-IISS, Bhopal was demonstrated at Mohammednagar (Sattikheda) village of Bhopal district for decomposition of wheat residue during Rabi 2022. Soil and residue samples were taken on the day of incorporation (DAI), after 15 and 30 DAI to analyze different physical, chemicals and biological properties.

Swachhata drive at MGMG village

The Swachhata drive was conducted in nearby villages, namely Bhairopura and Kalayanpur village. A message was conveyed to maintain cleanliness of surroundings and environment.

AICRP on Soil Test Crop Response

FLDs on farmers' fields

Centre	Crop	Number	Villages, Block
Hyderabad	Maize, Paddy, Bengalgram and Sesamum	27	Maddur, Rangareddy district; Venkatapur, Nagarkurnool district; Sakinapur, Adilabad district and Vizianagaram district, Andhra Pradesh
Jorhat	Rice (Ranjit sub 1)	20	Birina Gaon, Danichapari, Komolia Chapari, Birina Gaon, , Dubi Gaon, Golaghat and Jorhat districts
Kalyani	Rapeseed (B9), Onion (Sukhsagar), Potato (Kufri jyoti), Broccoli (CSH-1), Tomato (Amlic), Cabbage (Green Express) and Cauliflower (Cashmiri)	31	Nadia district
Palampur	Soybean	6	
	Toria	6	
Raipur	Rice, Soybean, Maize, Chickpea	62	Kondagaon and Surguja; Bastar; Kabirdham
Coimbatore	Barnyard millet, Foxtail millet, Hybrid maize (TNAU maize Hybrid CO 8) under drip fertigation, Bengalgram	12	Palaniyur, Kandhasamipuram, S. Ayyampatti and Viralipatti in Dindigul Dist; Thondamuthur in Coimbatore district

Trainings conducted by different centers of AICRP on STCR

Center	No of Trainings	Participants	Districts
Bikaner	2	50	SKM Agriculture College, Padampur & SKRAU, Bikaner
Hyderabad	6	289	PJTSAU,Hyderabad; ARS,Utukur,Kadapa, YSR districts
Jorhat	2	50	Garumoragaon, Jorhat district
Palampur	2	200	Nichar, Distt Kinnaur; Ghar, Distt Kangra
Raipur	5	290	Ambikapur, (Surguja), Kondagaon,w Kabirdham & Bastar
Coimbatore	2	80	Online & Seengapathy Tribal hamlet, Thondamuthur Block, Coimbatore
Vellanikkara	3	55	EdathuruthyThrissur; Kaipamangalam KrishibhavanThrissur; College of Agriculture, Vellanikkara
Barrackpore	1	20	ICAR-CRIJAF, Barrackpore

4. Training and Capacity Building

4.1. Training attended by staffs

a. Participation in training (category-wise)

S. No.	Category	No. of employees undergone training during 2022
1	Scientist	14
2	Technical	1
3	Administrative & Finance	2
4	Skilled Supporting Staff	0
Total		17

b. HRD fund allocation and utilization (Rs. in Lakhs April 2022 to March 2023)

S. No.	RE for HRD	Actual Expenditure for HRD
1.	2.00	1.39

C. Training attended during January to December, 2022

C1 Category: Scientific staff

S.No	Name of employee	Title	Organizer	Duration
1	Dr KC Shinogi	Winter school on farm mechanization for facilitating conservation agriculture and climate smart technology	ICAR-CIAE, Bhopal	January 04-24, 2022
2	Dr Asha Sahu	Hands on training on microbial techniques	Centre of Excellence in Biotechnology, MPCST, Bhopal	February 14-18, 2022
3	Drs Abinash Das and Khushboo Rani	Online training programme on "Geospatial analysis using QGIS & R"	ICAR-NAARM, Hyderabad	February 14-19, 2022
4	Dr AB Singh	Online training programme on recent advances in organic farming research	ICAR-NAARM, Hyderabad	February 23, 2022
5	Drs Abinash Das and Khushboo Rani	Short course training programme on concepts and mechanisms of soil carbon sequestration and stabilization for soil health improvement and climate change mitigation	ICAR-IISS, Bhopal	March 02-11, 2022
6	Dr DK Yadav	Orientation workshop for nodal officers of disaster management of ministries/departments of Government of India	NIDM, Ministry of Home Affairs, New Delhi	June 27-28, 2022
7	Dr Jitendra Kumar	Evaluating ecosystem services with remote sensing	Online By NASA Applied Remote Sensing Training (ARSET) program	August 23-30, 2022
8	Dr Prabhat Tripathi	Workshop cum training program for vigilance officer	NAARM Hyderbaad	August 24-26, 2022

9	Dr Jitendra Kumar	Selecting climate change projection sets for mitigation, adaptation and risk management applications	Online By NASA Applied Remote Sensing Training (ARSET) program	September 19-20, 2022
10	Dr M Homeshwari Devi	Online training programme on community resource management for women scientist and technologists	IIFM, Bhopal	October 17-21, 2022
11	Drs Khushboo Rani, DK Yadav, Abinash Das, Immanuel Chongboi Haokip, Dhiraj Kumar, Rahul Mishra	Participated in NGP-DST summer school on geospatial technologies (level 1)	ICAR-Indian Institute of Soil Science, Bhopal	November 03-23, 2022
12	Dr Asit Mandal	On-line training program on RNA world: Advance bioinformatics for deciphering regulatory molecules,	ICAR-IASRI, New Delhi	November 03-09, 2022
13	Dr Sangeeta Lenka	Online training program on ensuring safe drinking water and managing wastewater and faecal sludge in rural regions.	Centre for Science and Environment, New Delhi	December 01-15, 2022

