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All India Coordinated Research Project
On
Long -Term Fertilizer Experiments to Study Changes in Soil Quality, Crop Productivity and Sustainability

INDIAN INSTITUTE OF SOIL SCIENCE (ICAR)
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FOREWORD

Long-term experiments started in early 70s have, of course, an initial relevance in the context of the objectives framed, but a wider relevance as platform sites for involving multi-discipline, a resource database for the development of crop/soil simulation models, assets for validation and calibration of soil/crop simulation models and opportunities to test basic ecological and biogeochemical questions that cannot be answered without long-term experiments. During the last 40 years many myths related to inorganic fertilizer use have been busted with respect to its impact on soil organic carbon, nutrient dynamics, microbial population and diversity, soil health and crop productivity. However, there is a need of retrospection for the betterment of these experiments in view of changing scenario of climatic change agriculture and the challenges emerged due to long-term treatments interventions. There is a need for monitoring of heavy metal build up in soil and plant system under long-term chemical fertilization and manuring treatments. Also the impact of long-term fertilization on crop produce quality has to be ascertained. In order to have greater output from the same experiment, there is a need of involvement of scientists from different disciplines of agriculture like Entomology, Pathology, Water Management, Crop Physiology, Statistics, Economist besides Soil Science and Agronomy for better understanding of the related discipline processes under the long-term fertilization/manuring experiments. Interaction with other disciplines and in particular with ecologists, modelers and statisticians may provide extra value to long-term trial researchers. Long-term experiments are not only vital for validation of crop/soil simulation models but also provide an opportunity to develop our own models. Well monitored long term experiments are the only satisfactory means of measuring long-term soil carbon dynamics and crop yields. Long-term experiments are the asset for determining the impact of climate change on soil-plant system. The long-term meteorological data coupled with soil and crop data set offers good opportunity for measuring the influence of climatic aberrations on soil processes and crop performance.

I appreciate the sincere and dedicated efforts of the team of scientists from ICAR and SAUs in generating the information on such vital issues. The document prepared gives the details of impact of fertilizer and manure on soil properties and crop productivity which would serve as reference material for researchers in advancing the science, planners for drawing action plan for judicious use of nutrient, improvement in the economy of the region and the extension worker for sustaining the productivity by implementing the outcomes of this vital experiment.

(A Subba Rao)
Director
Indian Institute of Soil Science

PREFACE

Sustainability of agriculture in the country like India is of prime importance. The result on long term fertilizer experiments world over proved that sustainability is impossible without the use of fertilizer. However, indiscriminate use of fertilizer without scientific basis may lead to harmful effect on soil and crops. Therefore, it is necessary to have a constant watch on soil properties. Long-term experiments in India have generated large and valuable informations which are used for sustainability of the intensive agriculture. Changes in soil fertility, as a result of imbalanced fertilizer use and faulty management practices takes few years to appear disorder in soil but regresses several years to bounce back the same condition. The change in climate also has effect on productivity and soil quality. Long-term experiments provide the best possible platform for studying the changes in soil properties and processes, identifying emerging trends in nutrient imbalances and deficiencies and to formulate future strategies for maintaining soil health and quality, it is our moral duty to pass on natural resources in better condition. In current report attempt has been made to highlight the comprehensive view of achievements of the project. I strongly believe that the results of these long-term experiments would benefit scientific and extension workers, policy makers and other personnel concerned with natural resource management for sustained agricultural production and environment protection.

The research findings reported herein is a combined effort of the Coordinating Centres and Project Coordinating Cell of the AICRP on Long Term Fertilizer Experiments. I profusely thank all the scientists' worked/ working in the project at different centres including voluntary centre at IASRI, New Delhi for their valuable contribution and cooperation in the execution of the project.

Thanks are due to Dr. S. Ayyappan, Director General, Indian Council of Agricultural Research (ICAR) and Secretary, Department of Agricultural Research and Education, Ministry of Agriculture, Government of India, New Delhi for keen interest and providing financial support for the project. I am greatly indebted to Dr. A.K. Sikka, Deputy Director General (NRM), ICAR for his valuable guidance, generous support and encouragement all the time in planning and execution of programme. I am extremely grateful to Dr. Mohan Kumar, Assistant Director General (Soils and Water), ICAR for his generous support and useful suggestions time to time. My thanks are due to Dr A Subba Rao, Director, Indian Institute of Soil Science, Bhopal for the facilities extended to coordinating cell in execution of the research programme of the project.

My sincere thanks are due to Dr. R.H. Wanjari, Sr. Scientist, PC LTFE Unit for his constant support in execution of programme and help rendered by him in compilation of the report. The help extended by Mr. Sunny Kumar, Jr. Stenographer for not only his secretarial assistance in preparation of manuscript but also day to day work of PC Unit is clearly acknowledged. Thanks are also due to Mr A.K. Mishra (Lab Attendant) for assisting me in day-to-day work.

IISS, Bhopal
30th December, 2013

(**Muneshwar Singh)**
PROJECT COORDINATOR

EXECUTIVE SUMMARY

- Experiment conducted across the country clearly brought out that it is not possible to sustain productivity without external supply of nutrient.
- In Alfisols crop did not show response to applied N and P until K is not supplied. Thus supply of K is essential to sustain productivity.
- Invariably in Alfisol, hidden hunger of S is recorded which resulted decline in yield. So to get the potential yield of a crop, one must ensure supply of S.
- As far as nutrient status in soil is concerned, varied with nature of nutrient. Balanced use of nutrient maintains soil N status at par with initial status. Accumulation of P was noted on continuous application of fertilizer while reverse was noted in the absence of P in fertilizer schedule.
- In case of K, the scenario is different. Irrespective of treatment (supply of K), decline in available K content was noted in Vertisols. However, in Inceptisols, little improvement in K status was noted. In Alfisols both reduction and increase in K status was noted depending upon the supply of K through irrigation water. In Inceptisol irrigation water, utilization of K from deeper layer by crop and upward movement of K along with water are responsible channels for increase in K status.
- In majority of places micronutrient status is maintained above the critical level in soil. Though treatment structure is such that does not allow decreasing Zn beyond a level. In Punjab improvement in Zn status as noted may be due to decline of soil pH.
- Micronutrient status at different locations indicated that balanced application of nutrient not only maintained micronutrient status but also increased their status at many locations. This could be the reason why at many locations increase in productivity led to diminishing the micronutrient problem.
- Studies conducted on heavy metal accumulation revealed that till date there was no accumulation of heavy metal in profile due to application of fertilizer. But little increase in DTPA extractable heavy metal was noted on application of lime and FYM. This is probably due to contamination of these metals in lime whereas mobilization of heavy metal through FYM could be possible reason. But in all the treatments the content of these metals is far below the limit prescribed by WHO.
- Analysis of data generated on physical condition of soils across the soils revealed that there is no adverse effect on physical condition of soils like bulk density, infiltration rate, hydraulic conductivity etc rather improvement was noted in fertilized plot.
- On balanced application of fertilizer nutrients increase in soil aggregation was noted almost at all the sites. Application of FYM further improved the properties. Aggregation is the property which helps in sequestering the carbon and improving aeration of soil.

- Analyses of data generated across the soil on physical properties revealed that increase in productivity on application of nutrient in balanced form resulted improvement in soil physical condition of soil. So better productivity helped in maintaining better soil condition.

- It is believed that application of fertilizer resulted decline in microbial population in soil which mediate nutrient transformations processes. Data accumulated clearly brought out that application of fertilizer nutrient resulted improvement in microbial population and enzymatic activity. This is due to addition of fresh biomass through root and rhizodeposition each year, which acted as substrate for these organisms.

- In spite of low K content of Alfisols, crop did not show response to applied K particularly in rabi season crop. This is due to addition of K through irrigation water which is not accounted in general.

- In spite of high K status in Vertisols, crops have shown response to applied K. Which is due to less release rate of K from non-exchangeable to exchangeable due to mineralogical make up of these soils.

- Studies on K released indicated that application of FYM resulted increase in release of K whereas decline in K release was noted in Vertisol on continuous application of fertilizer in Vertisols. They also reported that conjunctive use of fertilizer and manure (FYM or Green manure) resulted in increase in K release from non-exchangeable K. Therefore to understand the K response of crop it is necessary to study the release pattern of K in soil.

- Demonstration conducted on farmers' field clearly brought out that soil is low in Zn and S. We shall have to ensure supply of Zn and S either through chemical fertilizer or through regular application of FYM along with NPK to sustain productivity.

- Demonstration carried out in Haryana clearly indicated to enhance productivity of pearl millet-wheat, there is need to increase the amount of NPK because both the crops are heavy feeder and crop residue is not recycled back to soil.

- The results indicated damage in rice through stem borer in the plot received 100% N without P and K. Which means application of N alone makes plant susceptible.

- Application of FYM increased the longevity of herbicide in soil and made it more effective. But at the same time does not have adverse effect on growth of microbial population for larger period.

- To assess soil quality soil indicators were identified. Soil indicator's varied with soil to soils. In Inceptisols available nutrient status was found to be soil indicator's in Vertisols soil physical properties like bulk density, soil aggregate and infiltration rate appeared to be more important whereas in Alfisols, soil pH, Ca, Mg and K status were noted as most important indicator which are responsible for productivity. However, in all the types of soils, one or other form of soil organic carbon showed their presence as one of the soil indicators.

सारांश

- देश भर में किए गए दीर्घकालीन उर्वरक परीक्षण परियोजना के अंर्तगत कार्यरत केंद्रों से प्राप्त आँकड़ों का विश्लेषण करने के बाद यह तथ्य सामने आया कि फसल की अनवरत उपज प्राप्त करने के लिए बाहर से पोषक तत्वों को देना अनिवार्य है विशेषकर नाइट्रोजन, फास्फोरस और पोंटैशियम और अम्लीय मृदाओं के फसलों में नाइट्रोजन और फास्फोरस का उपज पर प्रभाव तब तक नहीं दिखाई पड़ता जब तक पोटैशियम न दिया जाए। इसलिए अम्लीय मृदाओं में फसलों की अनवरत उपज प्राप्त करने के लिए पोटैशियम एक महत्वपूर्ण पोषक तत्व है।
- सभी अम्लीय मृदाओं में सल्फर की कमी पायी गइ । सल्फर की कमी की वजह से उपज में गिरावट भी देखी गयी। इसलिए इन मृदाओं में भरपूर फसल प्राप्त करने के लिए पोटाश के साथ–साथ सल्फर को प्रदाय कराना भी आवश्यक है।
- रासायनिक खाद के प्रयोग के बारे में बहुत–सी भ्रांतियाँ हैं जैसे मिट्टी की उर्वरता कम होना तथा कार्बन की मात्रा में कमी आना। परंतु दीर्घकालीन उर्वरक परीक्षण परियोजना से प्राप्त आँकड़े इस बात को नकारते हैं। विभिन्न दीर्घकालीन उर्वरक परीक्षण केंद्रों से प्राप्त मिट्टी परीक्षण से ज्ञात हुआ कि लगातार संतुलित मात्रा में पोषक तत्वों को प्रदाय करने से मिट्टी में नत्रजन की मात्रा में कोई कमी नहीं आयी। कहीं–कहीं तो उसमें बढ़ोत्तरी पायी गई जिन उपचारों में लगातार फास्फोरस का उपयोग किया गया। इन मिट्टीयों में सुलभ फास्फोरस की मात्रा में वृद्धि पायी गई जो समय के साथ लगातार बढ़ रही हैं। हाँ इसके विपरीत जिन उपचारों में फास्फोरस नहीं दिया गया उनमें फास्फोरस की मात्रा में बहुत कमी आ गई है तथा कहीं–कहीं तो फसल की उपज में भी बहुत अधिक मात्रा में गिरावट दर्ज की गयी।
- जहाँ तक पोटैशियम का सवाल है उसका वर्ताव विभिन्न प्रकार के मिट्टीयों में भिन्न है। काली मिट्टीयों में पोटैशियम की मात्रा देने के बावजूद भी पोटैशियम की सुलभ मात्रा में लगातार कमी आ रही है, इसके विपरीत एलुवियल मिट्टीयों में पोटैशियम की सुलभ मात्रा में वृद्धि पायी गई। एल्युवियल मिट्टीयों में पोटैशियम के बढ़ने के दो कारण हैं पहला कारण सिंचाई के पानी के साथ पोटैशियम की मात्रा का जाना तथा दूसरा नीचे की सतह से पोटैशियम पानी के साथ उपर आना तथा पौधों द्वारा नीचे की सतह से पोटैशियम को प्राप्त करना मुख्य है। कभी नदी के पानी से सिंचाई करने पर सिल्ट द्वारा पोटैशियम का मिट्टी में जाना भी एक कारण है।
- अम्लीय मृदाओं में कहीं पर पोटैशियम की मात्रा में कमी तथा कहीं पर वृद्धि पायी गई। इसकी वजह सिंचाई के पानी में पोटैशियम होना या तालाब में इकट्ठे किए गए पानी में जिसमें काफी मात्रा में सिल्ट होता है।

- अधिकतर जगहों पर सूक्ष्मतत्व क्रांतिक स्तर के आसपास बने हुए हैं, क्योंकि जैसे ही इन तत्वों की कमी आती है तब उन्हें प्रदाय करा दिया जाता है। पंजाब में जिंक की सुलभ मात्रा में बढ़ोत्तरी पायी गयी जिसका कारण मिट्टी के pH मान में कमी होने की वजह हो सकती है। इस पर गहन अध्ययन की जरूरत है।
- ऐसी धारणा है कि लगातार रासायनिक खाद के प्रयोग करने से मिट्टीयों में भारी तत्वों की मात्रा में वृद्धि होती है, परंतु मिट्टी की जाँच से प्राप्त आँकड़ों का विश्लेषण करने से पाया गया कि 40 वर्षों के बाद भी मिट्टी में भारी तत्वों की मात्रा में कोई खास वृद्धि नहीं पाई गई। हाँ जहाँ चूना तथा गोबर की खाद का प्रयोग किया जा रहा है, वहाँ पर इन तत्वों की मात्रा में थोड़ी सी वृद्धि पायी गई जो WHO द्वारा निर्धारित मानक से बहुत कम है। चूने के प्रयोग करने से इन तत्वों में वृद्धि का होना चूने में इनकी मिलावट की वजह हो सकती है तथा गोबर की खाद का प्रयोग करने से मिट्टी में उपलब्धता के बढ़ने की वजह गोबर की खाद द्वारा मिट्टी में पाये जाने वाले मिनरल से इन तत्वों का निकलना है।
- मिट्टी के भौतिक गुण बहुत ही महत्वपूर्ण हैं जो मिट्टी में हो रही रासायनिक तथा जैविक क्रियाओं के लिए उपयोगी होते हैं। देश के विभिन्न क्षेत्रों में किये गये परीक्षणों से प्राप्त आँकड़ों के विश्लेषण करने से यह पता चला कि रासायनिक खादों के प्रयोग करने से मिट्टी के भौतिक गुण जैसे मिट्टी का घनत्व, मिट्टी की संरद्रता, मिट्टी में पानी नीचे जाने की गति इत्यादि पर कोई विपरीत असर नहीं पड़ा। अपितु इनमें बढ़ोत्तरी पायी गई जो एक अच्छा लक्षण है।
- मिट्टी में ढेला बनने की क्षमता मिट्टी का बहुत ही उपयोगी गुण है। रासायनिक खादों के प्रयोग करने से मिट्टी में बड़े ढेले बनने की क्षमता में वृद्धि पायी गई। यदि गोबर की खाद रसायनिक खाद के साथ प्रयोग में लाया जाए तो यह क्षमता और भी बढ़ जाती है। मिट्टी में ढेलों की क्षमता बढ़ने के कारण फसलों की जड़ों में वृद्धि होती है जो ताजा कार्बनिक पदार्थ जैसे डंठल तथा जड़े फसल कटने के बाद मिट्टी में रह जाती है। वो सूक्ष्मजीवों के लिए खाद्य पदार्थ का काम करते हैं और जैव रासायनिक क्रियाओं के द्वारा पोलीसॅकराइड का उत्सर्जन करते हैं। पोलीसॅकराडस छोटे कणों को आपस में जोड़ने का काम करती है जिससे ढेले बड़े हो जाते हैं।
- आम लोगों में धारणा है कि रासायनिक खाद के प्रयोग करने से मिट्टी में सूक्ष्मजीव जो रासायनिक तथा जैव रासायनिक क्रियाओं में भाग लेते हैं उनकी मात्रा में कमी आ रही है। दीर्घकालीन उर्वरक परीक्षणों से प्राप्त आँकड़ों के विश्लेषण से ये बात सामने आयी है कि रासायनिक खाद के प्रयोग करने से इन सूक्ष्मजीवों की मात्रा में वृद्धि पायी गई। मिट्टी में एंजाइम की अधिक सक्रियता इस बात की पुष्टि करती है। सूक्ष्मजीवों की वृद्धि पौधों की जड़ों

के द्वारा सुगर का निकलना तथा फसल काटने के बाद अवशेषों के मिलने की वजह से होती है, क्योंकि ये कार्बनिक पदार्थ सूक्ष्मजीवों के लिए भोजन का काम करते है।