C2 Category: Technical staff

S.No.	Name of employee	Title	Organizer	Duration
1	Mr Jai Singh	Motivation, positive thinking and communications skills of technical officers	ICAR-NAARM, Hyderabad	September, 13-16, 2022

C3 Category: Administrative & Finance

S.No.	Name of employee	Title	Organizer	Duration
1	Mr Anupam S Rajput	Smart governance in office system & office procedure	ICAR-NBAIM, Mau, Uttar Pradesh	October 10-12, 2022
2	Mr Bansilal Sarsodia	Smart governance in office system & office procedure	ICAR-NBAIM, Mau, Uttar Pradesh	October 10-12, 2022

4.2. Research Guidance for Degree Students

S.No.	Name of the Student	Name of the College/ Institute/University	Degree	Name of the Guide/Co-Guide
1	Mr Prakash Davel	RVSKVV Gwalior	M.Sc (Soil Science & Agricultural Chemistry)	Dr Priya P Gurav
2	Mr Eklavya Thakur	IGKV Raipur	M.Sc (Soil Science & Agricultural Chemistry)	Dr R Elanchezhian
3	Mr Harish	IGKV Raipur	M.Sc (Soil Science & Agricultural Chemistry)	Dr MV Coumar
4	Mr Dharmendra Singh	RVSKVV Gwalior	Ph.D (Soil Science & Agricultural Chemistry)	Dr Sangeeta lenka
5	Mr Rakesh Kumar Yadav	RVSKVV Gwalior	M.Sc (Soil Science & Agricultural Chemistry)	Dr Dinesh K Yadav

6	Ms Pragya Kurmi	RVSKVV Gwalior	Ph.D (Soil Science & Agricultural Chemistry)	Dr Somasundram Jayaraman
7	Mr Sourav Raghuvanshi	RVSKVV Gwalior	Ph.D (Soil Science & Agricultural Chemistry)	Dr Somasundram Jayaraman
8	Ms Milli Sharma	RAK, College of Agriculture, Sehore, RVSKVV	M.Sc (Soil Science & Agricultural Chemistry)	Dr Nishant K Sinha
9	Mr Vishal Patidar	RAK, College of Agriculture, Sehore, RVSKVV	M.Sc (Soil Science & Agricultural Chemistry)	Dr RK Singh
10	Ms Dipali Jain	RAK, College of Agriculture, Sehore, RVSKVV	M.Sc (Soil Science & Agricultural Chemistry)	Dr Jitendra Kumar
11	Mr Shubham Singh	RVSKVV, Gwalior	Ph.D (Soil Science & Agricultural Chemistry)	Dr AB Singh
12	Ms Komal Agarwal	RVSKVV Gwalior	Ph.D (Soil Science & Agricultural Chemistry)	Dr K Bharati
13	Mr Manjeet Singh	Bundelkhand University, Jhansi, Uttar Pradesh	M.Sc (Soil Science & Agricultural Chemistry)	Dr Asit Mandal
14	Ms Shivani Sankla	RAK, College of Agriculture, Sehore, RVSKVV	M.Sc (Soil Science & Agricultural Chemistry)	Dr Asha Sahu
15	Ms Divya Pipalde	RAK, College of Agriculture, Sehore, RVSKVV	M.Sc (Soil Science & Agricultural Chemistry)	Dr Nisha Sahu
16	Ms Sonia Sisodiya	RAK, College of Agriculture, Sehore, RVSKVV	M.Sc (Soil Science & Agricultural Chemistry)	Dr Sudeshna Bhattacharjya
17	Mr Omprakash	RAK, College of Agriculture, Sehore, RVSKVV	M.Sc (Soil Science & Agricultural Chemistry)	Dr JK Thakur

Training Imparted to the Farmers/Extension Officers/Students/Visits:

Name of Scientist	Topic	Date	Venue	Remarks
Drs Jitendra Kumar, Nishant K Sinha, J K Thakur, Dhiraj, Dolamani Amat	Climate-Smart Agriculture and Soil Health Management	February, 23-25, 2022; March, 2-4, 2022; March, 8-10, 2022; March, 14-16, 2022	Raipur; Begonia; Parwlia Sadak; Kanara	ICAR- Indian Institute of Soil Science and NICRA
Drs AB Singh, Abinash Das and Dolamani Amat	Field visit of organic farming field and Demonstration of Vermicomposting to the students of Maharani Laxmibai Girls School, BHEL campus	May 27, 2022	ICAR-IISS, Bhopal	Visit was successfully conducted

Drs AB Singh, Abinash Das and Dolamani Amat	Visit of ICAR-IISS, Bhopal campus and showcasing research activities to the ACABC trainees from CARD, Bhopal, MANAGE, Hyderabad	June 20, 2022	ICAR-IISS, Bhopal	35 trainees and 1 faculty came for the visit
Drs Jitendra Kumar, Nishant K Sinha, JK Thakur, Dhiraj, Rahul Mishra and AB Singh	Conservation agriculture to mitigate climate change	September 20, 2022	Parwalia Sadak	Field and farmer day
Jitendra Kumar	Exposure visits to input dealers	November 11, 2022	ICAR-IISS, Bhopal	Field visit
Drs Brij Lal Lakaria and Jitendra Kumar	Integrated nutrient management for sustainable soil health under SCSP project	December 07, 2022	Raipur	One-day awareness campaign