- यद्यपि अम्लीय क्रियाओं में पोटैशियम की मात्रा बहुत कम होती है। फिर भी फसलों में पोटैशियम की उपज पर प्रभाव एक–दो स्थानों पर नहीं पाया गया खासकर रबी की फसल में इसकी वजह सिंचाई के पानी में पोटैशियम का होना है। खरीफ की फसल में बाहर से पानी नहीं दिया जाता इसलिए फसलों में पोटैशियम का प्रभाव पाया गया है। इसके विपरीत काली मिट्टी में अधिक पोटैशियम होने के बावजूद फसलों की उपज पर पोटैशियम का प्रभाव पाया गया। वैज्ञानिक अध्ययन करने से यह ज्ञात हुआ कि काली मिट्टीयों में पाये जाने वाले मिनरल से पोटैशियम का निस्तारण बहुत कम मात्रा में होता है जो फसल की जरूरत को पूरा नहीं कर पाता इसलिए पोटैशियम के डालने से उपज में प्रभाव दिखायी देता है। इसके विपरीत एलुवियल मिट्टी में पाये जाने वाला मिनरल पोटैशियम को आसानी से निस्तारित कर देते हैं।
- किसानों के खेतों पर किए गए परीक्षण में पाया गया कि तराई के मिट्टीयों में जिंक तथा सल्फर की कमी है, जिसको प्रदाय कराने से फसलों की पैदावार में वृद्धि होती है। यदि गोबर की खाद का प्रयोग किया जाए तो इनकी जरूरत पूरी हो जाती है। हरियाणा के गुडगाँव जिले में किए गए परीक्षणों से ज्ञात हुआ कि बाजरा, गेहूँ फसल चक्र में निर्धारित की गई NPK की मात्रा कम है, क्योंकि दोनों ही फसल इन तत्वों को अधिक मात्रा में लेती हैं तथा फसलों के अवशेष मिट्टी में नहीं मिलाये जाते। इसलिए भरपूर फसल लेने के लिए इनकी मात्रा बढ़ाने की आवश्यकता है।
- चावल की फसल में जिन उपचारों में केवल नाइट्रोजन दिया जा रहा है, उसमें तनाछेदक का प्रकोप देखा गया है जो इस बात की ओर इशारा करता है कि केवल नाइट्रोजन देने से पौधे अधिक मुलायम हो जाते हैं तथा तनाछेदक के प्रकोप के शिकार हो जाते है। इसके विपरीत फास्फोरस तथा पोटैशियम की वजह से पौधे मजबूत हो जाते हैं तथा तनाछेदक किटाणु का प्रभाव कम होता है।
- काली मिट्टीयों में नान–एक्सचेंजेवल पोटैशियम से विनिमय पोटैशियम में बदलने की प्रक्रिया के अध्ययन से सामने आया कि गोबर की खाद का प्रयोग करने से इसमें वृद्धि होती है जबकि पोटैशिक खाद देने से इसमें कमी आती है। रासायनिक तथा गोबर/हरी खाद के मिश्रित रूप से प्रयोग करने से पोटैशियम निस्तारण की मात्रा में वृद्धि पायी गई है। इसलिए फसलों की उपज पर पोटैशियम का प्रभाव होगा या नहीं उसकी (पोटैशियम) निस्तारित होने वाली मात्रा पर निर्भर करेगा।
- गोबर की खाद प्रयोग करने से घास को मारने के लिए प्रयोग किए गए हर्वीसाइड अधिक लंबे समय तक मिट्टी में रहते हैं तथा उसकी हॉफ लाइफ में 3–4 दिन की वृद्धि होती है, हर्वीसाइड का प्रभाव थोड़े समय के लिए ही सूक्ष्मजीवों पर रहता है जो थोड़े समय के बाद

फिर से अपनी वृद्धि दर प्राप्त कर लेते हैं। इसलिए इनके प्रयोग करने से बहुत लंबे समय तक सूक्ष्मजीवों पर विपरीत प्रभाव नहीं रहता है।

- मिट्टी के गुणों को परखने के लिए कुछ सूचकों की आवश्यकता है। इसलिए मिट्टी के सूचक गुणों की बढ़ोत्तरी को अध्ययन किया गया। अध्ययन से पता चला कि ऐलुवियल मिट्टीयों में ये सूचक पोषक तत्व होते हैं तथा काली मिट्टीयों में मिट्टी के भौतिक गुण जैसे मिट्टी का घनत्व, ढेले बनाने की क्षमता तथा मिट्टी में पानी का नीचे की ओर रिसना (इनफिल्टरेशन) मुख्य सूचक गुण सामने आए। इनके विपरीत अम्लीय मृदाओं में मिट्टी का pH मान कैल्शियम, मैग्निशियम तथा पोटैशियम की मात्रा मिट्टी के सूचक गुणों के रूप में सामने आये। सभी मिट्टीयों में कार्बन की एक या एक से अधिक प्रकार सूचक गुण के रूप में सामने आयी जिससे यह ज्ञात होता है कि सभी मिट्टीयों के स्वास्थ्य की परख करने के लिए कार्बन बहुत अधिक महत्वपूर्ण है।
- अम्लीय मृदाओं में लगातार यूरिया का प्रयोग करने से pH मान में गिरावट आयी जिससे मिटट्ी में उपलब्ध P तथा K जिनकी मिट्टी में पहले से ही कमी थी और कमी आ गयी, जिसके कारण फसलों का उत्पादन ना के बराबर हो गया। इसलिए ये आवश्यक है कि हम लगातार मिट्टी के स्वास्थ्य पर ध्यान रखें अन्यथा अचानक आयी उपज में गिरावट का पता करने में समय लगेगा तब तक काफी क्षति हो चुकी होगी।

1. INTRODUCTION

1.1 Historical background of Long Term Experiments

J. B. Lawes and J. H. Gilbert started nine long-term experiments between 1843 and 1856, one of these was discontinued in 1878. Even after the death of Lawes in 1900, the eight remaining experiments were continued more or less as, originally planned; these are called the *'Rothamsted Classical Experiments'*. Their main objective was to measure the effects of inorganic compounds containing nitrogen, phosphorus, potassium, sodium and magnesium elements known to occur in considerable amounts in crops and farmyard manure on crop yields but their separate actions as plant foods had not been studied systematically. The effects of these inorganic fertilizers alone and in various combinations were compared with those of FYM and rape cake in most of the experiments. These experiments are continued for more than 160 years continuously and yielded most valuable information, used to develop an efficient approach for managing the crops and cropping systems. Growing of the same crop year after year on the same land was considered bad farming in the nineteenth century, but it has now become an established practice for cereal growing due to some compulsion. It has added emphasis on the urgency and priority of these experiments, as the information emerging from these studies has led to many timely interventions in agronomic practices. From 1957 several classical experiments were modified to evaluate the residual effects of the annually repeated dressings of different combinations of nutrients. These experiments are continuously providing the valuable information for refining the strategy and policy to enhance productivity without adverse effect on environment.

In India also a series of long-term fertilizer experiments were established at different locations in the country in the beginning of 20th century. These were at Kanpur, Uttar Pradesh (1905); Pusa, Bihar (1908); and at Coimbatore, Tamil Nadu (1909). Later on more long term fertilizer experiments were established with more heavily fertilized crop such as sugarcane at Shahjahanpur (Uttar Pradesh) 1935; Padegaon (Maharashtra) 1939; Indore (Madhya Pradesh) 1947; Muzaffarnagar (Uttar Pradesh) 1949; and at Anaka Palle (Andhra Pradesh) 1950 and on cereal based cropping system at Ranchi (Jharkhand) 1956. Unfortunately, some of these experiments were either discontinued or seriously altered, as they were found inadequate in respect of the statistical requirement pertaining to the design of experiments or suffered from some management problems. However, the experiments at Coimbatore and Ranchi are still being continued.

During late sixties high yielding varieties (HYV) were introduced which later on proved to be the main pillar of Green Revolution. Intensification of agriculture under irrigated condition resulted in acceleration of nutrient mining from soil to harness the potential of the HYV for long term. Under this situation, it has become imperative to maintain supply of the nutrient in sufficient quantity without external use of fertilizers. To sustain the productivity a need of interventions in soil fertility maintenance programme was felt.

1.2 Brief about AICRP on Long Term Fertilizer Experiments

Since fertilizer has become a key factor for increasing agricultural production and its consumption in agriculture is increasing rapidly, a need is felt for studying the impact of fertilizers not only on the crop yields and quality but also on the soil and environment under intensive cropping systems which are major users of fertilizers. This gavea call for a long term studies at fixed sites for monitoring the changes in the nutrient dynamics with the objectives of developing strategies for sustained

productivity by incorporating the intervention. In view of these emerging compulsions the Indian Council of Agricultural Research decided to launch the "All India Coordinated Research Project on Long-Term Fertilizer Experiments (AICRP-LTFE)" in September 1970 at 11 centres (Fig. 2.1 and Table 2.1).

The work carried out at different centers of LTFE was reviewed by QRT during 1997 and recommended to enlarge the mandate and objectives of the project and changed its title as AICRP on "Long-term fertilizers experiments to study changes in soil quality, crop productivity and sustainability". The purpose of conducting long term fertilizer experiments at fixed sites in different agroecological zones (AEZ) with important cropping systems was not only to monitor the changes in soil properties and yield responses and soil environment due to continuous application of plant nutrient inputs through fertilizers and organic sources, but also to help in the synthesizing the strategies and policies for rational use and management of fertilizers to improve soil quality and to minimize environment degradation. Thus, the thrust of AICRP is on productivity, sustainability and environment safety.

1.3 Mandate

- To conduct coordinated long term fertilizer experiments in different soil types under diversified cropping system and
- To collate information on long term soil fertility trials

1.4 Objectives

- To study the effect of continuous application of plant nutrients, singly and in combination, in organic and inorganic forms including secondary and micronutrient elements (as per the need) on crop yield, nutrient composition and uptake in multiple cropping systems;
- To study the effect of application of secondary and micronutrients (as per the need) on crop yield and also on the assessment of the need for these elements under an intensive cropping programme;
- To work out the amount of nutrient removal by the crops;
- To monitor the changes in soil properties as a result of continuous manuring and cropping with respect to the physical, chemical and microbiological characteristics of the soil in relation to its productivity;
- To investigate the effect of intensive use of biocidal chemicals (weedicides and pesticides) on the build up of residues and soil productivity;
- To make an assessment of the incidence of soil borne diseases and changes in pests and pathogens 0075nder the proposed manuring and cropping programme.

2. TECHNICAL PROGRAMME

2.1 Treatment Details

Initially project experiments were started at 11 centres in irrigated and intensively cultivated areas representing different agroclimatic regions. Five of these are located at CRIJAF, Barrackpore (West Bengal) TNAU, Coimbatore (Tamil Nadu), IARI, Delhi (Delhi) ANGRAU, Hyderabad (Andhra Pradesh) and PAU, Ludhiana (Punjab) on Inceptisols. Four experiments were established on Alfisols at HPKV, Palampur (Himachal Pradesh), BAU, Ranchi (Jharkhand), and UAS, Bangalore (Karnataka) OUAT, Bhubaneswar (Orissa) rice-rice; one each on Vertisol at JNKVV, Jabalpur (Madhya Pradesh) and on Mollisol at GBPUAT, Pantnagar (Uttaranchal). Cropping system and soil type is given in Table 2.1. There are **10 treatments** in each experiment. These are: $\mathbf{T_1}$ 50% optimal NPK dose; $\mathbf{T_2}$ 100% optimal NPK dose; $\mathbf{T_3}$ 150% optimal NPK dose; $\mathbf{T_4}$ 100% optimal NPK dose + hand weeding; $\mathbf{T_5}$ 100% optimal NPK dose + Zinc or lime; $\mathbf{T_6}$ 100% optimal NP; $\mathbf{T_7}$ 100% optimal N; $\mathbf{T_8}$ 100% optimal NPK + FYM; $\mathbf{T_9}$ 100% optimal NPK (Sulphur free/sulphur source); $\mathbf{T_{10}}$ Unmanured (Control) with a provision of one or two additional treatments that may be of local or regional interest. The treatments are replicated four times in a randomized block design. The unit plot size varied from 100 to 300 m^2 except at Palampur centre where it was only 15 m^2 because of non availability of large sized plots in the hilly areas.

After realizing the importance of the information generated from LTFE centres, The Indian Council of Agricultural Research (ICAR) sanctioned six new centres to cover more climatic zones and soils during 1995-96. They are at MAU, Parbhani, PDKV, Akola, KAU, Agricultural Regional Station Pattambi, RAU, Udaipur, GAU, Junagadh and IGKVV, Raipur during 1996-97. The centre at OUAT Bhubaneswar had to be shifted from the original site during 1996-97 because of acquisition of land by Airport Authority of India. Due to shortage of water the centre at ANGRAU, Hyderabad was shifted to its Regional Station at Jagtial and was initiated during 2000-2001.

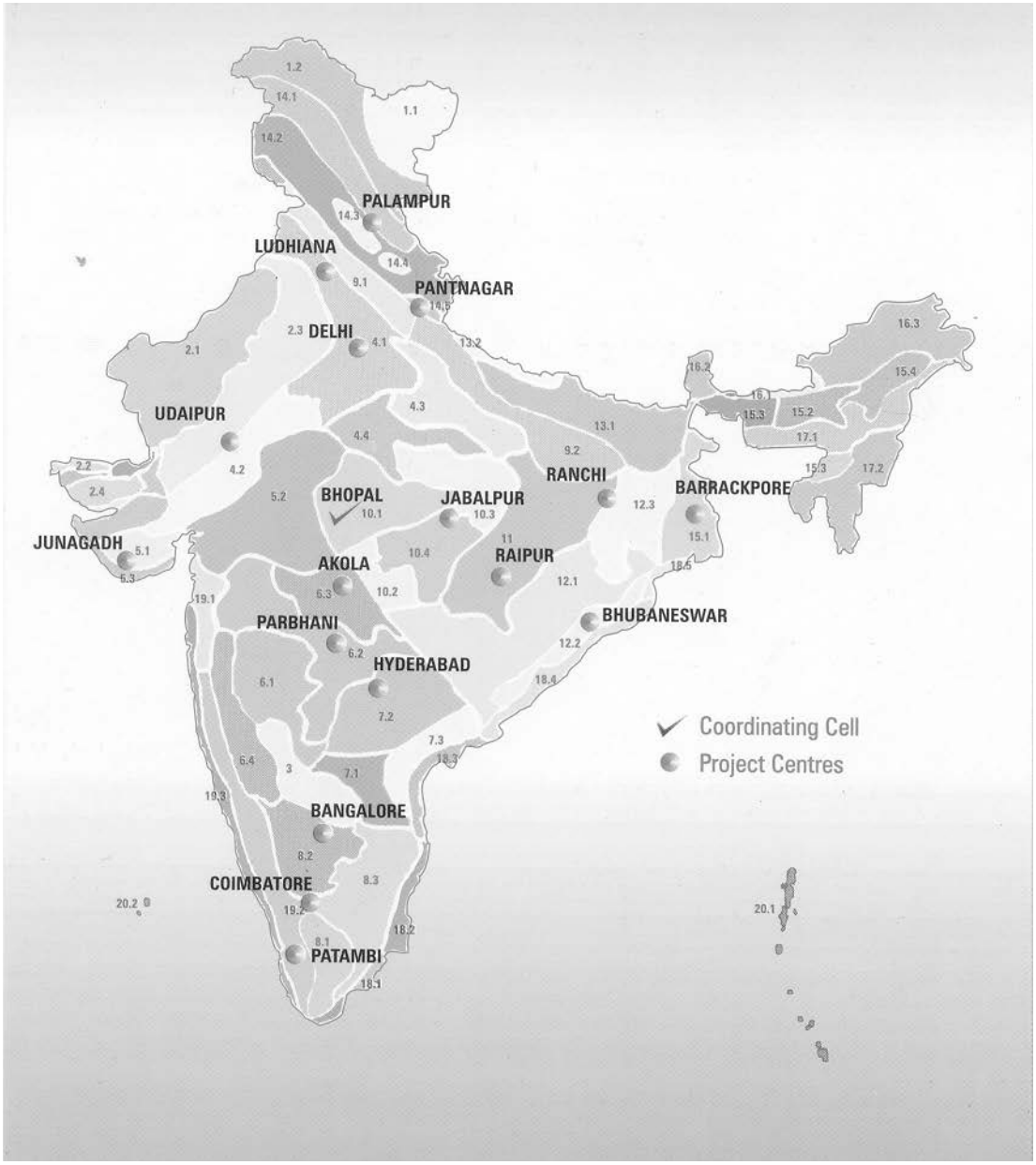

Fig. 2.1 The map showing location of different cooperating centers of AICRP -LTFE

Table 2.1 Details with soil type, cropping system and Agroecological zone of each Centre of AICRP on LTFE

S. No.	Location (State)	Soil Type	Year of start	Taxonomic Class	Cropping system	Agro-eco region	Sub-region
1.	CRIJAF Barrackpore (W.B.)	Inceptisols	1971	Typic Eutrochrept	Rice-wheat-jute fibre	15	15.1
2.	PAU Ludhiana (Punjab)	Inceptisols	1971	Typic Ustochrept	Maize-wheat-cowpea fodder	4	4.1
3.	IARI New Delhi (Delhi)	Inceptisols	1971	Typic Ustochrept	Pearlmillet-wheat-cowpea fodder (till 1981-82) ; Maize-wheat-cowpea fodder (since 1982-83)	4	4.1
4.	TNAU Coimbatore (T.N.)	Inceptisols	1971	Vertic Ustopept	Fingermillet-maize-cowpea fodder	8	8.1
5.	JNKVV Jabalpur (M.P.)	Vertisols	1972	Typic Chromustert	Soybean-wheat-maize fodder	10	10.1
6.	GKVK Bangalore (Karnataka)	Alfisols	1972	Kandic Paleustalf	Fingermillet-maize-cowpea-fodder (Cowpea discontinued w.e.f. 1994)	8	8.1
7.	ANGRAU RRS Jagtial, (AP)	Inceptisols	2000	Typic Tropaquept	Rice-rice [Earlier expt. continued till 1996 (at Hyderabad,1971-96)]	7	7.2
8.	OUAT Bhubaneswar (Orissa)	Inceptiols	2002	Aeric Haplaquept	Rice - rice (Expt. continued till 2001) Rice - rice (new Expt. started wef.2002)	12	12.2
9.	BAU Ranchi (Jharkhand)	Alfisols	1972	Typic Haplustalf	Soybean-potato-wheat (till 1984) Soybean-wheat (since 1985)	12	12.3
10.	CSKHPKV Palampur (H.P)	Alfisols	1972	Typic Hapludalf	Maize-potato-wheat (till 1977-78) Maize-wheat (since1978-79)	14	14.3
11.	GBPUA&T Pantnagar (Uttaranchal)	Mollisosl	1971	Typic Hapludoll	Rice-wheat	14	14.1
12.	JAU Junagadh (Gujarat)	Vertisols	1996	Vertic Ustochrept	Groundnut-wheat	2	2.4
13.	Dr. PDKV, Akola (Maharashtra)	Vertisols	1996	Typic Haplustert	Sorghum-wheat	6	6.2
14.	KAU Pattambi (Kerala)	Alfisols	1996	Typic Haplustalf	Rice-rice	19	19.2
15.	IGKV Raipur (Chhatisgarh)	Vertisols	1996	Typic Haplusterts	Rice-wheat	11	11.0
16.	MPUA&T Udaipur (Rajasthan)	Inceptisols	1996	Typic Ustochrept	Maize-wheat	4	4.2
17.	MPKV Parbhani (Maharashtra)	Vertisols	1996	Typic Chromustert	Soybean -safflower	6	6.2

B	**Voluntary centre**						
18.	IASRI New Delhi	-	1972	-	-	-	-

Table 2.2 Nutrient rates used under various cropping systems at different centres of LTFE

Location	*Crop*	Fertilizer rates at 100% NPK based soil test (kg ha^{-1})			*FYM added (t ha^{-1})
		N	P	K	
Barrackpore	Rice	120	26	50	10
	Wheat	120	26	50	-
	Jute	60	13	50	-
Ludhiana	Maize	120	26	25	10
	Wheat	120	26	25	-
New Delhi	Maize	120	26	33	15
	Wheat	120	26	33	-
Coimbatore	Finger millet	90	20	14	12.5
	Maize	135	29	29	-
Jabalpur	Soybean	20	35	17	15
	Wheat	120	35	33	-
Bangalore	Finger millet	100	26	21	15
	Maize	120	26	21	-
Jagtial	Rice (kharif)	120	26	33	10
	Rice (rabi)	120	26	33	-
Ranchi	Soybean	25	26	33	10
	Wheat	80	26	33	-
Bhubaneswar	Rice (kharif)	100	26	50	5
	Rice (rabi)	100	26	50	-
Palampur	Maize	120	26	75	10
	Wheat	90	39	38	-
Pantnagar	Rice	120	26	38	15
	Wheat	120	26	33	-
Junagarh	Groundnut	25	22	0	-
	Wheat	120	26	50	-
Pattambi	Rice (kharif)	90	20	38	5
	Rice (rabi)	90	20	38	-
Udaipur	Maize	90	30	15	10
	Wheat	90	30	15	-
Raipur	Rice	100	26	33	5
	Wheat	100	26	33	-
Akola	Sorghum	100	50	40	10
	Wheat	120	26	50	-
Parbhani	Soybean	30	26	25	10
	Safflower	60	18	0	

* FYM application is at 5 t per ha on oven dry basis since 2010

2.3 Superimposition of Treatments

Continuous use of fertilizers either singly, in combination or integration with FYM resulted in either high build of P, and Zn fertility or accentuated the deficiencies of micronutrients, soil acidity, and excessive depletion of P or K. Therefore interventions were needed to address issues emerged out of the information generated. Superimposition of treatments was done using nested design in one of the replications in certain specified treatments at the following centers. To address the issues of yield plateau and organic farming, some of the treatments were superimposed with small dose of FYM over and above NPK. To address the issue of organic farming treatment were modified and nutrient were supplied through FYM fully.

2.3.1 Pantnagar

Treatment	Superimposed treatments since 1993
150% NPK	S_1 150% NPK S_2 150% NPK + S S_3 150% NPK – S + Zn S_4 150% NPK + S +Zn S_5 150% NPK + S + Zn + FYM
	Superimposed treatments since 2000-01
100% NPK	S_1 100% NPK S_2 100% NPK + S S_3 100% NPK – S + Zn S_4 100% NPK + S +Zn S_5 100% NPK + S + Zn + FYM

2.3.2 Ludhiana

Treatment	Superimposed treatments since 1994
50% NPK	S_1 50% NPK S_2 100% N, 50% P, 50% K S_3 100% N, 50% P, 100% K + Zn
100% NPK	S_1 100% NPK S_2 100% N, 50% P, 100 %K S_3 100% N, 50% P, 100% K + Zn
150% NPK	S_1 150% NPK S_2 150% N, 50% P, 150% K S_3 150% N, 50% P, 150% K + Zn
100% NPK (S free)	S_1 100% NPK (S free) S_2 100% NK S_3 100% NPK + Zn

2.3.3 Ranchi

Treatment	Superimposed treatments since 2002-2003
100% NP	S_1 100% NP (original) S_2 100% NP + Lime* S_3 100% NP + FYM
100% N	S_1 100% N (original) S_2 100% N + Lime* S_3 100% N + FYM
100% N(S)PK [S= $NH_4(SO_4)_2$]	S_1 100% NPK S_2 100% NPK+ Lime* S_3 100% NPK + FYM

* Lime as per requirements

2.3.4 Bangalore

Treatment	Superimposed treatments since 2002-2003
100% NPK+HW	S_1 100% NPK + HW (original) S_2 100% N, 50% P_2O_5, 100% K_2O and FYM (15 t ha^{-1}) S_3 100% N, 50% P_2O_5, 100% K_2O, FYM (15 t ha^{-1}) & liming
100% NP	S_1 100% NP (original) S_2 100% N, 50% P_2O_5, 100% K_2O and FYM (15 t ha^{-1}) S_3 100% N, 50% P_2O_5, 100% K_2O, FYM (15 t ha^{-1}) & liming
100% N	S_1 100% N (original) S_2 100% N, 100% P_2O_5, 100% K_2O and FYM (15 t ha^{-1})
150% NPK	Superimposed treatments since Kharif, 2005-06 S_1 150% NPK S_2 150% NPK+ 5 t ha^{-1} FYM S_3 100% NPK + 10 t ha^{-1} FYM

2.3.5 New Delhi

Treatment	Superimposed treatments since 2002-2003
100% NPK+HW	S_1 NPK + HW (original) S_2 FYM alone on N basis 120 kg (24 t ha^{-1}) S_3 50% N basis FYM + 50% NPK
100% N	S_1 100% N (original) S_2 FYM alone on N basis 120 kg (24 t ha^{-1}) S_3 50% N basis FYM + 50% NPK
Control	S_1 Control (original) S_2 FYM alone on N basis 120 kg (24 t ha^{-1}) S_3 50% N basis FYM + 50% NPK

2.3.6 Jabalpur

Treatment	Superimposed treatments since 2002-2003
150% NPK	S_1 150% NPK (original) S_2 150% NPK + 2.5 t FYM ha $^{-1}$ S_3 150% NPK + 5.0 t FYM ha $^{-1}$ S_4 150% NPK + 10.0 t FYM ha $^{-1}$

2.3.7 Coimbatore

Treatment	Superimposed treatments since 2002-2003
100% NK	S_1 100% NK S_2 100% NK + 50% P S_3 100% NK + 100% P (original) S_4 100% NK + 150% P
150% NPK	S_1 150% NPK (original) S_2 150% NPK + 2.5 t FYM ha $^{-1}$ S_3 150% NPK + 5.0 t FYM ha $^{-1}$ S_4 150% NPK + 10.0 t FYM ha $^{-1}$

2.3.8 Barrackpore

Treatment	Superimposed treatments since 2002-2003
100% NPK	S_1 100% P S_2 66% P S_3 33% P
150% NPK	S_1 100% P S_2 66% P S_3 33% P
100% NP	S_1 100% P S_2 66% P S_3 33% P
100% NPK+ FYM	S_1 100% P S_2 66% P S_3 33% P

The results, obtained on superimposition of treatments at different centres brought out the information for developing the strategies for utilizing the accumulated nutrients as a result of continuous application and mitigating the deficiency of K, P, Zn or S due to absence of these nutrients in fertilizer schedule for long time.

3. CROP PRODUCTIVITY

It is essential for us to sustain and enhance productivity to feed ever growing population with decreasing availability of natural resources like land and water. To enhance and sustain productivity use of chemical nutrients in integrated manner is essential. In this section impact of fertilizer and organic manure on productivity of different cropping system is given here under.

3.1 Inceptisol

3.1.1 Barrackpore (Rice-wheat-jute)

Rice-wheat-jute is an important cropping sequence of West Bengal. Grain yield of rice and wheat along with fibre yield of jute are shown in Table 3.1. It was observed that the maximum yield was recorded in 150% NPK treated plot with exception in jute 2011-12 and wheat 2011-12 where highest yield was observed in 100% NPK+FYM treated plot. The maximum yield in jute, rice and wheat was 3126 kg ha^{-1}, 5300 kg ha^{-1} and 4700 kg ha^{-1}, respectively in the year 2010-2011. The increase in yield of jute, rice and wheat on application of 150% NPK over 100% NPK indicates that 100% NPK dose was inadequate to get potential yield. Lower yield was recorded in the imbalanced treatment. Yield of jute, rice and wheat ranged from 575 to 2510 kg ha^{-1}, 2150 to 3890 kg ha^{-1} and 846 to 3140 kg ha^{-1}, respectively, under different treatments, the lowest being in unfertilized control plots for all the crops in both the years compared to treated plots. The yield improved with the balanced application of NPK fertilizers and highest crop yield was obtained with 100% NPK+FYM in jute and wheat whereas 150% NPK gave the highest yield in rice. Yield data indicated response of N and P in only rice and wheat whereas jute did not show any response to applied P. This is probably due to good root system of jute.

Table 3.1.Grain yield of rice and wheat & fibre yield of jute (kg ha^{-1}) at CRIJAF Barrackpore

Treatments	Rice			Wheat			Jute		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean
50% NPK	4575	3271	3923	3125	1961	2543	2634	1509	2072
100% NPK	5075	3522	4299	3950	2565	3258	2917	2108	2513
150% NPK	5300	3887	4594	4700	3065	3883	3126	2405	2766
100% NPK+ HW	4600	3476	4038	3700	2522	3111	2883	1742	2313
100% NPK + Zn	4875	3409	4142	3975	2821	3398	2965	1994	2480
100% NP	4700	3219	3960	3900	2494	3197	2723	1548	2136
100% N	4550	2462	3506	3575	1705	2640	2743	1437	2090
100% NPK+ FYM	5175	3655	4415	4400	3139	3770	3065	2510	2788
100% NPK-S	4675	3442	4059	3650	2772	3211	2813	1873	2343
Control	2925	2148	2537	900	846	873	1404	575	990
LSD (*P*≤0.05)	761	409	585	498	278	388	484	150	317

3.1.2 Coimbatore (Finger millet-maize)

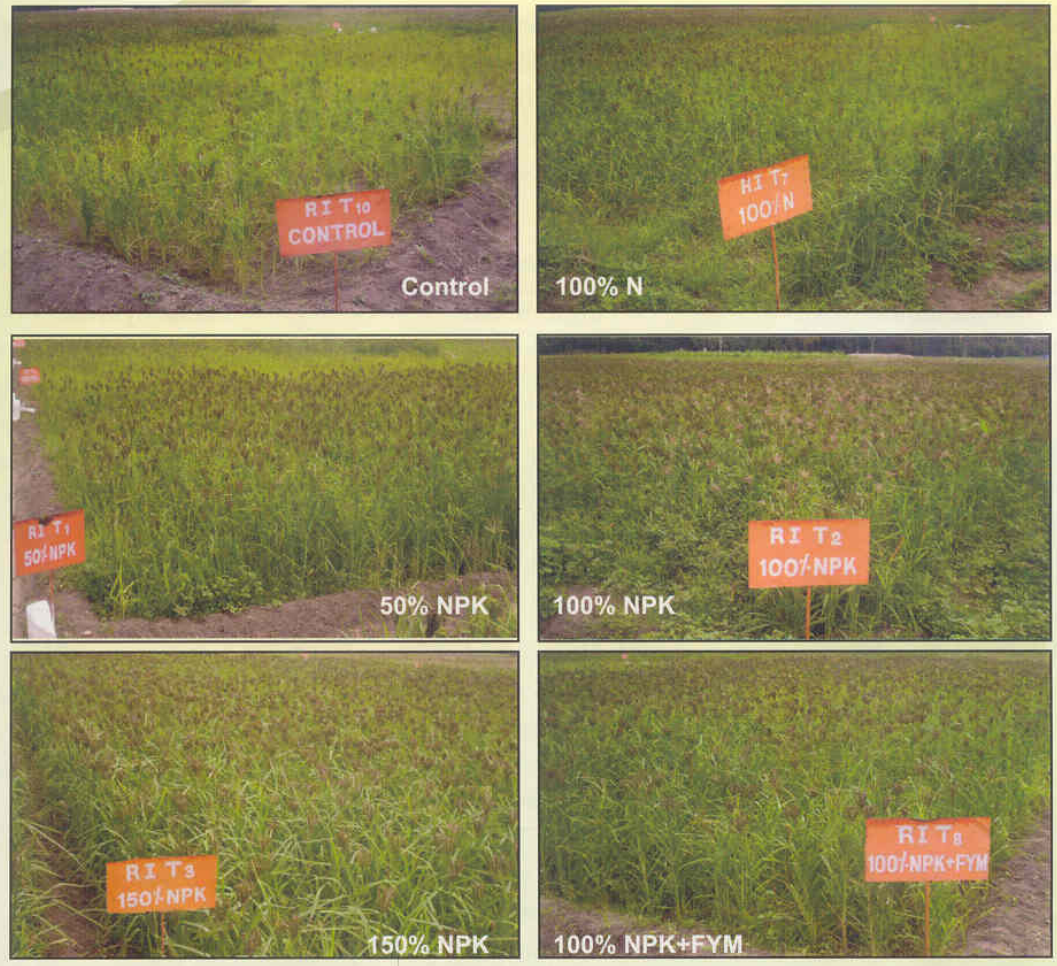

Plate 3.1 Impact of balance and integrated nutrient management on growth of finger millet at Coimbatore

Plate 3.2 Impact of balance and integrated nutrient management on the cob developments of maize (Coimbatore)

In last few years finger millet gain the importance in human diet. Till date there was no response to applied K, Zn and S in finger millet (Table 3.2). Very extensive root system of finger millet is one of the reason for absence of respone to these nutrients. However, maize (Table 3.2) has shown response to applied K, S and Zn. Response of maize is due to high demand of these nutrients because of very high productivity. The native source of these nutrients is not able to synchronize demand of maize in a limited period of growth. Therefore, at high level of productivity crop may show response to a nutrient even if it exists in large quantity.

Table 3.2 Grain yield of finger millet and maize hybrid (Mean 2010-12)

Treatments	Finger millet		Maize hybrid	
	Grain (kg ha^{-1})	Straw (kg ha^{-1})	Grain (kg ha^{-1})	Straw (kg ha^{-1})
50% NPK	2371	5024	6370	10184
100% NPK	2558	5560	7493	11892
150% NPK	2722	5889	8295	13078
100% NPK + HW	2528	5395	7186	11537
100% NPK + $ZnSO_4$	2614	5678	7971	12470
100% NP	2558	5475	7147	11476
100% N	2115	4215	5117	8710
100% NPK + FYM	2894	6477	8911	13545
100% NPK (-S)	2490	5359	6752	10917
Control	1743	3239	3697	6931
LSD (*P*≤0.05)	79.5	227.0	164.8	296.0

3.1.3 Ludhiana (Maize-wheat)

Data (Table 3.3) revealed that both maize and wheat responded to applied N and P, however, crop did not show any response to applied Zn.

Table 3.3 Effect of application of organic manures and inorganic fertilizers on maize and wheat yield (kg ha^{-1})

Treatment	Maize		Wheat	
	2010	2011	2010-11	2011-12
50% NPK+FYM	3820	3430	4040	4250
100% NPK+W	4420	4200	4990	5210
150% NPK	5330	4550	5710	5370
100% NPK	4590	4380	5120	5300
100% NPK+Zn	4420	4470	4830	5370
100% NP	3560	3630	4900	5010
100% N	2920	2870	4180	4200
100% NPK+FYM	5650	5250	5840	5800
100% NPK(-S)	4750	4330	5100	5390
Control	2250	2140	1780	1800
LSD (*P*≤0.05)	820	-	690	-

It is interesting to note that maize responded to applied K, whereas wheat did not show any response. The response of maize to applied K is due to absence of irrigation because maize is a rainfed crop of Kharif season. Absence of response of wheat to applied K is due to supply of K through irrigation water. Irrigation water contains potassium which supplement K requirement of wheat to some extent. In addition supply of K through irrigation water to wheat being deep rooted exploite K from lower layer of soils. Till date crop did not show response to applied sulfur. Integrated and balanced application of nutrient always outyielded in comparasion of imbalanced use of nutrients.

3.1.4 New Delhi (Maize-wheat)

The grain yields of maize in different treatments were averaged across the years (1994 to 2012) and compared with the yields obtained in 2012 (Table 3.4), and interesting change in the magnitude of response to different nutrients was recorded. The extent of yield gain due to super-optimal NPK over 100% NPK and to NP over N alone was greater in 2012 than that in the averaged yield data. Apparently, the crop response to P as also to the enhanced rate of NPK was increased with the passage of time. The yield response to FYM used along with 100% NPK compared with sole fertilizer application was also increased over the years. Increase in yield was also recorded in control plot. The larger response of nutrient and increase in yield in control plot is due to introduction of maize hybrid in recent past.