Capacity building

Particulars	No. of training & Date	No. of villages covered	No. of farmers benefited
Climate-smart agriculture and soil health management	4 (23 Feb to 16 March 2022)	04	240
Integrated nutrient management for sustainable soil health under SCSP project	1(Dec, 07 2022)	01	100

Farmer FIRST

(a) Capacity building

Particulars	No. of training	No. of villages covered	No. of farmers benefited
Workshop	01	04	70
Training programme	1	4	50
Training cum soil health awareness day	01	04	180
Farmers training on nursery management	02	03	53

(b) Extension activities

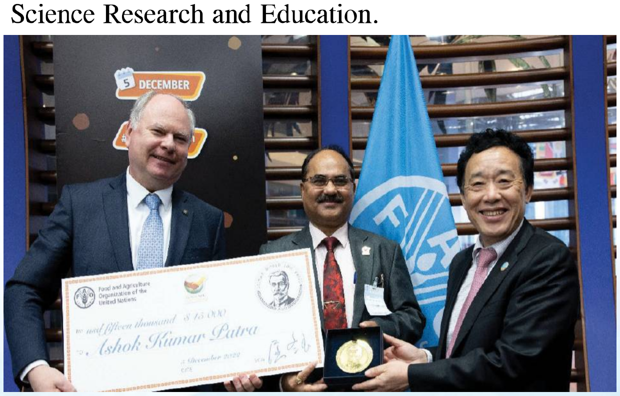
Name of Extension activities	No. of activity	No. of villages covered	No. of farmers benefited
Site committee meeting	01	01	73
Demonstration of microbial decomposer under NRM	02	02	10
Field visit cum farmers-scientist interaction meet	04	05	75
Field visit	04	06	105

5. Awards, Honours and Recognitions

Awards

- Dr Priya P Gurav was awarded Fellowship for training of young scientists by M.P. Council of Science and Technology at the 37th M.P. Young Scientist Congress hosted on virtual platform by Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot during March 14-17, 2022.
- Dr Asha Sahu awarded as Best Waste Management Expert 2022 in the Powerful Women Awards season -2 at the Maharashtra Sadan, Connaught Place, New Delhi organized by Crazytales on May 11, 2022.
- Dr Nisha Sahu received Best Oral Presentation Award in 5th National Conference and Webinar on Doubling Farmers Income for Sustainable and Harmonius Agriculture "DISHA-2022" during June 11-12, 2022.
- Dr AK Patra, Director was conferred with prestigious 'Rafi Ahmed Kidwai Award' from Hon'ble Union Agriculture Minister Narendra Singh Tomar on the occasion of 94th Foundation Day of ICAR on July 16, 2022.

- Dr Ashok Kumar Patra was awarded with the seventh Glinka World Soil Prize of FAO in 2022. He was rewarded for his 33-year dedicated career in Soil Science Research and Education.



- Drs S Bhattacharjya, Asha Sahu, JK Thakur, Asit Mandal, AB Singh and AK Patra received the best scientific poster award on "Potential of lignocellulolytic microbial consortia in achieving in-situ crop residue decomposition to abate residue burning" in Global Symposium on Soils for Nutrition organized virtually during July 26-29, 2022 by Food and Agricultural Organization (FAO), Rome.
- Dr Asha Sahu received 50 USD as "Third Prize" in the Soil Essay Competition organized by the East and South East Asian Federation of Soil Science Societies and Malaysian Society of Soil Scienceon August 25, 2022.
- Dr Jitendra Kumar received Golden Achiever Award from Council for academic performance and appraisal, New Delhi on September 11, 2022.
- Dr Pramod Jha was conferred Fellow of IASWC (2021), Dehradun during National Seminar on Landscape management for preventing flood and reservoir sedimentation on September 22, 2022 at BAU, Ranchi

- Dr NK Lenka was conferred with Dr DN Puri award for excellence in research, development and training in Natural Resource Conservation from the Indian Association of Soil & Water Conservationists, Dehradun on September 22, 2022.
- Dr Priya P Gurav was awarded Best Poster Presentation Award entitled "Estimation of layer charge by using clay CEC in Shrink-Swell soils of India" in 24th Annual Convention of the Clay Minerals Society of India at ICAR-NBSS & LUP, Regional Centre, Kolkata during September 23, 2022.

- Dr JK Thakur awarded Agriculture Scientist Award-2022 from Dr B Vasantharaj David Foundation on October 1, 2022.
- Dr JK Thakur awarded NESA Eminent Scientist of the Year Award 2022 from National Environmental Science Academy, New Delhi, on November 30, 2022.
- Dr Khushboo Rani was conferred with ISSS best doctoral research presentation award 2022 at 86th annual convention of Indian Society of Soil Science held at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra during November 15-18, 2022.

- Dr NK Lenka was conferred with Fellow of "The Society for Science of Climate Change and Sustainable Environment", New Delhi on November, 2022.

- Dr Sangeeta Lenka received Fellowship Award of "The Society for Science of Climate Change and Sustainable Environment (SSCE)" on December 10, 2022.
- Dr Nisha Sahu received Best Scientist Award from 11th EET CRS Science and Technology Awards 2022, Bangalore.
- Dr Nisha Sahu received Excellence in Research Award from Society for Scientific Development in Agriculture and Technology, Meerut.