Wheat yields averaged for past 18 years (1993-94 to 2011-12) *vis-à-vis* those obtained in 2011-12 are presented in Table 3.4. Treatments receiving N alone produced lower yield in 2011-12 compared with the 18- year average yield. Over the years, response to P and K, and also to an enhanced NPK application rate showed substantial increase while response to FYM remained almost consistent. These data indicated emerging inadequacy of P and K in the soil owing to continuous mining, which could be offset only through an enhanced rate of NPK application or inclusion of FYM in fertilizer schedule. In contrary to maize, continuous decline in yield of wheat in control plot is recorded that is due to mining of native nutrient and use of varieties of wheat having similar potential.

Table 3.4 Mean yields of maize (kg ha^{-1}) under different fertilizer options

Treatment	2011 - 2012		Mean yield (1994 to 2012)	
	Maize	Wheat	Maize	Wheat
50% NPK	2590	3880	1860	3900
100% NPK	3310	4850	2300	4540
150% NPK	3930	5520	2680	4990
100% NPK + HW	3540	4920	2360	4510
100% NPK	3420	5130	2460	4630
100% NP	3010	4190	2040	4150
100% N	2560	3370	1750	3730
100% NPK + 5 t FYM ha^{-1}	4180	5480	2760	5020
100% NPK + 45 kg S ha^{-1}	3370	5040	2440	4660
Control	1560	2090	1220	2350
LSD ($P \leq 0.05$)	410	570	-	-

3.1.5 Jagtial (Rice-rice)

In eastern and southern part of the country rice-rice is one of predominant cropping systems. Data on influence of nutrient application on productivity of rice (Table 3.5) revealed that increase in dose of nutrient from 50%NPK to150% NPK resulted in increase in productivity. Yield data further revealed response of N and P in both the rice crops. However, both the crops of rice did not show response to applied K till date. It may be because of high status and contribution of K through canal irrigation water during rabi which meet out a part of K requirement. Though more yield of rice is expected during rabi season due to more sunshine hours compared to kharif but at Jagtial reverse was noted probably due to non availability of irrigation water during rabi season. Even after so many years response to applied S and Zn was also not seen. During both the seasons yields obtained under NPK+FYM are larger than 100% NPK but lower than 150% NPK which means applications of chemical fertilizer alone also one can get the highest yield of rice

Table 3.5 Effect of long term fertilizer application on rice grain yield (kg ha^{-1}) during *Kharif* and rabi season

Treatment	*Kharif*			*Rabi*		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean
50% NPK	6090	6324	6207	5050	3793	4422
100% NPK	6788	6994	6891	5266	4720	4993
150% NPK	6818	7528	7173	6473	5739	6106
100% NPK + HW	6767	7034	6901	5471	4823	5147
100% NPK + Zn	6957	7027	6992	5579	4921	5250
100% NP	6724	6708	6716	5456	4850	5154
100% N	5716	5532	5624	4237	3440	3839
100% NPK + FYM	6622	7152	6887	5955	5212	5584
100% NPK - S	6742	6735	6739	5492	4651	5072
FYM (20 t ha^{-1})	5595	5666	5631	4189	4051	4120
Control	4191	4186	4189	3252	2783	3018
LSD ($P \leq 0.05$)	557	756	442	712	438	400

3.1.6 Bhubaneswar (Rice-rice)

Yield data of both Kharif and Rabi rice (Table.3.6) reveled that the yields obtained during rabi season are larger than kharif season which in due to more sunshine hours. So far response of Zn and S was not recorded. It is interesting to note that kharif rice responded to applied K and the rice grow during rabi did not show response to applied K in spite of low K content. During rabi season, rice in grown with irrigation (tubewell) water which contains K and this is the reason rice grown during rabi did not show any response to applied K. Application of FYM over and above NPK irrespective of seasons and years resulted in increase of rice productivity whereas no additional benefit was noted on amending soil with lime. This could be because rice is grown under submerged condition and the effect of lime is ruled out. From the results it appears that K, P and B are nutrient limiting factors in addition to N. Hidden huger of S, Zn and B is ruled out if FYM is applied on regular basis.

Table 3.6 Effect on rice yield (kg ha^{-1}) in *kharif* and rabi (2010 & 11) at Bhubaneshwar

Treatments	Kharif rice			Rabi rice		
	2010	2011	Mean	2010	2011	Mean
50% NPK	2391	2281	2336	2670	2600	2635
100% NPK	2575	2485	2530	2850	2960	2905
150% NPK	2828	2750	2789	2971	3106	3039
100% NPK +Zn	2667	2688	2677	3000	2920	2960
100% NPK +FYM	3459	3234	3347	3381	3528	3455
100% NPK + Lime + FYM	3250	3078	3164	3289	3414	3352
100% NPK + B + Zn	2705	2563	2634	3020	3020	3020
100% NPK + S + Zn	2610	2594	2602	2908	2903	2906
100% N	2103	2047	2075	2450	2525	2488
100% NP	2306	2406	2356	2610	2636	2623
100% NPK + Lime	2625	2578	2602	2868	2955	2912
Control	1341	1150	1245	1320	1480	1400
LSD (*P*≤0.05)	388	387	236	298	261	280

3.1.7 Udaipur (Maize-wheat)

On perusal of yield data (Table 3.7) of maize and wheat, it was noted that both the crops responded to applied N, P and K. The response of K was, however, marginal. There was no response to applied Zn and S as well. Application of FYM over and above 100% NPK resulted increase in productivity of both maize and wheat whereas yields obtained were less on substitution of N through FYM. Yields were at par to that obtained on application of 100% NPK. Data further indicated even after application of exclusively FYM since last 16 years continuously, yields obtained were similar to that of 100% N. Eventhough there has been increase in yield in maize with incorporation of azotobacter but was statistically non significant.

Table 3.7 Long-term effect of nutrient management on grain yield (kg ha^{-1}) of maize and wheat along with overall average yield (1997-98 to 2011-2012) at Udaipur

Treatments	Maize			Wheat		
	2010-11	2011-12	Average	2010-11	2011-12	Average
Control	1438	1285	1696	1702	1587	1815
100% N	2337	2137	2358	3089	2963	3041
100% NP	2950	2779	2802	3797	3787	3640
100% NPK	3408	3194	3087	4330	4446	3986
100% NPK + Zn	3595	3290	3244	4546	4573	4167
100% NPK + S	3460	3274	3134	4431	4535	4076
100% NPK + Zn + S	3690	3487	3290	4642	4712	4281
150% NPK	3777	3698	3367	4711	4720	4368
100% NPK + FYM	4075	3912	3543	4990	5139	4562
100% NPK – FYM	3469	3440	3128	4645	4677	4192
FYM	2360	2364	2414	3136	3093	2933
100% NPK + *Azatobactor*	3508	3377	3193	4462	4510	4113
LSD (*P*≤0.05)	354	304	120	300	420	122

3.2 Vertisols

3.2.1 Jabalpur (Soybean-wheat)

Yield data (Table 3.8) clearly demonstrated significant increase in yield of both soybean and wheat with application of N, P and K. Response of applied S was noted in wheat only. The mean yield of soybean and wheat reduced to 12 and 19%, respectively in plots receiving 100% NP as compared to 100% NPK treatments (2161 and 5703 kg ha^{-1}, respectively). Reduction in soybean yield was obviously due to continuous omission of K in fertilizer schedule that resulted in mining of this nutrient from the soil reserves. The balanced application of 100% NPK through chemical fertilizers produced higher soybean and wheat yield. The highest soybean and wheat grain yield (2470 and 6191 kg ha^{-1}, respectively) was obtained with 100% NPK+FYM. However, the yield obtained on application of 150% NPK was more or equal to yield reconded in 100%NPK+FYM.

Table 3.8 Yield of soybean and wheat (kg ha^{-1}) at JNKVV Jabalpur (AICRP LTFE)

Treatments	Soybean			Wheat		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Control	1200	750	975	1350	1656	1503
100% N	1625	875	1250	1800	2019	1909
100% NP	2275	1525	1900	4875	4413	4644
50% NPK	2138	1450	1794	4175	4375	4275
100% NPK	2490	1831	2161	5200	6206	5703
150% NPK	2513	1994	2253	5550	6288	5919
100% NPK-S	2313	1706	2009	4910	5750	5330
100% NPK+HW	2475	1775	2125	5050	6119	5584
100% NPK+Zn	2488	1813	2150	5165	6175	5670
100% NPK+FYM	2665	2275	2470	5800	6581	6191
LSD ($P \leq 0.05$)	325	240		696	728	
Interaction (TxY)	T = 179 ; Y = 80; TxY= 254			T = 449 ; Y = 201 ; TxY= 636		

3.2.2 Raipur (Rice-wheat)

Rice-wheat is predominant cropping system in IGP, central and northern parts of India. Yield data (Table 3.9) revealed increase in productivity of both rice and wheat with concomitant increase in nutrients (NPK) doses from 50% to 150% but increase in yield is due to N only. It is because on application of NP, the yield was at par with 100% NPK that indicated increase in utilization efficiency of P and K on application of N. There was significant response to application of plant nutrients over control. Highest grain yield was recorded with 150% NPK level .It was at par with 100% NPK + FYM treatment, while the lowest yield was recorded in control plot .The yield level of 100% NPK and 100% NP were at par. It showed that K is sufficient in soil and showed no response to potassium application. Whereas yield of 100% N was significantly lower as compared to 100% NP treatment this showed the importance and essentiality of phosphatic fertilizer in Vertisol. It is interesting to note rice yield at par with 150% NPK and better than 100% NPK and in

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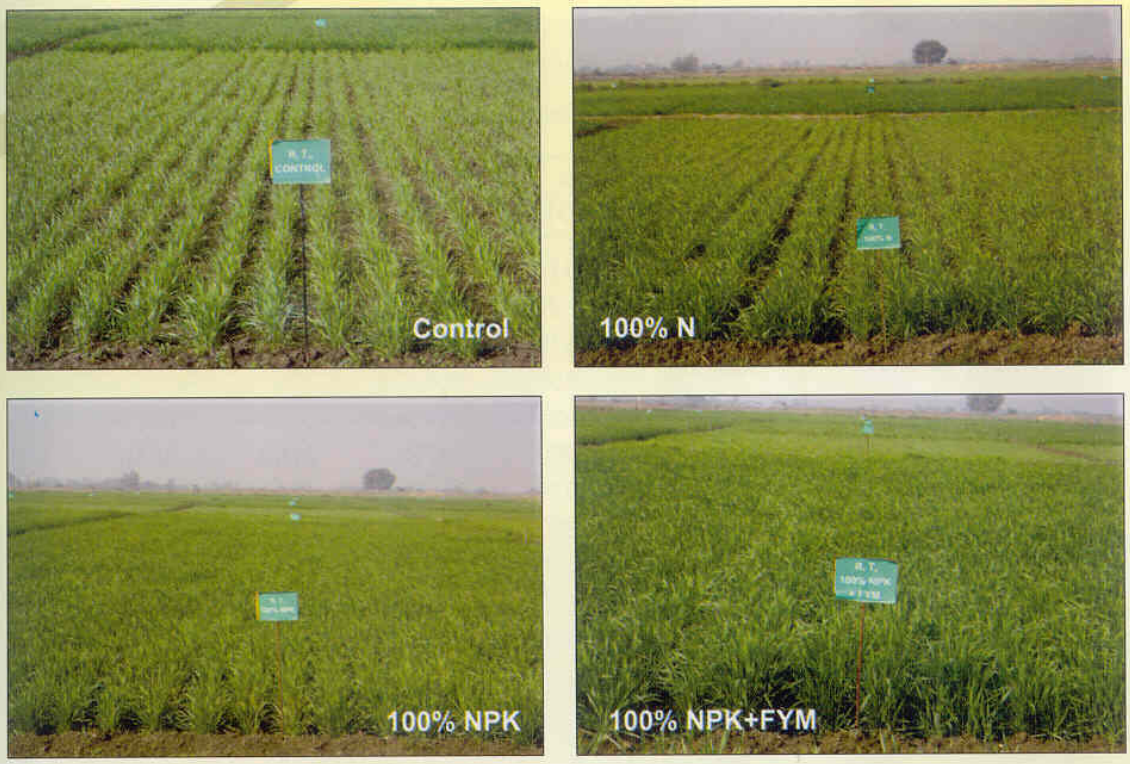

Plate 3.3 Impact of imbalance nutrient application on growth of wheat at Jabalpur

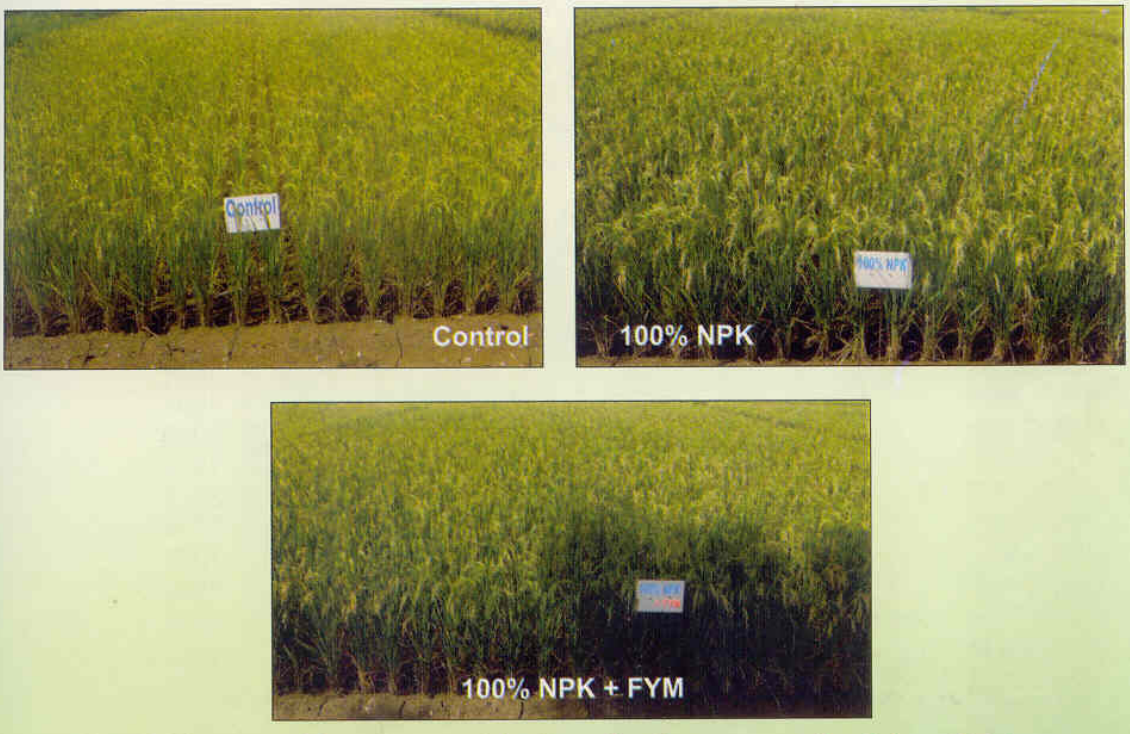

Plate 3.4 Impact of long term nutrient application on growth of rice at Raipur

situ green manure with 50% NPK. This has resulted in saving of good amount of fertilizer. However, residual effect of green manure was not poor with NPK in wheat but was more than 50% NPK.

Table 3.9 Yield of rice and wheat (kg ha^{-1}) at IGKV Raipur (AICRP LTFE)

Treatments	Rice			Wheat		
	2010	2011	Mean	2010-11	2011-12	Mean
Control	2585	2615	2600	1175	1280	1228
50% NPK	3840	4720	4280	1840	1970	1905
100% NPK	4543	5670	5107	2770	2960	2865
150% NPK	5055	6255	5655	3025	3415	3220
100% NPK+Zn	4545	5595	5070	2887	2938	2912
100% NP	4565	5580	5073	2753	3010	2882
100% N	3740	4010	3875	1760	1803	1782
100% NPK+FYM	4955	5950	5453	2925	3085	3005
50% NPK+BGA	3738	4835	4287	1988	2290	2139
50% NPK+GM	4518	6255	5387	2136	2410	2273
LSD (*P*≤0.05)	317	649	483	400	593	497

3.2.3 **Parbhani** (Soybean-safflower)

Yield data of soybean and safflower (Table 3.10) indicated a very good response of these crops to applied phosphorus. However, response to K and Zn was not observed so far. Evern absence of S in fertilizer schedule also did not have any adverse effect on productivity of both the crops. Application of FYM alone (10 t ha^{-1}) in both the crops could not keep the pace with the productivity obtained with application of 50% NPK. Like other places here also application of FYM over and above NPK resulted in highest productivity of both the crops which was at par with the yield obtained at 150% NPK.

Table 3.10 Effect of manures and fertilizers on grain and straw yield (kg ha^{-1}) of soybean, safflower (Means 2010-11 & 2011-12)

Treatments	Soybean	Safflower
50% NPK	2708	1664
100% NPK	3047	1994
150% NPK	3336	2220
100% NPK+HW	3166	1942
100% NPK + Zn,	3270	2128
100% NP	2987	1788
100% N	1259	1275
100% NPK + FYM	3356	2239
100% NPK – Sulphur	2972	1732
FYM @ 10 t /ha.	2342	1434
Control	1147	1198
LSD (*P*≤0.05)	313	284

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Plate 3.5 Impact of balance and integrated nutrient management on growth of safflower at Parbhani

3.2.4 Akola (Sorghum-wheat)

Perusal of data (Table 3.11) on grain yield of sorghum revealed that both sorghum and wheat responded to applied N, P, K and S significantly. Substitution of 25% N through FYM in NPK treatment resulted in yield (2697 kg ha^{-1}) of sorghum which is significantly lower than the yield recorded in 100% NPK. Application of 10 t FYM alone yield almost equal to 100% N alone. So one thing in clear 20 t FYM (10 t in kharif and 10 t in rabi) is not sufficient to get respectable yield. Application of 150% NPK certainly yielded greater than 100% NPK but was found significantly less than 100% NPK+FYM. The same is true with wheat yield. It means supply of organic manure (5 t ha^{-1} over and above 100% NPK is good option than to supply of 50% NPK.