Honours and Recognitions

- Mrs Alka Rani received The "Certificate of Excellence" for the poster presentation on the topic "Evaluation of satellite-derived soil moisture products with observed data over India" in the National Seminar on Agrophysics for Smart Agriculture organized by Indian Society of Agrophysics and Division of Agricultural Physics, ICAR-Indian Agricultural Research Institute, New Delhi from February 22-23, 2022.
- Dr Pramod Jha delivered invited talk on carbon sequestration in agricultural soils during the national seminar on Managing Soils in a Changing Climate organized by ISSLUP, Nagpur during March 24-26, 2022.
- Dr JK Saha delivered invited online lecture on 'Soil Pollution and Its Assessment' for M.Tech/PGD course on Remote Sensing and GIS Applications in Agriculture & Soils in Indian institute of Remote Sensing, Dehradun on April 8, 2022.
- Dr DK Yadav delivered invited lecture on "Spurious Agrochemicals" on April 09, 2022 in the Agri-Clinics and Agri-Business Centre training organized by Centre for Advanced Research & Development (CARD).
- Drs BL Lakaria, Asit Mandal and JK Thakur acted as Rapporteur in technical session of National Workshop on Natural Farming for Sustainable Agriculture & Environment organized on April 24, 2022 at IISS Bhopal.
- Dr Narayan Lal was invited as guest speaker on "Nutrient Management in Horticultural Crops"in the 5 days National programme on "Innovations in Plant Propagation anf Hi-Tech Nursery Management during April 25-29, 2022 organized by ISP, NAHEP, College of Agriculture, Khandwa, MP.
- Dr R Elanchezhian invited as Lead Speaker at the National Workshop on Effective use of Nano fertilizers in Agriculture organized by IIRR Hyderabad and Coromandel International Ltd. on September 01, 2022.
- Dr R Elanchezhian acted as Panelist in the Brainstorming session on "Exploring Researchable Issues in Plant Physiology" organized by TNAU, Coimbatore on September 14, 2022.
- Dr RH Wanjari acted as an External Expert in a 'Think Tank Brainstorming' Session on the 'Researchable Issues for PG and PhD Research in the field of Soil Science & Agricultural Chemistry (SSAC) organized by TNAU Coimbatore on September 19, 2022.
- Dr Asit Mandal acted as Member of External Advisory Board of the SYMBIOREM Project during September 21-22, 2022, Bilbao (Spain).

- Dr Pramod Jha delivered lead lecture on carbon sequestration and stabilization in agricultural soils: challenges and opportunities during National Seminar on Landscape management for preventing flood and reservoir sedimentation on September 22, 2022 at BAU, Ranchi.
- Dr NK Lenka presented lead paper on Improving soil health and soil resilience for reversing land degradation, Conference Souvenir, National Conference on "Landscape Management for Preventing Flood and Reservoir Sedimentation", held at Birsa Agricultural University, Ranchi during September 22-24, 2022.
- Dr Brij Lal Lakaria acted as Rapporteur in the conference on National Conference on Landscape Management for Preventing Flood & Reservoir Sedimentation organised by IASWC Dehradun during September 22-24, 2022 at BAU, Ranchi
- Dr Brij Lal Lakaria presented a lead paper on role of biochar in soil carbon sequestration and climate change mitigation on September 23, 2022 at BAU Ranchi in National Conference on Landscape Management for Preventing Flood & Reservoir Sedimentation organised by IASWC Dehradun.
- Dr JK Saha delivered invited lecture on 'City Compost Quality-FCO Norms' on September 30, 2022 at Swachh Shehar Samvad-cum-Exhibition at Talkatora Stadium, New Delhi, organized by Ministry of Urban Development, Govt. of India.
- Dr Narayan Lal was invited as Chief Guest by S.V. Convent School, Nazirabad, Bhopal for junior scientist fellowship award ceremony programme on October 20, 2022.
- Dr JK Thakur delivered Invited talk on 'Antibiotics in Soil and its solution' on November 22, 2022 at AIIMS, Bhopal in Trans-sectoral symposium on Anti-microbial resistance: Horizon beyond human health.
- Dr Sangeeta Lenka delivered an online invited talk on "Soil Health and Farm Women" on December 05, 2022 at Central Institute for Women in Agriculture.
- Dr R Elanchezhian acted as Editor of Plant Physiology Reports of Indian Society for Plant Physiology.
- Dr R Elanchezhian acted as NABL Assessor cum Observer for accreditation of NABL laboratories.
- Dr Nishant K Sinha nominated as selection Committee Members-'Swachhta Saarthi Fellowship', nominated by Office of Principal Scientific Advisor, New Delhi.
- Dr BP Meena acted as external examiner to set paper of Agro-meteorology and Climate Change (HNM 312) at Banda University of Agriculture & Technology, Banda-210001 (U.P.), India during 2022.
- Dr Pramod Jha was DG nominee of CAS committee evaluation of performance of Scientist (Soil Science) and to provide recommendation on his eligibility for promotion from 7000 to 8000 RG at NIASM, Baramati
- Dr Pramod Jha acted as Editor of JISSS, New Delhi and PJR, Pantnagar.
- Dr Sangeeta Lenka was external examiner of Ph.D. thesis evaluation in soil science and agricultural chemistry from TNAU, Coimbatore.
- Dr DK Yadav acted as External Examiner to the Agriculture University, Kota, Rajasthan.
- Dr Nisha Sahu recognized as Member of Editorial Board of Agriculture Letters.
- Dr Nisha Sahu recognized as Editorial Board Member of American Journal of Environmental Science and Engineering (AJESE).
- Dr Nisha Sahu invited as Key speaker to deliver on "Role of Remote Sensing data for quantification of contaminated soils in India" online in Global Conference on Environmental Science & Applications (GCESA 2022).
- Dr Brij Lal Lakaria acted as member of Editorial Board of the Indian Journal of Soil Conservation.

6. Linkages and Collaboration

The Institute has linkages with several ICAR institutes and SAUs located throughout the country. The three AICRPs (LTFE, MSPE & STCR) and AINP on SBB stationed at ICAR-IISS, Bhopal have 82 cooperating centers spread across almost all the SAUs of the country. As lead centre, the Institute is undertaking platform project of CRP on Conservation Agriculture and external funded projects (ICRAF, CEFIPRA, UKRI, NASF, DST, DBT, NICRA, MPCOST, EPCO) involving linkage with several ICAR Institutes. Also, efforts have been made to strengthen research collaborative activities with SAUs through guidance of PG students by the Institute scientists. Besides, several private firms, *viz.*, M/s Privi Life Science, Mumbai, M/s Blu Soils Agro Pvt. Ltd, Patna, M/s Groweco Ventures LLP, Indore are collaborating with the Institute on various R&D activities.

List of Co-operating Centres under AICRPs/AINP

AICRPs/AINP	No. of Cooperating Centres		
	ICAR	SAUs/ SGUs	Total
AICRP on LTFE UAS GKVK, Bangalore; OUAT, Bhubaneswar; TNAU, Coimbatore; PJTSAU, Hyderabad; JNKVV, Jabalpur; PAU, Ludhiana; CSKHPKV, Palampur; BAU, Ranchi; GBPUAT, Pantnagar; KAU, Pattambi; JAU, Junagarh; MPUAT, Udaipur; VNMAU, Parbhani; Dr PDKV, Akola; IGKVV, Raipur; ICAR-IARI, New Delhi; ICAR-CRIJAF, Barrackpore; ICAR-IASRI, New Delhi	3	15	18
AICRP on MSPE PJTSAU, Hyderabad; RAU, Pusa; AAU, Anand;HAU, Hisar; JNKVV, Jabalpur; Dr PDKV, Akola; OUAT, Bhubaneshwar;PAU, Ludhiana;TNAU, Coimbatore;GBPUAT, Pantnagar;AAU, Jorhat; BCKV, Kalyani; RAU, Ranchi;CSKHPKV, Palampur; CSAUAT, Kanpur; KAU Kerala; UAS Bengaluru; CAU, Manipur; NIANP Bengaluru;ICAR-IARI, New Delhi; RLBCAU, Jhansi	2	19	21
AICRP on STCR PJTSAU, Hyderabad; RAU, Pusa; IGKV, Raipur; ICAR-IARI, New Delhi; HAU, Hisar; HPKV, Palampur, GKVK, Bengaluru; KAU, Vellanikara; JNKVV, Jabalpur; MPKV, Rahuri; OUAT, Bhubaneswar; PAU, Ludhiana; SKRAU, Bikaner; TNAU, Coimbatore; GPUAT, Pantnagar; BCKVV, Kalyani; ICAR-CRIJAF, Barrackpore; PAJANCOA, Puduchery; BHU, Varanasi; AAU, Jorhat; JAU, Gujarat; SKUAT, Srinagar; BAU, Ranchi; ICAR-IISR, Lucknow; ICAR-Complex, Manipur	4	21	25
AINP on Soil Biodiversity-Biofertilizers AAU, Jorhat; ANGRAU, Amaravathi; BAU, Ranchi; HAU, Hisar; JNKVV, Jabalpur; KAU, Thrissur; MAU, Parbhani; MPUAT, Udaipur; OUAT, Bhubaneswar; RAU, Pusa; TNAU, Coimbatore; YSPUHF, Solan; CRRI, Hazaribagh; ICAR-IARI, New Delhi; DGR, Junagarh; GBPUAT, Pantnagar; UAS, Dharwad	3	14	17
CRP on CA PIC New Delhi, PIU Bhopal, ICAR-IISS Bhopal, ICAR-CRIDA Hyderabad, ICAR-IARI Delhi, ICAR-DWR Jabalpur, ICAR-RCER Patna, ICAR-CSSRI Karnal, ICAR-NIASM Baramati, ICAR-IIWBR Karnal, ICAR-NRRI Cuttack, ICAR-IIFSR Modipuram, ICAR-CIAE Bhopal	13	0	13

7. Ongoing Research Projects

7.1 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

   Investigators: BP Meena, AK Biswas, AB Singh, RS Chaudhary, RH Wanjari, Khushboo Rani, Hiranmoy Das

2. Enhancing the productivity of major crops through improving the natural resource base of tribal inhabited areas of central India

   Investigators: Shinogi KC, Sanjay Srivastava, BP Meena, NK Sinha, K Bharati, Gurav Priya Pandurang, AK Tripathi, Hiranmoy Das, Abhijit Sarkar, RL Raut (KVK, Balaghat), Rameshwar Ahirwar (KVK, Balaghat), Aparna Jaiswal (COA, Balaghat)

4. Mineralogy of Vertisols in relation K availability in central and western India

   Investigators: Gurav Priya Pandurang, AO Shirale, BP Meena, BL Lakaria, Sanjay Srivastava, P Chandran (ICAR-NBSS&LUP, Nagpur), S Sandeep

5. Micronutrients distribution in major soil orders of India as influenced by soil properties and land use pattern

   Investigators: SK Behera, AK Shukla, NK Sinha, JK Thakur, K Kartikeyan (ICAR-NBSS&LUP, Nagpur)