Table 3.11 Average yield of sorghum and wheat at Akola (Average of 2010-11 & 2011-12)

Treatments	Sorghum	Wheat
50% NPK	2105	1363
100% NPK	3095	2188
150% NPK	4090	2632
100% NPK S free	2829	1782
100% NPK + Zn @ 2.5 kg ha^{-1}	3449	2357
100% NP	2463	982
100% N	1620	651
100% NPK + FYM @ 5 t ha^{-1}	4488	2813
100% NPK + 37.5 kg S ha^{-1}	3464	2382
FYM @ 10 t ha^{-1}	1774	744
75% NPK + 25 % N through FYM	2697	1469
Control	237	44
LSD ($P \leq 0.05$)	478	120

3.2.5 Junagadh (Groundnut-Wheat)

Data on pod yield of groundnut and grain yield of wheat (Table 3.12) revealed no response of ground nut to applied P and S, whereas response to these nutrients (applied P and S) was recorded in wheat. Poor yield of ground nut is the probable reason for not responding to applied nutrient. It is interesting to note that in spite of being Vertisol the crop responded to applied K. Yield obtained on application of NPK as general dose and through STCR recommendation are almost equal. Data also indicated very negligible effect of rhizobium and phosphate soubulising microorganisms on yield of ground nut pod. Pod yield of ground nut and wheat grain yield on application of 25 t FYM was more or less similar to that of obtained on application of 50% NPK+10 t FYM. We can say that till date we don't have any additional effect of organic manure.

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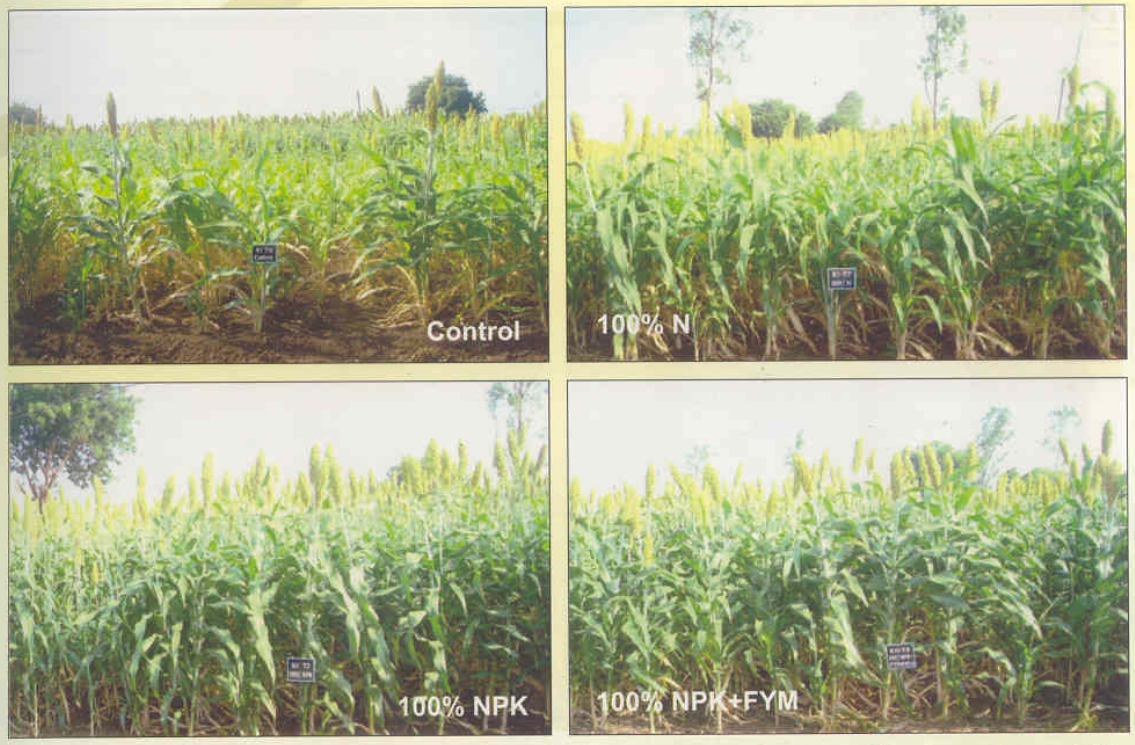


Plate 3.6 Impact of balance and integrated nutrient management on growth of sorghum at Akola

Plate 3.7 Impact of balance and integrated nutrient management on growth of groundnut at Junagadh

Table 3.12 Mean yield (kg ha^{-1}) of groundnut (*Kharif*-2011) and wheat (*Rabi* 2011-12)

Treatments	Groundnut (pod)	Wheat
50% NPK	300	2254
100% NPK	305	2872
150% NPK	337	2765
100% NPK+ Zn*	319	2700
100% NPK as per soil test	317	2783
100% NP	194	2562
100% N	174	1670
50% NPK+10 t ha^{-1} FYM	350	3537
FYM 25 t ha^{-1} (10 +15)	321	3204
50% NPK + Rhizobium + PSM	307	2662
100% NPK (P as SSP)	273	2830
Control	279	1829
LSD (*P*≤0.05)	57	349

*Applied once in three years during Kharif

3.3 Alfisols

3.3.1 Bangalore (Finger millet-maize)

The demand of finger millet in the market is gaining momentum due to inclusion in the preparation of balance food items otherwise it was a poor man's crop. Yield data (Table 3.13) demonstrated a very good example that the integrated nutrient is the key for sustainable productivity. Finger millet did not show any response to applied N and P until K is not supplied. In spite of acidic nature of soil, finger millet did not respond to lime because it is well suited for acid soils. However, residual effect of lime was recorded in maize yield. In Alfisol continuous absence of S resulted in decline in yield of maize only, while finger millet grew well at the same level of sulfur. From the results it is concluded that balanced nutrition is essential to realize the potential yield in Alfisols at Banglore. Continuous use of FYM over a long period may substitute lime in these acid soils.

Table 3.13 Effect of long term fertilizer and manure application on grain yield (kg ha^{-1}) of finger millet and maize at GKVK Bangalore (AICRP LTFE)

Treatments	Fingermillet			Hybrid maize		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean
50% NPK	3353	1408	2381	4284	3983	4134
100% NPK	4223	2165	3194	6104	4767	5436
150% NPK	4807	3082	3945	6439	5786	6113
100% NPK+HW	4353	2474	3414	6106	5484	5795
100% NPK+lime	4023	2263	3143	5773	4664	5219
100% NP	789	903	846	1807	1254	1531
100% N	656	761	708	1292	1094	1193
100% NPK+FYM	4540	3021	3781	6364	6060	6212
100% NPK (S-free)	4438	2532	3485	6163	3520	4842
100% NPK+FYM+lime	4823	2886	3855	6854	5522	6188
Control	676	743	710	1387	907	1147
LSD (*P*≤0.05)	368	554	-	865	895	-

Plate 3.8 Continuous (A) imbalance nutrient application led to (B) deficiency of potassium and (C) sulphur in maize compared to (D) balance nutrition at Bangalore

late 3.9 Application of zinc and FYM on growth of rice and wheat at Pantnagar

3.3.2 Palampur (Maize-wheat)

Yield data (Table 3.14) revealed that application of alone N resulted in adverse impact on productivity of both maize and wheat crops. At present yields of both these crops are zero. It is because of absence of P and K continuously over forty years. Big jump in productivity of both the crops on application of P and K confirms the above statement. Data clearly demonstrated that use of N alone should be avoided and should be applied along with P and K to get the good yield. Soils of Palampur are acidic in nature so lime is recommended. Application of lime resulted increase in productivity of both the crops but was comparatively less effective than FYM. It indicates that farmer can get better yield on application of FYM. It could be due to additional supply of nutrient and moderation effect of FYM, whereas lime has got only moderation effect and does not supply nutrients. Sulfur is another crucial nutrient to sustain the productivity. Invariably in Alfisol, hidden hunger of S is recorded which resulted decline in yield. So to get the potential yield of a crop, one must ensure supply of S.

Table 3.14 Long-term effect of fertilizers and amendments on yield (kg ha^{-1}) of maize and wheat at Palampur (Mean 2010 - 2012)

Treatment	Maize		Wheat	
	2010	2011	2010-11	2011-12
50% NPK	2508	3150	1417	1717
100% NPK	3989	4111	2063	2041
150% NPK	3899	3726	1879	1909
100% NPK+HW	4351	4476	2546	2367
100% NPK+ Zn	3797	4211	2146	2175
100% NP	2288	2233	1333	1258
100% N	0.0	0.0	0.0	0.0
100% NPK+FYM	5565	5787	3478	3284
100% NPK(-S)	1415	1666	1042	1308
100% NPK+ Lime	5028	5498	3271	3116
Control	472	605	792	725
LSD ($P \leq 0.05$)	394	615	407	294

Due to build up in available P, the optimal and super optimal dose of P has been reduced by 50% from *Kharif* 2011. T_1 has been changed from 50% NPK to 50% NPK FYM (5t/ha) since 2012.

3.3.3 Ranchi (Soybean-wheat)

Data (Table 3.15) revealed that application of N had adverse effect on productivity of both soybean and wheat. Integration of P with N resulted increase in yield of soybean to a very low magnitude, however, in wheat, very big jump (20-30 q ha^{-1}) in yield was noted. This is due to non-availability of K because of shallow root soybean system whereas wheat root goes down as low as 1 m and absorb K from lower layer. Increase in soybean yield on application of K support our statement. Incorporation of both FYM and lime resulted in increase in yield of both the crops but magnitude of increase was found to be more in case of FYM compared to lime. This is again due to limited supply of P and K in case of lime. Whereas FYM not only moderates the soil conditions but also adds P and K in large quantity.

In addition to P and K, S is also limited and restricted the yield of both the crops. At Ranchi, in one of the treatment N_2 is supplied through NH_4SO_4 which also had not supported to sustainability rather altected advesly.

Table 3.15 Effect of continuous use of fertilizer, manure, and lime on grain yield (kg ha^{-1}) and average (1973-2011) of crops

Treatments	Soybean			Wheat		
	2010-11	2011-12	Average (40 yrs)	2010-11	2011-12	Average (40 yrs)
50% NPK	1453	1569	1291	2030	2220	2030
100% NPK	1808	1830	1567	3020	3640	2800
150% NPK	1935	1932	1548	3070	3670	2870
100% NPK+HW	1763	1726	1565	2850	3670	2860
100% NPK + Lime	2301	2019	1828	3140	4270	3160
100% NP	724	770	863	2890	3510	2490
100% N	593	237	296	510	660	420
100% NPK + FYM	2348	2251	1911	3320	4330	3340
100% N (S) PK	1395	1669	692	2240	3260	1810
Control	412	409	579	340	410	720
LSD ($P \leq 0.05$)	229	203	-	410	530	-
CV (%)	10.69	9.72	-	12.1	12.3	-

3.3.4 Pattambi (Rice-rice)

A yield data (Table 3.16) revealed that application of N, P and K resulted increase in yield of both rice (kharif and rabi). The magnitude of increase in yield was more during rabi. Probably due to better yield during rabi as a result of more sunshine hours. In spite of Alfisol, there was no effect of lime on productivity of any crop. This is due to submergence of soil during whole rice growing period in both seasons. *In situ* green manuring resulted increase in yield compared to NPK and significant residual effect of green manure was also observed on rabi rice. Incorporation of FYM over and above NPK resulted in maximum production even better than green manuring. More productions on application of FYM is due to additional supply of nutrients (N, P and K). Soils are inadequate in supply of P and K which is supplemented through FYM. Data further revealed that application of 5 t

FYM along with 50% NPK resulted in almost equal yield obtained in the plot that received 100% NPK which means 50% saving in chemical fertilizer can be made. Superiority of FYM over green manuring is due to additional supply of P and K. Even though green manure also supplies P and K on decomposition which were absorbed by green manure from soil only. Thus, only N and green biomass were supplied. But in long run green manure would help in built up of SOC.

Table 3.16 Average grain and straw yields (kg ha^{-1}) of rice (kharif and rabi) at Pattambi

	2010-11		2011-12	
Treatments	Kharif	Rabi	Kharif	Rabi
50% NPK	2854	3091	2062	2801
100% NPK	2879	3289	2549	3114
150% NPK	2941	3448	2750	3227
100% NPK +Lime)	2841	3287	2784	3151
100% NPK+Cu	2874	3126	2685	3026
100% NP	2549	2994	2167	2700
100% N	2453	2470	1750	1955
100% NPK + FYM	3572	3853	3333	4069
50% NPK + FYM	3409	3416	2967	3669
100% NPK+GM	3122	3618	3167	3817
50% NPK +GM	2895	3171	2833	3474
Control	2062	2072	1661	1937
LSD ($P \leq 0.05$)	513.3	545.8	94.43	104.6

3.4 Mollisols

3.4.1 Pantnagar (Rice-wheat)

The data pertaining to the grain yield of rice and wheat (Table 3.17) clearly showed that in control, grain yields of both the crops were lowest in both the years while all other treatments produced significantly higher grain yields as compared to control. Application of 50% NPK along with Zn gave significantly lesser grain than 100% NPK+Zn and better than 100% NPK and 150% NPK with out Zn. Increase in productivity of both rice and wheat on application Zn demonstrate that to sustain the productivity Zn in essential. Both the crops responded to applied fertilizer. Thus, an application of S and Zn is essential in Mollisols of Pantnagar to sustain the productivity of rice-wheat in addition to N and P.

Table 3.17. Effect of long term fertilization on yield (kg ha^{-1}) of rice and wheat on Mollisols at Pantnagar

. Treatment	2010-11		2011-12		Total	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
50% NPK+Zn	3820	3190	3930	3250	3875	3220
100% NPK	3733	3461	3725	3400	3729	3430
150% NPK	3643	3595	3505	3300	3574	3447
100% NPK+HW+Zn	4712	3855	4800	3933	4756	3894
100% NPK +Zn	5030	4212	5180	4040	5105	4126
100% NP+Zn	4562	3687	4400	3200	4481	3443
100% N+Zn	3945	3223	3760	3300	3852	3261
100% NPK+FYM	5260	4587	5170	4934	5215	4760
100% NPK(-S)+Zn	4460	3577	4570	3620	4515	3598
Control	1525	1335	1250	1010	1387	1172
LSD ($P \leq 0.05$)	786	501	--	--	--	--

4. SOIL HEALTH

4.1 Soil Chemical Properties

Use of chemicals and soil amendments leave the impact on soil health. However, good health of soil is essential to sustain the productivity. Impact of fertilizer and soil amendment is given hereunder.

4.1.1 Soil pH

In general, application of fertilizer resulted decline in soil pH (Table 4.1) irrespective of treatment and soil except in few cases. The effect was more pronounced in Alfisols. Application of urea without phosphate and potassic fertilizer resulted in more decline in soil pH in Alfisols (Bangalore, Ranchi and Palampur). However, application of lime did not allow changing the soil pH. Effect of fertilizer was not seen on soil reaction in Vertisols, however in Inceptisols of Ludhiana little decline in soil pH was reported. Decline in soil pH is due to production of H^+ ions during conversion of NH_4 into NO_2 and NO_3. The larger change in Alfisols is because of dominance Al ion in the system.

Table 4.1 Effect of nutrient management on soil pH at AICRP LTFE centres (2012)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK + Zn	NPK+ Lime	NPK+ FYM
Akola	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.1
Bangalore	6.2	6.0	5.0	4.8	5.6	5.1	-	6.0	5.9
Bhubaneshwar	5.8	5.4	5.3	5.4	5.4	5.3	5.3	5.3	5.9
Jabalpur	7.6	7.6	7.5	7.6	7.6	7.6	7.6		7.6
Jagtial	8.2	8.1	8.2	8.2	8.3	8.3	8.2	8.2	8.1
Junagadh	8.2	8.0	7.8	7.9	7.9	7.9			
Ludhiana	8.0	7.6	7.4	7.4	7.3	7.1	7.2	-	7.2
Palampur	5.8	5.6	4.6	5.3	5.1	5.0	5.0	6.1	5.2
Parbhani	8.1	8.1	8.1	8.1	8.1	8.2	8.2	-	8.1
Pattambi	8.0	5.5	5.7	5.8	5.3	5.5			5.4
Ranchi	5.3	5.1	3.9	4.5	4.8	4.5	-	6.1	4.8
Udaipur	8.2	8.3	8.2	8.2	8.2	8.3	8.2	8.2	8.2

4.1.2 Electrical Conductivity

As far as electrical conductivity is concerned, none of the centre reported increase in EC except at Junagarh and Udaipur. Both the centers are in semiarid region and rainfall is less which encourage accumulation of salt on surface layer during summer season when soil samples were taken. Thus, such increase is temporary and attains normal values during rainy season.

4.1.3 Soil Organic Carbon (SOC)

Amongst soil constituents, organic carbon is most important which governs soil health and availability of nutrients to plant. Perusal of data (Table 4.3) revealed that application of fertilizer improved SOC content of soils at majority of sites except at Ranchi, Pantnagar and Barrackpore. Increase in SOC content was found to be more in the treatment that received fertilizer nutrient in balanced way. Increase in SOC is related to productivity of a treatment. More the productivity more

would be soil organic carbon (SOC) because of incorporation of larger amount of biomass of roots, stubble and leaves. However, an imbalanced use of nutrient decline in SOC was reported which is obviously due to incorporation of residual biomass in less quantity due to poor yield. Decline in SOC at Barrackpore and Pantnagar even in spite on balance application is due to increase in oxidation of soil carbon on cultural intervention and fertilizer application. The soils of both the places were under forest and SOC was under quasi equilibrium. However, after few years (10 years) further decline was not observed. At Pantnagar in some of the treatments sign of improvement in SOC was recorded in last few years. At Ranchi soils are porus having high infiltration rate. Climate is hot and humid both encourage the loss of carbon through percolation and oxidation, respectively.