6. Enhancement of soil health and livelihood of tribals in Central India

   Investigators: RH Wanjari, R Elanchezhian, Prabhat Tripathi, RK Singh, KC Shinogi, MV Coumar, Narayan Lal, J Somasundaram, AO Shirale, Asit Mandal, Hiranmoy Das, AB Singh, Asha Sahu, SK Behera, AK Vishwakarma, M Mohanty, Seema Bhardwaj, Madhumonti Saha, Sanjay Srivastava, K Bharati, Priya Gurav, BP Meena, AK Tripathi, Abhijit Sarkar, NK Sinha, JK Thakur, Khushboo Rani, DK Yadav, Immanuel C Haokip, Dhiraj Kumar, Rahul Mishra, M Homeshwari Devi, I/c KVK Barwani (MP), I/c KVK Rajnandgaon (Chhattisgarh) and I/c KVK Betul (MP)

7. Assessment of nutrient (N & P) use efficiency in wheat genotypes for improved crop productivity

   Investigators : R Elanchezhian, AO Shirale, BP Meena, Alka Rani, Sanjay Srivastava, Ajay, AK Biswas, MV Coumar, AB Singh and Renu Pandey (ICAR-IARI, New Delhi).

8. Soil health assessment and input use efficiency

a. Development of agri-horticultural system for central India under Vertisols, its impact on soil health and improvement in productivity and quality of fruits

   Investigators: Narayan Lal, BL Lakaria, AK Vishwakarma, Asha Sahu, Hironmoy Das, AK Biswas and Pradip Dey

9. Studying of climate change impact on nitrogen dynamics and water use in two contrasting cropping system of Central India

   Investigators: NK Lenka, Sangeeta Lenka, Pramod Jha, JK Thakur, BP Meena

10. Enhancing livelihood security of subsistence farming community through improvement in soil health crop productivity and capacity building in Bhopal district of Madhya Pradesh

   Investigators: BL Lakaria, Ajay, AK Vishwakarma, Jitendra Kumar, Dolamani Amat and all scientists

11. Phosphorus potassium and zinc dynamics under conservation agriculture in diverse agro-ecological zones

   Investigators: Khushboo Rani, Priya Gurav, Pramod Jha, AK Vishwakarma, Sanjay Srivastava and AK Biswas

12. Effect of long term nutrient management on various fractions and forms of soil organic carbon and nitrogen, carbon stabilization and biological activity in dominant cropping systems

   Investigators: Dhiraj Kumar, RH Wanjari, Pramod Jha, Somasundaram Jayaraman, Jitendra Kumar, Sudeshna Bhattacharjya, Immanuel C Haokip and Rahul Mishra

13. Assessing soil quality and yield sustainability under long term soil test crop response correlation (STCR) based nutrient in major soil orders of India

Investigators: Immanuel C Haokip, Pradip Dey, NK Lenka, Dhiraj Kumar, M Homeshwari Devi, Khushboo Rani, RH Wanjari, AK Tripathi

(B) Externally Funded Projects

14. All India Network Programme on Organic Farming (ICAR, New Delhi)

Investigators: AB Singh, BP Meena, BL Lakaria, R Elanchezhian, JK Thakur, NK Sinha, Abinash Das

15. Ensuring food security, sustainability and soil health through resource conservation based farmer FIRST approach in central India, (ICAR New Delhi)

Investigators: AK Patra, AK Vishwakarma, RK Singh, AB Singh, BL Lakaria, RH Wanjari, K Bharati, Asha Sahu, Shinogi KC, AO Shirale, Hiranmoy Das, Narayan Lal

16. Assessing the impact of imbalanced use of chemical fertilizer on soil health using a soil function based quantitative approach (DST, New Delhi)

Investigators: NK Lenka, BP Meena, Sangeeta Lenka, AO Shirale, RH Wanjari

17. Long-term monitoring of soil processing in forests and grasslands (MOEF, GOI)

Investigators: Pramod Jha, Sumanta Bagchi

18. Studies on N-(n-butyl) ThiophosphoricTriamide (NBPT) as a Urease Inhibitor for Improving Nitrogen Use Efficiency in major cropping systems in India funded by ICAR- CIMMYT collaboration

Investigators: Pramod Jha, R Elanchezhian, BL Lakaria, BP Meena, Pradip Dey, AK Biswas

19. Sustainable biochar production agroforestry systems and its application: A climate resilient soil management approach funded by ICRAF

Investigators: BL Lakaria, Pramod Jha, AK Biswas, AK Vishwakarma, BP Meena, M Vassanda Coumar, Jitendra Kumar, Abinash Das, AK Patra, Javed Rizvi, SK Dhyani, Aqeel Hasan Rizvi, Archna Singh, Jamal Pervez Noor

20. Development of Nano Sensor and its application through cloud-based network for real time irrigation to soil and plant funded by NASF, ICAR, New Delhi

Investigators: Tapan Adhikari, CD Singh, Samir Kumar Pal, SN Bose

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

A. Institute Projects

21. Climate change impact on water productivity of major crops in central India

Investigators: NK Sinha, M Mohanty, J Somasundaram, Pramod Jha, Alka Rani, Seema Bhardwaj, Hiranmoy Das, KM Hati, RS Chaudhary

22. Impacts of conservation agriculture on runoff and soil loss under different cropping system in Vertisols

Investigators: Prabhat Tripathi, RK Singh, RS Chaudhary, Seema Bhardwaj, J Somasundaram, M Mohanty, KM Hati, Rahul Mishra.