Table 4.2 Effect of nutrient management on EC (dS m^{-1}) (2012)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Akola	0.30	0.23	0.31	0.32	0.33	0.36	0.33	0.33	0.35
Bangalore	0.06	0.05	0.16	0.15	0.11	0.15	-	0.12	0.14
Bhubaneshwar	0.12	0.02	0.02	0.03	0.04	0.07	0.07	0.07	0.06
Jabalpur	0.18	0.13	0.14	0.18	0.18	0.19	0.16	0.16	0.19
Jagtial	0.47	0.31	0.28	0.24	0.26	0.30	0.26	0.26	0.24
Junagadh	0.18	0.32	0.36	0.39	0.36	0.40			
Ludhiana		0.18	0.17	0.18	0.18	0.18	0.18	-	0.19
Palampur		0.03	0.05	0.04	0.05	0.05	0.05	0.05	0.05
Parbhani	0.22	0.22	0.23	0.24	0.24	0.25	0.25	0.25	0.24
Udaipur	0.48	0.82	0.82	0.88	0.84		0.84	0.84	0.85

Table 4.3 Effect of nutrient management on SOC (g kg^{-1}) at AICRP-LTFE (2012)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Akola	4.6	2.9	4.5	4.9	5.3	6.6	6.5	6.5	7.85
Bangalore	4.6	5.3	5.0	4.8	5.2	5.5	-	5.1	5.8
Barrackpore		5.5	5.9	6.4	6.3	6.4	6.8	6.8	8.2
Bhubaneshwar	4.3	3.2	4.4	4.5	4.5	4.8	4.8	4.8	5.8
Coimbatore	3.0	3.7	4.4	5.0	5.3	5.6	5.3	-	6.3
Jabalpur	5.7	4.2	5.3	6.7	7.7	8.7	7.7	-	9.9
Jagtial	7.9	8.1	8.0	8.2	8.4	8.5	8.7	-	10.8
Junagadh		6.2	6.7	7.8	7.7	8.4			
Ludhiana	2.2	2.9	3.9	3.1	4.3	4.3	3.3	-	5.4
Palampur	7.9	8.2	9.0	9.7	10.0	10.6	9.9	10.6	13.6
Parbhani	5.5	5.7	5.6	5.9	6.3	6.6	6.3	6.3	6.7
Pattambi		11.9	13.7	14.1	14.5	15.5	0.0	0.0	17.8
Raipur	6.2	5.1	5.2	6.1	5.9	6.0	6.2	6.2	6.8
Ranchi	5.0	3.0	4.0	4.0	4.0	4.0	-	4.0	5.0
Udaipur	6.8	5.3	6.4	6.9	7.5	7.5	7.6	7.6	9.0

4.2 Nutrient Status

4.2.1 Available N

Soil nitrogen (N) is most dynamic in nature and depends on soil organic carbon content. In general, decline in available N content (Table 4.4) was noted in soils which are not able to maintain SOC like Mollisols of Pantnagar and Alfisols of Ranchi, Palampur. In contrary to these soils, increase in available N was noted in soils of Jabalpur, Ludhiana, Parbhani, Junagadh, Akola. Inceptisols group of soil like Udaipur and Barrackpore which also could not maintain SOC. So, increase in nitrogen in soil is dependent on SOC and clay content of soil. Though Vertisols are rich in SOC and clay content as well compared to Inceptisols or Alfisols but available content of in these soils is relatively low because of high protection of carbon due to clay which is not exposed to reaction very easily.

Table 4.4 Available soil N (kg ha^{-1}) under different nutrient management options at AICPR-LTFE (2012)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Bangalore	257.0	174.2	194.2	200.3	196.2	236.0	-	185.8	189.9
Coimbatore		141.0	179.0	184.0	183.0	193.0	188.0	-	202.0
Ranchi	295.0	220.7	229.9	199.4	201.1	231.3	-	201.2	223.9
Ludhiana	86.8	100.4	110.8	113.9	125.4	133.8	130.7	130.7	142.2
Pantnagar	392.0	148.0	220.0	230.7	237.3	332.0	211.6	211.6	312.6
Bhubaneshwar	187.0	130.0	200.0	196.0	202.0	218.0	200.0	200.0	230.0
Parbhani	216.0	192.9	228.7	229.1	230.6	258.5	235.1	235.1	271.8
Jabalpur	193.0	182.7	207.9	259.0	283.5	319.7	274.1	274.1	342.8
Palampur	736.0	255.4	289.0	297.9	302.4	320.3	318.1	306.9	333.8
Junagadh	193.0	169	182.0	187.0	191.0	216.0			
Udaipur	360.0	225	272.0	291.0	342.0	367.0	346.0	-	463.0
Raipur	236.0	180	216.9	203.1	222.7	213.3	216.4	-	235.6
Jagtial	108.0	198	184.0	191.0	195.0	219.0	199.0	-	217.0
Akola	120.0	133.6	217.5	233.0	245.4	288.9	264.1	-	295.2
Barrackpore		263	290	282	298	310	298	-	314

4.2.2 Available Phosphorus

Phosphorus in soil is most stable nutrient. Data on available P content (Table 4.5) clearly revealed that application of P and phosphatic fertilizer resulted increase in available P irrespective of soils. However, increase was more in Alfisol and Inceptisol group of soil compared to Vertisol. Increase in available P on application is due to application of P in quantity larger than uptake and decline in P status in absence of phosphatic fertilizer is obviously due to no phosphorus application.

Less build up of available P in Vertisols is due to very high fixation capacity of Vertisols compared to Inceptisols. In some of the Alfisols like Pattambi and Bhubneshwar built up in P status is low which is due to fixation of P as aluminum phosphate and sites are relatively new and the sites are not saturated over the years. At Jabalpur, Akola, Parbhani and Coimbatore increase in P status is relatively less because of fixation of applied P as calcium phosphate. These soils are very rich in Ca content because of their basaltic material. Application of FYM and lime irrespective of soil resulted

increase in soil P status. This is due to addition of additional amount of P through FYM whereas application of lime increases the pH of soil which enhance the availability of P in soil.

Table 4.5 Effect of nutrient management options on available soil P status (kg ha^{-1}) at AICRP-LTFE locations (2012)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Bangalore	34.3	21.8	29.5	100.2	83.8	117.6	-	87.2	105.2
Coimbatore		6.4	11.4	17.9	20.4	22.8	20.0	-	24.3
Ranchi	12.0	8.3	9.6	151.7	153.0	407.0	-	104.1	282.3
Ludhiana	9.0	15.3	18.4	72.3	84.2	91.6	86.7	-	98.7
Pantnagar	18.0	6.8	7.9	18.6	18.8	32.5	18.9	-	29.0
Palampur	12.1	17.7	20.6	164.0	107.1	219.5	156.4	106.8	179.4
Bhubaneshwar	19.1	5.9	9.4	11.4	10.7	12.9	9.9	9.9	21.8
Parbhani	16.0	14.9	15.8	18.6	18.5	19.4	18.4	-	20.8
Junagadh	7.6	17.1	17.1	20.1	23.4	25.3			
Udaipur	22.4	15.8	15.2	23.5	23.5	28.6	23.2	-	26.9
Raipur	16.0	9.6	8.6	27.3	28.2	29.1	28.2	-	29.3
Jagtial	19.6	20.1	19.8	29.2	31.3	42.9	31.4	-	40.3
Pattambi		9.1	8.9	10.5	10.4	10.8	-	10.5	12.6
Akola	8.4	4.5	9.1	13.5	14.3	16.6	15.5	-	18.5
Jabalpur	7.6	9.8	11.8	29.2	33.1	14.2	32.2	-	43.3
Barrackpore		19.9	17.8	66.9	77.2	88.4	65.2	-	82.3

4.2.3 Available Potassium

Potassium though is not a constituent of plant but it is required in large quantity to perform various physiological functions. Data (Table 4.6) indicated reduction in available content of soil even on application of K in Vertisols except in NPK+FYM and 150% NPK. However, in Inceptisol (Delhi, Ludhiana) and Mollisol of Pantnagar increase in available status of K was observed in almost all treatments. It is strange to note that the soil (Alfisols) which are inherently low in available K are maintaining K status. Decline in available K status in Vertisols is obviously due to larger uptake than applied. However, increase in available K in Inceptisols and maintaining of K status in Alfisols is due to addition of K through irrigation water and deposition through silt on application of water through canal. In spite of low K, crops grown in Alfisol during rabi season did not show any response to applied K which support the statement.

Table 4.6 Effect of nutrient management options on available soil K status (kg ha^{-1}) at AICRP-LTFE locations (2012)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Akola	155.0	179	227.0	241.0	372.0	448.0	375.0	375.0	468.0
Bangalore	123.1	70.9	54.7	53.8	148.4	203.5	140.1	140.1	169.2
Barrackpore		140.0	114.0	136.0	187.0	191.0	184.0	184.0	202.0
Bhubaneshwar	43.4	64.6	70.7	66.8	100.4	115.8	95.7	95.7	111.0
Coimbatore	907.0	487.0	545.0	545.0	668.0	711.0	641.0	641.0	761.0
Jabalpur	370.0	182.0	194.6	231.6	271.7	295.3	248.4	248.4	336.2
Jagtial	364.0	318	288.0	322.0	325.0	352.0	316.0	316.0	328.0

Junagadh	370.0	173	158.0	159.0	222.0	241.0			
Ludhiana	88.0	76.9	78.4	84.7	108.3	121.3	113.9	113.9	122.1
Palampur	194.2	129.9	139.3	133.7	172.9	192.0	156.8	178.5	196.4
Pantnagar	125.0	92.7	89.3	91.3	129.3	142.0	123.3	123.3	145.3
Parbhani	766.0	741.0	760.9	776.2	782.3	814.8	783.5	783.5	817.1
Pattambi	358.0	60.7	65.4	63.0	84.6	91.1			80.1
Raipur	364.0	346.5	327.3	374.7	405.1	418.9	391.6	391.6	417.1
Ranchi	157.0	93.7	70.9	69.9	103.5	119.1	96.5	96.5	133.0
Udaipur	671.0	480	484.0	489.0	548.0	592.0	576.0	576.0	582.0

4.2.4 Available Sulphur

Perusal (**Table** 4.7) revealed that application of SSP as a source of P also adds S by default that resulted increase in sulphur status of soil. However, absence of S in fertilizer schedule maintains the sulphur status more or less similar to initial. Probably S content in irrigation water is responsible for maintaining the crop productivity. The S status was found to be relatively more in Alfisols compared to Vertisols and Inceptisol which could be due to high S fixation capacity of later two soils because of higher Ca content.

Table 4.7 Effect of nutrient management options on available soil sulphur status (kg ha^{-1}) at AICRP-LTFE locations (2012)

Location	Initial	Control	N	NP	NPK(-S)	NPK	150% NPK	NPK+ Lime / Zn	NPK+ FYM
Bangalore	20.30	61.51	88.28	88.73	68.17	103.04	109.18	98.78	117.92
Palampur	13.4	14.1	22.8	27.3	17.2	29.6	35.4	31.1	29.6
Bhubaneshwar	22.20	17.63	32.37	32.57		35.53	40.58	38.77	45.51
Parbhani	30.50	23.98	22.83	23.90	23.90	25.45	28.02	27.10	29.10
Pantnagar		10.23	15.66	14.06	27.66	20.16	22.26	20.56	17.96
Junagadh		22.1	23.30	24.10		23.90	26.90		
Udaipur	22.40	13.72	13.43	14.47	22.56	16.02	17.38	16.99	17.47
Jagtial	14.00	22.2	24.80	26.60	22.6	28.50	35.00	30.10	34.20
Akola	12.00	8.9	11.48	19.55	11.05	22.03	26.18	22.53	29.90
Jabalpur	16.00	10.98	11.75	30.55	14.35	34.24	41.63	32.53	44.47

4.2.5 Available Micronutrient Cations (DTPA Extractable Micronutrient)

4.2.5.1 Barrackpore

The DTPA extractable Cu, Fe, and Mn decreased compared to the initial values (Table 4.8). After 41 years of continuous cropping and manuring, depletion of Mn was highest, and Cu was the least affected. Result showed that in 150%NPK and NPK + FYM treated plots, the reduction of DTPA extractable Fe was comparatively less. The reduction was comparatively less in 150%NPK treated plot and maximum in control. This might be due to the fact that fertilizers like SSP contains significant amounts of Fe as contaminant and incorporation of the same in the field might have helped in checking the diminishing trend of Fe in NPK and NPK + FYM treated plots. The DTPA extractable Mn was observed to be decreased by more than 80% in both NPK and control plots after 41 years of cultivation from the initial value of 60 ppm. The degree of decrease was less in FYM added soils. FYM being a modest source of Mn, might have compensated some amount of Mn.

Initial status of Mn, Fe and Cu were 60, 31 and 3.6 ppm respectively. Rice is one of the crops at Barrackpore which is grown under submerged condition. Under submerged condition Mn is reduced and gets leached down during rice growing season.

Table 4.8 DTPA extractable micronutrients (mg kg^{-1}) in Inceptisol of Barrackpore

	Cu		Fe		Mn	
Treatments	2010	2011	2010	2011	2010	2011
50% NPK	3.18	3.1	16.5	15.65	9.3	9
100% NPK	3.14	3.23	23.8	19.25	8.1	8.98
150% NPK	3.31	3.3	28.9	22.78	9.8	9.88
100% NP	3.31	3.3	22.8	19.08	9	8.98
100% N	3.01	3.15	16.3	15.13	8.9	8.9
100% NPK + FYM	3.52	3.5	22.3	22.08	10	10.15
Control	3.31	3.23	13	12.15	9.6	9.3
Initial	3.6		31		60	

4.2.5.2 Coimbatore

Continuous addition of inorganic fertilizers with or without FYM significantly influenced the status of micronutrients (Table 4.9). The DTPA extractable Cu and Fe were found to be deficient whereas Mn was found to be sufficient in all the treatments. In all the treatment Zn in found in sufficient range.

Table 4.9 DTPA extractable micronutrients (ppm) at TNAU Coimbatore

Treatments	Cu	Zn	Mn	Fe
50% NPK	0.62	1.09	3.69	1.56
100% NPK	0.64	1.11	4.52	1.54
150% NPK	0.59	1.44	4.47	1.45
100% NPK + HW	0.58	1.46	4.61	1.44
100% NPK + $ZnSO_4$	0.59	3.57	4.13	1.46
100% NP	0.58	1.07	4.78	1.4
100% N	0.59	0.99	4.67	1.38
100% NPK + FYM	0.58	1.48	4.54	1.43
100% NPK (-S)	0.59	1.11	4.18	1.5
Control	0.66	0.94	3.74	1.55
LSD ($P \leq 0.05$)	NS	0.92	NS	NS

4.2.5.3 Pantnagar

Available micronutrients (DTPA extractable Fe, Mn, Zn and Cu) status of soil in present study decreased after the harvest of 39th crops when their values were compared with initial status. The available micronutrients increased with the application of FYM alone or in combination with chemical fertilizers. The higher availability of micronutrients in soil on application of manures could be ascribed to mineralization of these nutrients from added manures. Chelating action of FYM during decomposition of organic manures increases the availability of micronutrient cations and also protects these cations from fixations. DTPA-Zn level in 100% NPK Zn and 100% NPK+ Zn +S treatments was significantly higher over control. This might be due to direct application of Zn in the soil. Simultaneously, it was followed by 100% NP+ Zn treatment in which Zn was applied @ 50 kg $ZnSO_4$ ha^{-1} when Zn dropped below its thresh hold value on soil test basis (<1.ppm).

Table 4.10 DTPA extractable micronutrients (ppm) at Pantnagar

Micronutrient	Initial	Control	100% N	100% NP	100% NPK	150% NPK	100% NPK+ HW	100% NPK+ Lime / Zn	100% NPK+ FYM
Zn	2.70	0.60	1.42	1.64	0.72	0.56	1.58	1.60	1.22
Cu	2.9	2.50	2.50	3.70	2.80	3.23	3.20	3.50	3.80
Fe	29.5	20.06	28.00	39.00	36.00	37.60	35.33	37.00	45.30

4.2.5.4 Bhubaneswar

Soil analysis (Table 4.11) revealed hidden hunger of Zn in plot received 100% N, 100% NP only whereas B status is low in all the treatments except the treatment received B. It indicates that Zn and B could be yield limiting nutrient at Bhubneshwar in near further.

Table 4.11 Effect of manurial treatments on available micronutrients of soil (2010-11)

.Treatments	Available Micronutrients (ppm)				
	Fe	Mn	Cu	Zn	B
50% NPK	60.81	49.02	0.82	0.61	0.30
100% NPK	57.32	17.89	0.38	0.65	0.46
150% NPK	74.61	17.19	0.66	0.32	0.28
100% NPK +Zn	65.93	22.17	0.79	0.98	0.23
100% NPK +FYM	87.17	28.24	0.55	0.44	0.37
100% NPK + Lime + FYM	93.86	29.18	0.95	0.60	0.58
100% NPK + B + Zn	65.24	32.10	0.79	1.06	0.99
100% NPK + S + Zn	47.40	20.58	0.88	1.10	0.32
100% N	39.47	60.89	0.81	0.38	0.25
100% NP	55.24	41.79	0.78	0.27	0.30
100% NPK + Lime	22.52	35.15	1.06	0.66	0.71
Control	42.13	22.88	0.95	0.48	0.23

4.2.5.6 Ludhiana

The data pertaining to micronutrient status (Table 4.12) revealed that availability of Zn significantly improved with balanced fertilization as compared to control. The maximum Zn content was recorded for 100%NPK+Zn treatment that was significantly higher than 100% NPK+FYM treated plot. However, the content of Zn was significantly higher in integrated treatment as compared to

application of various chemical fertilizers. Similarly, application of balanced fertilization significantly improved available Fe as compared to control and 100% N. The maximum Fe content was recorded in integrated fertilizer application, which was significantly higher than chemical fertilizer application. There was improvement in Mn with fertilization except 100%N treatment where it was significantly lower. The highest Mn content was observed in 100% NPK+FYM plot. The available Cu ranged from 0.36 mg kg^{-1} soil to 0.51 mg kg^{-1} soil with the minimum and maximum value in control and 100% NPK+FYM plot.

Table 4.12. Effect of fertilizer application on soil micronutrients status (mg kg^{-1}) (2011-12)

Treatment	Zn	Fe	Mn	Cu
50% NPK	1.28	8.45	8.7	0.48
100% NPK+W	1.26	8.63	7.7	0.50
150% NPK	1.30	12.64	12.4	0.45
100% NPK	1.55	10.38	9.5	0.37
100% NPK+Zn	3.43	11.05	8.8	0.49
100% NP	1.45	9.76	8.5	0.48
100% N	1.32	5.43	6.7	0.36
100% NPK+FYM	1.63	13.56	11.1	0.51
100% NPK(-S)	1.24	10.49	7.5	0.48
Control	1.05	5.16	7.8	0.36

4.2.5.7 Udaipur

Micronutrient analysis (Table 4.13) of soil indicated no hidden hunger of any micronutrient cations. Incorporation of FYM with and without NPK maintained greater amount of available micronutrient in soil. It is interesting to note that in spite of higher uptake/removal of micronutrient because of higher productivity in balance treatment maintain to higher amount of micronutrient compared to control or 100% N treatment. This is probably due to mobilization of micronutrients during decomposition of root biomass.

Table 4.13 Long-term effect of fertilizer manure and their combination on available micronutrients of the soil after fifteen years of maize-wheat cropping system

Treatment	Available Zn (mg kg^{-1})	Available Cu (mg kg^{-1})	Available Fe (mg kg^{-1})	Available Mn (mg kg^{-1})
Control	2.00	1.72	2.40	9.00
100% N	2.42	1.68	2.42	9.54
100% NP	2.72	1.96	2.52	9.60
100% NPK	2.80	2.00	2.65	9.66
100% NPK + Zn	3.85	2.10	2.80	9.92
100% NPK + S	4.25	2.20	3.12	10.96
100% NPK + Zn + S	2.65	2.22	3.04	10.32
150% NPK	2.85	1.85	2.74	9.42
100% NPK + FYM	3.20	2.44	3.20	13.00
100% NPK – FYM	3.25	2.58	3.12	12.90

FYM	3.32	2.48	3.50	13.80
100% NPK + Bio	2.72	1.80	2.98	11.10
LSD (*P*≤0.05)	0.14	0.13	0.17	0.14
Initial	3.76	3.12	2.52	17.4

4.2.5.8 Pattambi

Micronutrients status (Table 4.14) of Pattambi is far above their critical limits. Coppor status scems to be very high and may have toxicity under continuous submergence. On the contrary content of bases (Ca and Mg) is far less than the required. Low content of Ca and Mg is responsible for acidity in soil and therefore lime is recommended for better availability of nutrients. Application of lime and green manure resulted little improvement in status Ca, which could be temporary on the sites of organic matter.

Table 4.14 Long-term effect of fertilizer manure on available micronutrients (Kharif 2010)

Treatments	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Ca (meq/100g)	Mg (meq/100g)
50% NPK	102.9	1.95	8.29	9.96	1.27	1.20
100% NPK	87.7	1.80	8.49	9.34	1.50	1.42
150% NPK	94.1	1.67	8.91	10.8	1.09	1.10
100% NPK +Lime)	54.8	1.92	8.95	8.78	1.94	1.21
100% NPK	51.6	1.60	8.15	8.64	1.21	1.30
100% NP	64.1	1.51	9.59	8.90	1.18	1.47
100% N	95.9	1.82	9.83	8.28	1.19	1.35
100% NPK + FYM	73.9	2.16	10.22	11.1	1.90	1.52
50% NPK + FYM	95.3	1.87	10.85	11.5	1.55	1.48
100% NPK+GM	77.8	1.87	9.08	9.66	1.78	1.30
50% NPK +GM	59.9	1.85	9.78	9.42	1.45	1.24
Control	47.9	1.65	8.32	9.04	1.02	1.20

4.2.5.9 Ranchi

Data at Ranchi (Table 4.15) revealed that there is no problem as far as status of micronutrient cation is concerned. Status of all four cations was above the critical value irrespective of treatments.

Table 4.15 Effect of cropping and fertilization on micronutrient status of soil

Treatments	DTPA – Fe (ppm)	DTPA – Cu (ppm)	DTPA – Mn (ppm)	DTPA – Zn (ppm)
50% NPK	37.7	0.6	60.1	2.7
100% NPK	37.6	0.6	27.8	6.5
150% NPK	47.6	0.5	61.1	5.4
100% NPK+HW	25.8	0.5	60.0	4.9
100% NPK + Lime	15.9	0.4	34.4	5.8
100% NP	25.9	0.4	68.0	4.0

100% N	28.5	0.6	33.9	3.0
100% NPK + FYM	37.3	1.1	67.0	6.3
100% N (S) PK	28.9	0.8	28.0	6.5
Control	22.2	0.6	84.0	5.1
LSD (*P*≤0.05)	6.29	0.08	22.52	0.84

4.2.5.3 LTFE Centre

Available Zn: Amongst the micronutrients, Zn is most widely applied nutrient in Indian agricultural because of the deficiency and low content in soil. Data (Table 4.16) revealed that available status of Zn was more in Alfisols (Bangalore, Ranchi, Bhubneshwar and Palampur) than Inceptisols. This is because of higher solubility of Zn at low pH. Continuous absence of Zn in fertilizer schedule resulted decline in available status compared to initial. It is interesting to note that other than acid soils, Zn status found to be less in low yielded plots (Control, 100% N and 100% NP) compared to treatment like 100% NPK and 150% NPK. This is due to addition of larger rood biomass as a result of higher productivity which on decomposition mobilizes Zn in addition to in-built Zn in soil. At Pantnagar, however, less Zn in 100% NPK and 150% NPK treatment is due to that no application of Zn in these plots with the objective to study the response of Zn.

Table 4.16 Effect of cropping and fertilization on available Zn status (mg kg^{-1}) of soil at AICRP LTFE

Location	Initial	Control	100% N	100% NP	100% NPK	150% NPK	100% NPK+ HW	100% NPK+ Lime / Zn	100% NPK+ FYM
Bangalore	2.34	2.16	2.15	2.83	3.09	4.12	2.65	3.06	3.88
Jabalpur	0.33	0.28	0.42	0.52	0.53	0.56	0.58	1.27	0.90
Parbhani	0.98	0.85	0.78	70.00	0.74	0.79	0.81	1.43	1.00
Palampur	1.90	1.30	1.50	1.00	1.30	1.40	1.30	5.80	2.20
Akola		0.35	0.38	0.47	0.60	0.70		0.99	0.98

Available Cu: So far Cu has not been observed as a limiting nutrient at any of the experimental sites like Zn. Relatively larger values of available Cu were noted in plots received balanced nutrients (Table 4.17). It is due to mobilization of Cu from decomposed sites of root biomass and addition of Cu through residue biomass in larger amount compared to unbalanced treatment. The Cu was recorded in larger quantity in Alfisols compared to other soils. The reason for higher status is due to acidic nature of these soils.

Table 4.17 Effect of cropping and fertilization on available Cu (mg kg^{-1}) in soil under AICRP LTFE

Location	Initial	Control	100% N	100% NP	100% NPK	150% NPK	100%NPK+ HW	100% NPK+ Lime / Zn	100% NPK+ FYM
Bangalore	2.30	2.08	2.08	2.35	2.25	2.56	2.59	2.49	2.19
Jabalpur	0.11	1.25	1.27	1.54	1.58	1.68	1.55	1.51	1.77
Palampur	0.4	1.6	1.9	1.7	1.7	1.8	1.9	1.9	2.3
Akola		2.35	3.33	3.58	3.71	4.03		3.92	4.28

Available Fe: Like Cu, Fe in also not a problem in any of the sites of LTFE. Available Fe content was far above the critical value (Table 4.18) at these centres. Similar to Zn and Cu in case of Fe

also, larger Fe status was recorded in plot received nutrients on balanced form. The higher root activities are responsible for higher status of Fe.

Table 4.18 Effect of cropping and fertilization on available Fe (mg kg^{-1}) in soil under AICRP LTFE

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ HW	NPK+ Lime / Zn	NPK+ FYM
Bangalore	5.20	20.29	25.67	26.53	23.39	29.53	25.44	25.72	33.39
Jabalpur	2.47	14.05	17.57	18.28	19.59	24.37	19.88	20.35	29.48
Palampur	26.00	19.60	35.00	27.00	26.60	31.00	27.50	25.70	40.50
Junagarh	2.52	2.40	2.42	2.52	2.65	2.74		2.80	3.20
Akola		4.06	5.83	5.89	6.60	8.56		6.94	9.45

Available Mn: Like other micronutrient cations, very high content of Mn (Table 4.19) was recorded in Alfisols (Banglore and Jabalpur) in comparison to other soils. Again relatively larger content was noted in plots received nutrient in balanced and integrated farm. At Barackpore, sharp decline in Mn Content was noted. However, in Vertisols of Jabalpur decline in Mn status was noted in control and 100% N compared to initial status, whereas in other treatments improvement in Mn content was noted.

Table 4.19 Effect of cropping and fertilization on available Mn (mg kg^{-1}) in soil under AICRP LTFE

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ HW	NPK+ Lime / Zn	NPK+ FYM
Bangalore	108.40	49.84	53.61	53.25	53.12	60.01	54.83	57.13	58.09
Jabalpur	16.1	11.31	11.32	16.53	40.57	30.33	12.92	13.65	14.87
Palampur	24.30	20.60	30.40	35.00	23.90	24.60	28.90	33.60	34.70
Akola		3.66	5.38	6.37	6.55	8.26		6.67	9.02

Boron Status: Perusal of data on B status revealed that B content is far less than the critical value (Table 4.20) of B in soil. Both the soils are acidic and B could be a problem in sustaining the crop productivity.

Table 4.20 Effect of cropping and fertilization on available boron (mg kg^{-1}) in soil under AICRP LTFE

Location	Control	100% N	100% NP	100% NPK	150% NPK	100% NPK(-S)	100% NPK+ HW	100% NPK+ Lime / Zn	100% NPK+ FYM
Ranchi	0.15	0.32	0.27	0.23	0.28	0.29	0.18	0.18	0.28
Bhubaneswar	0.23	0.25	0.30	0.46	0.28	-	-	0.23	0.37

4.3 Heavy Metals Contamination

4.3.1 Bhubaneshwar

The Cd content measured very low values which varied from 0 to 0.0027 ppm and Cr content varied from 0.064 to 0.269 ppm. The Pb content varied from 0.606 to 1.706 ppm in different treatments. The concentration of different heavy metals found in soil were below the critical limits of their toxicity in plants.

Table 4.21 Heavy metal (ppm) accumulation of post *rabi* soil samples'2010-11

Treatment	Cd	Cr	Pb
50 % NPK	0.0010	0.209	1.039
100 % NPK	0.0000	0.186	1.282
150% NPK	0.0000	0.128	0.779
100 % NPK +Zn	0.0011	0.088	1.108
100 % NPK +FYM	0.0000	0.114	1.024
100 % NPK + Lime + FYM	0.0024	0.269	1.184
100 % NPK + B + Zn	0.0025	0.203	0.883
100 % NPK + S + Zn	0.0000	0.184	0.798
100 % N	0.0010	0.194	1.333
100 % NP	0.0010	0.200	0.606
100 % NPK + Lime	0.0013	0.208	1.040
Control	0.0012	0.192	0.925

4.4 Soil Physical Properties

4.4.1 Jabalpur

4.4.1.1 Soil Aggregation

The findings showed that there was a positive effect of balanced nutrition under intensive cropping on soil aggregation (Table 4.22). In general, bigger size aggregate per cent increased in all the treatments at the expense of smaller size aggregates. The maximum increase was noted in treatments with 100% NPK + FYM and 150% NPK. It means smaller size aggregate united together and formed bigger size aggregate. This is due to addition larger amount of SOC as a result of higher productivity.

Table 4.22 Effect of different treatments on soil aggregation of surface soil

Treatments	Aggregate size (%)				
	0.25-0.10 (mm)	0.50-0.25 (mm)	1.0-0.50 (mm)	2.0-1.0 (mm)	> 2.0 (mm)
50% NPK	11.51	30.34	25.05	14.05	3.03
100% NPK	7.44	31.56	30.30	12.51	3.92
150% NPK	5.69	27.54	31.85	16.64	5.22
100% NPK + HW	6.70	29.18	30.60	15.22	4.63
100% NPK + Zn	5.98	30.22	31.06	15.22	4.81
100% NP	6.25	32.05	28.78	15.65	2.96
100% N	10.12	32.04	22.56	13.19	2.38
100% NPK + FYM	9.19	22.15	35.88	18.67	7.44

100% NPK – S	7.94	30.74	29.16	14.09	4.44
Control	9.30	31.98	26.06	13.15	2.97
Fallow	8.82	32.60	27.75	15.60	3.21

4.4.1.2 Infiltration rate

Application of balanced fertilizer and manure increased both initial and cumulative infiltration rates and the values ranged between 3 to 20 mm hr^{-1} and 0.2 to 1 mm hr^{-1}, respectively. The greater initial and saturated (constant) infiltration rate (Table 4.23) on application of 100% NPK along with FYM and 150% NPK is due to development of larger size aggregate which could have been resulted in higher porosity.

Table 4.23 Effect of Long Term Fertilizer application on infiltration rate of soil

Treatments	Infiltration rate (mm hr^{-1})	
	Initial	Constant
50% NPK	7.20	0.30
100% NPK	11.66	0.70
150% NPK	16.92	0.90
100% NPK+HW	8.40	0.40
100% NPK+Zn	9.96	0.50
100% NP	10.80	0.60
100% N	3.96	0.20
100% NPK+FYM	29.16	1.00
100% NPK-S	11.66	0.70
Control	4.44	0.30

4.4.2 Barrackpore

Bulk density: Bulk density in all the treatments increased from initial (1.35 g cc^{-1}) except in FYM treated plots where it decreased slightly (1.30 g cc^{-1}). Bulk density in control and N only plots increased significantly (1.69 g cc^{-1} and 1.65 g cc^{-1}) by 25.2% and 22.2% respectively. This could be due to loss of organic carbon.

Water holding capacity (WHC): Significant changes in WHC were observed amongst the treatments. Only inorganic applications of fertilizer encountered a decrease in WHC while integrated application of inorganic fertilizers and organic manure increased the WHC. Application of FYM increased WHC significantly over others (50.25%). Control and 100% N only plots recorded the lowest WHCs of 40.45% and 41.1%, respectively.

4.4.3 Parbhani

After six rotations of soybean-safflower cropping system on Vertisol with different nutrient sources through organic manures and inorganic fertilizers indicated considerable change in physical properties of soil in FYM added plots over imbalanced chemical fertilizer treatments during 2011-12 (Table 4.24). Balanced application of nutrients either excluively through inorganic or with FYM resulted decline in bulk density and increas in water holding capacity, infixtration rate and hydroulic conductivity. Decline in bulk density is due to aggregation of soil particles resulted increase in pore

space. Increase in infiltration rate under better nutrition is due to increase in posrosity which is dependent on soil aggregation.

Table 4.24 Effect of organic manures and fertilizers on soil physical properties after harvest of experimentation at Parbhani (2011-12)

Treatment	Bulk density (Mg m^{-3})	Porosity (%)	Maximum WHC (%)	IR (cm hr^{-1})	HC (cm hr^{-1})
50% NPK	1.31	48.36	53.42	1.73	0.96
100% NPK	1.28	52.71	55.34	1.81	1.05
150% NPK	1.27	53.21	56.31	1.98	1.14
100% NPK+HW	1.26	51.32	55.56	1.84	1.06
100% NPK + Zn	1.25	52.79	56.29	1.86	1.10
100% NP	1.28	51.02	55.04	1.77	1.01
100% N	1.32	47.42	53.07	1.70	0.91
100% NPK+FYM	1.23	53.09	57.16	2.05	1.15
100% NPK – Sulphur	1.28	51.13	53.79	1.79	1.04
FYM @10 t ha^{-1}	1.25	52.18	55.17	1.83	1.05
Control	1.34	47.49	52.78	1.69	0.90
Fallow	1.35	46.83	51.69	1.65	0.87
LSD (*P*≤0.05)	0.022	2.32	2.17	0.066	0.027
Initial	1.31	50.00	52.5	1.68	0.84

WHC, water holding capacity; IR, Infiltration rate; HC, hydraulic conductivity.

4.4.4 Palampur

Data (Table 4.25) indicated that application of nutrient in balanced form resulted improvement in saturated hydraulic conductivity (SHC) and mean weight diameter (MWD) of aggregate. Incorporation of FYM further facilitated these properties. From the SHC data one can conclude that in spite of high rainfall there are very poor chances of water logging.

Table 4.25 Long-term effect of fertilizers and amendments on physical properties of soil after wheat harvest (2010-11)

Treatment	Saturated hydraulic conductivity (cm/h)	Mean weight diameter (MWD) (mm)
50% NPK	9.6	1.57
100% NPK	10.2	1.75
150% NPK	10.7	1.83
100% NPK +HW	12.6	2.16
100% NPK + Zn	10.5	1.80
100% NP	8.9	1.64
100% N	3.1	1.03
100% NPK+FYM	16.4	3.87
100% NPK (-S)	9.2	1.68
100% NPK + lime	6.6	4.14
Control	4.2	1.23
LSD (P≤0.05)	0.19	0.03

4.4.5 Akola

Results obtained on physical properties (Table 4.26) revealed that significantly highest water retention at field capacity was recorded in the treatment of 100% NPK + FYM @ 5 t ha^{-1} (51.10%). This could be ascribed to the improvement in structural condition of soil due to the application of FYM with inorganics. Application of 100% NPK + FYM @ 10 t ha^{-1} reported highest water retention at 1500 k Pa (32.39%). The soil aggregate ranged between 58 to 69%. Highest soil aggregation (69 %) was reported in 100% NPK + FYM @ 5 t ha^{-1}. The beneficial role of FYM could be attributed to the marked effect of certain polysaccharides formed during decomposition of organic residues due to microbial activity as well as the cementing action of the bacteria and fungi themselves in soil that helped in soil aggregation.