23. Impact of climate change on soil processes

a. Impact of climate change on soil physical process in maize based cropping systems in vertisols of central India

Investigators: Jitendra Kumar, NK Sinha, M Mohanty, J Somasundaram, Alka Rani, KM Hati and RS Chaudhary

b. Soil moisture estimation through remote sensing for agriculture drought monitoring and early warning

Investigators:Alka Rani, NK Sinha, M Mohanty, Jitendra Kumar, Seema Bhardwaj, RS Chaudhary, KM Hati and RK Singh

B. External funded projects

24. Assessment of important soil properties of India using mid-infrared spectroscopy (ICAR-ICRAF, Nairobi)

Investigators: KM Hati, M Mohanty, Pramod Jha, RS Chaudhary, NK Sinha, JK Thakur, MV Coumar, Pradip Dey, Dhiraj Kumar, AK Patra, Javed Rizvi

25. CRP-Conservation Agriculture (LCPC: Dr AK Biswas and DLCPC: Dr RSChaudhary) (ICAR)

a. Development, refinement and validation of conservation agriculture in Vertisols of central India and quantifying impact of CA practices on soil and environment

Investigators: KM Hati (PPI), J Somasundaram, AK Vishwakarma, RK Singh, Pramod Jha

b. Demonstration of best-bet conservation agriculture practices on farmers' fields in Vertisols of central India

Investigators: AK Vishwakarma, RH Wanjari, RK Singh, KC Shinogi, AK Tripathi

c. Fine-tuning of conservation agricultural practices for Vertisols of central India

Investigators: J Somasundaram, BP Meena and AO Shirale

d. Development of water and nutrient management practices in conservation agriculture for Vertisols of central India

Investigators: RK Singh, Sanjay Srivastava, Priya Gurav and NK Sinha

e. Impact of conservation agricultural practices on soil health, carbon sequestration and greenhouse gas emissions in different production systems

Investigators: Pramod Jha, BL Lakaria, M Mohanty, JK Thakur and K Bharati

26. Modelling soil carbon storage and dynamics in different agro-ecosystems of India under the changing climate scenarios funded by NICRA

Investigators: NK Sinha, M Mohanty, Pramod Jha, J Somasundaram, Dhiraj Kumar, RH Wanjari, Prabhat Tripathi, AK Patra

27. Integrated assessment of soils and crops under varying climate conditions to improve nutrient dynamics and efficiencies, carbon sequestration and greenhouse gas mitigation funded by NICRA

Investigators: NK Sinha, M Mohanty, J Somasundaram, Pramod Jha, K Bharati, Jitendra Kumar, Sangeeta Lenka, JK Thakur, Abinash Das, KM Hati, RS Chaudhary, AK Patra, Dhiraj Kumar

28. Vulnerability and impact assessment of climate change on soil and crop production in Madhya Pradesh (UNDP-GEF-MoEFCC)

Investigators: Sangeeta Lenka, NK Lenka, M Mohanty, RH Wanjari and AK Patra

26. Assessing the potential impact of climate smart technologies on soil health and nutrient accounting in selected vulnerable districts of MP (EPCO, Bhopal)

Investigators: Sangeeta Lenka, NK Lenka, MV Coumar, M Mohanty, Dolamani Amat, JK Saha, AK Patra, DK Yadav

29. Assessing the potential impact of climate change and management on soil carbon and nitrogen storage in selected ecosystems of India (NASF, ICAR)

Investigators: Sangeeta Lenka, NK Lenka, Vasudev Meena, Asit Mandal, Kaushik Batabayal (BCKV, West Bengal)

30. ICAR Network Program on Precision Agriculture

Investigators: NK Sinha, J Somasundaram, M Mohanty, Pradip Dey, Jitendra Kumar, Dhiraj Kumar, Alka Rani, KM Hati, RS Chaudhary, AK Patra, Rahul Mishra

7.3 Programme III – Soil Microbial Diversity and Biotechnology

A. Inter-Institute Project

31. Characterization and prospecting of soil biota for enhancing nutrient use efficiency

a. Deciphering thermophiles from hot springs of Central India for rapid decomposition of crop residues

Investigators: Asha Sahu, Sudeshna Bhattachrjya, Dolamani Amat, Nisha Sahu, K Bharati and Anita Tilwari

b. Exploring endophytic microbial diversity of selected major field crops of India for nutrient supplementation and biocontrol

Investigators: JK Thakur, Asit Mandal, Dolamani Amat and MC Manna

B. Externally Funded Projects

32. Ecogenomics of soil microbes involved in global climate mitigation and nitrogen use efficiency in rice-wheat agroecosystem of central India under elevated CO_2 and temperature (DST, New Delhi)

Investigators: SR Mohanty, K Bharati, S Gangil (ICAR-CIAE, Bhopal), AK Vishwakarma

33. Evaluation of Soybean-rhizobia interaction under elevated CO_2 and temperature to develop climate ready microbial inoculants for central India (ICAR, AMAAS)

Investigators: SR Mohanty, K Bharati, Asit Mandal

34. Methanogenic bio-electrode driven conversion of CO_2 to CH_4 to enhance methanogenesis and mitigation of greenhouse gas from agro-waste based bioenergy systems (DST-JSPS programme)

Investigators: SR Mohanty, K Bharati, AK Patra, Seiya Tsujimura, Masanori Kaneko

35. Microbial based agricultural waste management using vermicomposting funded by Swachchta Action Plan, ICAR, New Delhi

Investigators: AK Patra (Project leader), AK Vishwakarma (PI), JK Thakur, AB Singh, BL Lakaria, BP Meena, RS Chaudhary, Asha Sahu, Asit Mandal

7.4 Programme IV: Soil Pollution, Remediation and Environmental Security

A. Institute Project

36. Quantitative assessment of acid mine drainage affected areas in Madhya Pradesh

Investigators: Madhumonti Saha, Ajay, Abhijit Sarkar, JK Saha and Hiranmoy Das

37. Heavy metal and its remediation for sustainable crop production and environmental protection

a. Assessment/quantification of soil heavy metals using spectroscopy and multi spectral remote data from industrial areas of Kanpur

Investigators: Nisha Sahu, JK Saha, NK Sinha, H Biswas (ICAR-NBSSLUP Nagpur), Mrunalini Kancheti (ICAR-IIPR, Kanpur), Rahul Mishra

b. Municipal solid waste compost quality assessment for sustainable crop production and environmental protection

Investigators: M Vassanda Coumar, Tapan Adhikari, Abhijit Sarkar, Nisha Sahu, JK Saha, Hiranmoy Das, Ajay, DK Yadav and SK Meena (CPCB)

c. Quantification of heavy metal concentration in contaminated soils, sludge and compost using pXRF and ICP-OES

Investigators: Rahul Mishra, NK Sinha, KM Hati, MV Coumar, M Mohanty, Abhijit Sarkar, Dhiraj Kumar, DK Yadav, RS Chaudhary, JK Saha

B. Externally Funded Projects

38. Use of fly ash in agriculture for sustainable crop protection and environmental protection funded by NTPC, Noida

Investigators: JK Saha, MV Coumar, AK Patra, Tapan Adhikari, Ajay, KM Hati, Abhijit Sarkar, Rahul Mishra, Sangeeta Lenka, Asit Mandal, AK Vishwakarma, Madhumonti Saha , Hiranmoy Das, Nisha Sahu

39. Investigation of potentials of soil as a sink for nitrous oxide and strategies for mitigation nitrous oxide emission funded by DST SERB –POWER Fellowship

Investigators: Sangeeta Lenka

40. Do agricultural micro plastics undermine food security and sustainable development in less economically developed countries?

Investigators: AK Patra, Tapan Adhikari, JK Thakur, Asit Mandal

Collaborative projects in other institutes where ICAR-IISS scientists are associated

- Development and promotion of CA machinery (ICAR-IISS, Bhopal and ICAR-CIAE, Bhopal)
  Investigators: Dushyant Singh, NS Chandel, AK Vishwakarma
- System for production of enriched biochar from crop residue (ICAR-IISS, Bhopal and ICAR-CIAE, Bhopal)
  Investigators: Sandip Mandal, Chirag Maheswari, AK Shukla, SK Behera
- Enhancing input use efficiency and productivity of pulses production system in central India (ICAR-IISS, Bhopal and ICAR-IIPR, Kanpur)
  Investigators: Sandeep Kumar, Narendra Kumar, Pramod Jha, R Elanchezhian
- Monitoring, mapping and development of agricultural farms using GIS at ICAR-CIAE
  Investigators: Shashi Rawat, K Singh, HS Pandey and Khushboo Rani
- Hyper spectral reflectance and multi nutrient extractant based rapid assessment of soil properties for sustainable soil health in India
  Investigators: P Santra, P Dey, MV Coumar and Immanuel C Haokip

8. Consultancies, Contractual Services, Patents and Technology Commercialization

Consultancies /Contractual Services

S.	Title	Sponsorer	Project team
1	Evaluating the impact of Geoxol.com on soil health and crop productivity	M/s Privi Life Science, Mumbai	J Somasundaram, NK Sinha, M Mohanty, RS Chaudhary, KM Hati, AO Shirale, AK Patra
2	Evaluating the effect of Bio.soilz on soil nutrient availability and microbial activity under maize-wheat cropping system in Vertisols of Central India	M/s Blu Soils Agro Pvt. Ltd, Patna	Asit Mandal, JK Thakur, AB Singh, R Elanchezhian, AK Patra
3	On farm evaluation of ECOWELL ORGANIC PRODUCTS under soybean-wheat cropping system	M/s Groweco Ventures LLP, Indore	Asha Sahu, Sudeshna Bhattacharjya, Dolamani Amat, K. Bharati, AB Singh, AK Patra

Patents

Patent filed at the Indian Patent Office on 23 March 2022 with application title "MICROBIAL CONSORTIA FOR ACCELERATED DECOMPOSITION OF ORGANIC WASTE, AND METHOD OF DECOMPOSITION" and number 202211016212.

Inventors: Drs MC Manna, JK Thakur, Asha Sahu, AB Singh, AK Tripathi, Asit Mandal, Sudeshna Bhattacharjya, Dolamani Amat, AK Patra, Shankar Jha

9. Publications

9.1 Papers in Research journal

9.1.1. International/ National (NAAS Rating more than 6)

Aher SB, Lakaria BL, Kaleshananda S, Singh AB (2022). Concentration and uptake of micronutrients (Fe, Zn, Cu and Mn) in soybean and wheat under organic, biodynamic and inorganic nutrient management in semi-arid tropical conditions of central India. *Communications in Soil Science and Plant Analysis*, 53(17), 2229-2244. https://doi.org/10.1080/00103624.2022.2071434. (NASS Rating 7.33).

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Butail NP, Kumar P, Shukla AK, Behera SK, Sharma M, Kumar P, Sharma U, Takkar PN, Rao CS, Trivedi V, Das S (2022). Zinc dynamics and yield sustainability in relation to Zn application under maize-wheat cropping on Typic Hapludalfs. *Field Crops Research*, 283, 108525. https://doi.org/10.1016/j.fcr.2022.108525. (NAAS Rating 9.25).

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