Table 4.26 Soil physical properties as influenced by long term manuring and fertilization after wheat (2011-12)

.Treatments	Water retention (%)		Soil aggregates (%)
	FC (33 kPa)	PWP (1500 kPa)	
50% NPK	45.85	28.35	61.38
100% NPK	47.41	30.26	62.63
150% NPK	50.76	31.45	65.51
100% NPK S free	46.97	29.89	61.89
100% NPK + Zn @ 2.5 kg ha^{-1}	48.47	29.81	61.50
100% NP	46.85	29.23	62.31
100% N	44.86	27.76	60.28
100% NPK + FYM @ 5 t ha^{-1}	51.10	32.39	68.76
100% NPK + 37.5 kg S ha^{-1}	47.86	27.95	63.39
FYM @ 10 t ha^{-1}	48.18	31.17	65.36
75% NPK + 25 % N through FYM	46.58	29.02	60.38
Control	41.91	26.00	57.96
LSD ($P \leq 0.05$)	4.17	3.27	4.82

4.4.6 Bhubaneshwar

Bulk density increased with depth whereas a reversed trend was observed in hydraulic conductivity in all treatments (Table 4.27). In 100% NPK + FYM treatment, bulk density was lowest, whereas hydraulic conductivity was highest. The increase in hydraulic conductivity is thus associated with decrease in bulk density, which is ultimately dependent on porosity or soil aggregation.

Table 4.27 Effect of long term manuring on bulk density and hydraulic conductivity of soil (post *Kharif* 2011)

Treatment	Bulk density (Mg m^{-3})			Hydraulic conductivity (cm hr^{-1})		
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
50% NPK	1.34	1.38	1.45	1.31	0.76	0.30
100% NPK	1.32	1.35	1.48	1.53	0.78	0.48
150% NPK	1.31	1.35	1.46	1.58	1.19	0.62
100% NPK + FYM	1.28	1.32	1.42	1.63	1.33	0.68
100% N	1.37	1.43	1.50	1.27	0.55	0.26

100% NP	1.36	1.40	1.47	1.31	0.89	0.53
100% NPK + Lime	1.30	1.38	1.45	1.14	0.46	0.23
Control	1.42	1.49	1.52	1.14	0.46	0.23

4.4.7 Pantnagar

In comparison to control higher hydraulic conductivity was recorded in all the treatments. Application of nutrients (NPK) resulted in improvement of hydraulic conductivity. Incorporation of FYM resulted in further increase in hydraulic conductivity. Perusal of data (**Table** 4.28) pertained to water stable aggregate and mean weight diameter (MWD) followed almost similar trend to that of hydroulic conductivity. However, reverse trend was noted for bulk density. Decline in bulk density was recorded on application of nutrient alone as well as with FYM. Increase in hydraulic conductivity is due to improvement in MWD which resulted in increase in pore space and thereby declined the bulk density. All these properties are dependent on soil organic carbon (SOC). Higher value of SOC in plot received nutrient in balanced form is due to incorporation of larger residual biomass as a result of better productivity. Incorporation of FYM not only yielded more but also added carbon to soil which is reflected in SOC and other soil properties.

Table 4.28 Effect of inorganic fertilizers and manure application on physical properties of soil (2011-12).

Treatments	Hydraulic conductivity (cm hr^{-1})	Water stable aggregates >0.025mm	MWD (mm)	Penetration resistance (kg cm^{-2})	Organic carbon (%)	Bulk density (Mg m^{-3})
50% NPK+Zn	0.72	40.81	0.66	3.36	0.80	1.38
100% NPK	0.76	52.10	0.70	3.32	0.86	1.36
150% NPK	0.75	50.40	0.71	3.36	0.89	1.32
100%NPK+H.W +Zn	0.79	53.01	0.77	3.20	0.96	1.30
100% NPK +Zn	0.86	54.10	0.78	3.16	1.08	1.31
100% NP+Zn	0.78	50.81	0.74	3.23	1.04	1.29
100% N+Zn	0.70	44.52	0.68	3.39	0.88	1.38
100% NPK+FYM	0.95	59.24	1.07	2.42	1.56	1.20
100% NPK(-S)+Zn	0.75	49.55	0.72	3.28	0.90	1.32
Control	0.63	34.84	0.55	3.54	0.61	1.52
LSD (*P*≤0.05)	0.09	4.53	0.042	0.073	0.59	0.035
Initial value	--	---	--	--	1.48	--
Natural fallow	1.02		1.14	2.15	1.59	1.08

4.4.8 Bangalore

Data on physical properties (Table 4.29) indicated little decline in bulk density on application of FYM. However, perceptive change in bulk density was not recorded on application of NPK irrespective of amount. A similar effect of FYM was noted on percent aggregate size.

Table 4.29 Effect of long term fertilization on physical properties of soil (2011 -12)

Treatments	Bulk Density (g/cc)	Aggregate size (%)
50% NPK	1.52	34.34
100% NPK	1.51	34.85
150% NPK	1.52	36.12
100% NPK+HW	1.52	34.01
100% NPK+Lime	1.52	35.06
100% NP	1.55	32.23
100% N	1.56	31.58
100% NPK+FYM	1.42	36.82
100% NPK(S-free)	1.53	32.74
100% NPK+FYM+lime	1.43	37.11
Control	1.54	33.02
LSD (*P*≤0.05)	0.02	3.65

4.4.9 Ludhiana

The effect of continuous application of fertilizer on soil physical properties like bulk density, median weight diameter and infiltration rate was determined during 2011-12 (Table 4.30). Bulk density decreased with the application of fertilizer, however the difference was not significant under chemical fertilizer application. The effect of integrated fertilizer application (100% NPK+FYM) on bulk density was highest and value was significantly lower than other treatments. The MWD value ranged from 0.317 mm to 0.543 mm in control and 100%NPK+FYM, respectively. The application of chemical fertilizer alone or with organic manure significantly improved MWD as compared to control. Similarly, infiltration rate significantly improved with fertilizer application as compared to control. The minimum and maximum IR was recorded for control (1.83 cm mm^{-1}) and 100% NPK+FYM (1.83 cm mm^{-1}). Application of integrated fertilizer further improves IR as compared to chemical fertilizer and the difference was significant.

Table 4.30 Effect of long term application of fertilizer on physical properties of soil (2011-12)

Treatment	Bulk density (Mg m^{-3})	MWD (mm)	IR (cm min^{-1})
50% NPK	1.5	0.403	0.140
100% NPK+W	1.56	0.420	0.148
150% NPK	1.56	0.417	0.160
100% NPK+W	1.56	0.420	0.155
100% NPK+Zn	1.56	0.430	0.154
100% NP	1.57	0.397	0.150
100% N	1.58	0.347	0.133
100% NPK+FYM	1.47	0.543	0.183
100% NPK(-S)	1.54	0.437	0.153
Control	1.68	0.317	0.123

MWD, mean weight diameter; IR, infiltration rate.

4.4.10 Udaipur

Bulk density : The lowest bulk density (1.32 Mg m^{-3}) was recorded with farm yard incorporation @ 20 t ha^{-1} followed by NPK + FYM (Table 4.31) which were at par with each other, whereas highest bulk density (1.46 Mg m^{-3}) was observed in N alone plot. Reduction in bulk density might be due to higher organic C, more pore spaces as a result of good soil aggregation. Porosity is a function of soil aggregation into bigger size.

Table 4.31 Long-term effects of fertilizer, manure and their combination on physical properties the soil after fourteen crop cycle

Treatment	Bulk density (Mg m^{-3})	Particle density (%)	Porosity (%)
Control	1.45	2.57	43.26
100% N	1.46	2.53	42.52
100% NP	1.45	2.52	42.15
100% NPK	1.43	2.56	45.13
100% NPK + Zn	1.43	2.56	44.29
100% NPK + S	1.42	2.54	44.05
100% NPK + Zn + S	1.42	2.53	43.62
150% NPK	1.42	2.50	45.60
100% NPK + FYM	1.35	2.51	46.89
100% NPK – FYM	1.34	2.51	47.55
FYM	1.32	2.51	43.93
100% NPK + Bio	1.44	2.51	43.43
LSD ($P \leq 0.05$)	0.03	NS	1.13

4.4.11 Pattambi

Perusal of data (**Table 4.32**) revealed that application of FYM resulted in decline of bulk density, improvement in water holding capacity and porosity compared to other treatments. Decline in bulk density is due to formation of bigger size aggregate which is responsible for more pore space and water holding capacity.

Table 4.32 Soil physical properties at Pattambi (Kharif 2010)

Treatment	Bulk density (g cm^{-3})	Water holding capacity %	Porosity (%)
50% NPK	1.22	34.40	42.97
100% NPK	1.24	34.20	44.95
150% NPK	1.22	35.99	44.79
100% NPK +Lime)	1.23	35.17	43.90
100% NPK	1.22	32.74	43.04
100% NP	1.26	34.76	43.55
100% N	1.26	35.73	42.75
100% NPK + FYM	1.17	40.89	49.25
50% NPK + FYM	1.21	38.77	47.39

100% NPK +GM	1.20	36.97	45.63
50% NPK +GM	1.26	34.97	43.17
Control	1.35	34.75	41.42

4.5 Soil Biological Properties

4.5.1 Jabalpur

4.5.1.1 Microbial Population

Microbial population (*Azotobacter,* PSB, *Nitrosomonas* and *Nitrobacter*) was significantly improved with increasing level of fertilizers. Further, maximum microbial population was found in 100% NPK+FYM treatment and minimum in control (Table 4.33). Data further indicated that continuous absence of K, S had adverse effect on population of all the four species studied.

Table 4.33 Effect of different treatments on microbial population (cfu $x10^4$ g^{-1}Soil)

Treatments	After harvesting of Soybean			
	Azotobacter	PSB	*Nitrosomonas*	*Nitrobacter*
50% NPK	39.25	13.30	18.60	17.80
100% NPK	52.42	17.85	25.15	18.57
150% NPK	68.11	25.07	34.61	25.32
100% NPK+HW	50.74	16.46	23.03	17.71
100% NPK+Zn	54.31	19.02	26.11	21.15
100% NP	51.57	19.40	30.12	20.05
100% N	41.03	15.11	28.01	22.19
100% NPK+FYM	78.76	30.23	39.07	32.34
100% NPK-S	51.17	16.13	21.63	18.77
Control	26.49	10.03	14.12	13.85
LSD ($P \leq 0.05$)	6.50	2.82	3.88	2.96

PSB, phosphate solubilizing bacteria

4.5.1.1 Microbial biomass C and N

Microbial biomass C and N are most easily available form of nutrients and they decide the nutrient availability. In general, decline in microbial biomass C and N is observed in lower depth. Inclusion of organic manure (FYM) significantly improved microbial biomass C and N contents over rest of the treatments. Wherever the balance application of nutrients was practiced, the soil condition was favorable for microbial biomass C and N contents (Table 4.34). This is due to availability of fresh biomass added each year in larger amount through leaves, root and stubbles compared to control and 100% N because of higher productivity in those treatments.

Table 4.34 Distribution of microbial biomass C and N (mg kg^{-1}) in soil

Treatments	Microbial biomass C				Microbial biomass N			
	0-20 (cm)	20-40 (cm)	40-60 (cm)	60-80 (cm)	0-20 (cm)	20-40 (cm)	40-60 (cm)	60-80 (cm)
100% NPK	224.52	136.50	43.82	14.82	26.96	13.53	5.20	1.52
150% NPK	222.70	119.81	45.06	10.35	25.21	12.45	4.51	1.47
100% NP	186.53	97.01	39.85	6.17	23.03	11.76	3.92	1.21
100% N	199.86	110.21	29.61	10.52	21.86	11.25	3.83	1.19
100% NPK+FYM	291.37	196.60	93.79	39.85	35.99	18.40	8.33	3.85
100% NPK- S	244.00	143.25	47.96	11.92	24.89	12.10	4.65	1.20
Control	170.29	94.26	17.49	2.39	20.62	10.25	3.24	0.79
Fallow	150.35	93.80	14.82	1.89	20.20	10.02	3.20	0.68
LSD (*P*≤0.05)	16.13	11.9	7.89	2.55	2.307	1.053	0.241	0.162

4.5.2 Barrackpore

The effect of various fertilizer treatments on the microbial dynamics in jute rhizosphere was studied during 2008-11 (**Table** 4.35 and 4.36). The population of beneficial microbes like *Azotobacter, Aspergillus, Penicillium, Trichoderma* and phosphapte solubilizing microbes were found to be higher after 60 days of sowing in jute rhizosphere as compared to 90 days after sowing and the maximum population was recorded with 100% NPK+FYM. The enzymatic activities of dehydrogenase, urease, fluorescein diacetate hydrolyzing activity, acid and alkaline phosphatase were studied in jute rhizosphere for three consecutive years and the application of fertilizer NPK with FYM recorded significantly higher enzyme activities over all treatments including 100% NPK and 150% NPK. The soil microbial biomass carbon and basal soil respiration rate in jute rhizosphere also followed the same trend to that of the enzymatic activities.

Table 4.35 Effect of various fertilizer treatments on population of beneficial microbes in jute rhizosphere (three years pooled data at 60 DAS*)

Treatments	*Azotobacter* (cfu x 10^5/g oven dry soil)	*Aspergillus*	*Penicillium*	*Trichoderma*	PSM	Phosphate solubilizing power (ppm)
		(cfu x 10^3/ g oven dry soil)				
Control	23.2	18.0	12.0	26.0	5.8	3.50
50% NPK	25.0	20.0	23.0	30.0	6.6	3.40
100% NPK	31.8	32.0	42.0	48.0	16.9	5.50
100% NPK+FYM	33.5	50.0	45.0	49.0	17.3	5.80
150% NPK	28.2	16.0	32.0	32.0	6.8	3.00
LSD (*P*≤0.05)	4.2	5.6	4.8	5.0	3.50	1.70
Initial status	25.5	2.1	2.3	3.9	6.5	2.5

*The microbial population was maximum at 60 DAS, so the data of only 60 DAS is presented

Table 4.36 Effect of various fertilizer treatments on microbial properties in jute rhizosphere in jute rhizosphere (three years pooled data at 60 DAS*)

	DHA	Urease	FDHA	ACP	ALP	SMBC	BSRR
Control	5.2	120	181	147	364	230	0.8
50% NPK	5.5	133	185	149	453	239	0.9
100% NPK	6.3	133	210	193	515	351	1.3
100% NPK+FYM	7.2	169	236	228	537	369	1.5
150% NPK	6.2	152	186	169	455	361	1.0
LSD (*P*≤0.05)	1.4	8	7	7	10	12	0.2
Initial	3.5	130	125	135	350	181	0.8

*The microbial population was maximum at 60 DAS, so the data of only 60 DAS is given in the table

DHG, Dehydrogenase (mg TPF/g oven dry soil/h at 37^{o}C); Urease, Urease (mg urea hydrolyzed/g oven; dry soil/h at 37^{o}C); FDHA (mg fluorescein/g oven dry soil); ACP, Acid phosphatase (mg p-nitro phenol released/g oven dry soil/h at 37^{o}C); ALP, Alkaline phosphatase (mg p-nitro phenol released/g oven dry soil/h at 37^{o}C); SMBC, soil microbial biomass carbon (mg C/g oven dry soil); BSRR, basic soil respiration rate (mgCO_2-C/g oven dry soil/h at 22^{o}C)

4.5.3 Palampur

Microbial Biomass Carbon (MBC): Microbial biomass carbon (Table 4.37) varied from 169.5 µg/g under 100% N to 994.4 µg/g under 100% NPK+FYM. Use of organics along with inorganics recorded 19% higher MBC as compared to 100% NPK.

Microbial Biomass Nitrogen (MBN): All the treatments recorded significantly higher microbial biomass nitrogen (Table 4.37) over control. Like MBC, highest MBN (23.6 µg/g) was recorded in the plot which received 100% NPK + FYM followed by 100% NPK + lime (21.2 µg/g) and minimum (10.4 µg/g) under control.

Table 4.37 Long-term effects of fertilizers and amendments on biological properties of soil after wheat harvest (2010-11)

Treatment	Microbial biomass carbon (µg g^{-1})	Microbial biomass nitrogen (µg g^{-1})
50% NPK	291.8	14.3
100% NPK	834.1	18.2
150% NPK	809.9	20.5
100% NPK +HW	752.3	19.2
100% NPK + Zn	646.7	17.9
100% NP	188.7	14.6
100% N	169.5	12.6
100% NPK+FYM	994.4	23.6
100% NPK (-S)	612.1	15.4
100% NPK + lime	886.5	21.2
Control	289.0	10.4
LSD (*P*≤0.05)	4.2	0.3

4.5.4 Pantnagar

Data on microbiological properties (Table 4.38) showed improvement in soil microbial biomass (MBC) and mineraligable N on application of nutrients. The higher activities of urea and phosphatase under balanced fertilization support the statement. Increase in population of bacteria, fungi and actinomyetes on application of fertilizer and organic manure is due to availability of nutrient and

substrate for their growth. The larger activities of delydrogenase support and confirms that application of nutrient either alone or in combination of organic manure improved the microbial population (Table 4.39) in soil which in turn does more turnover of nutrient in soil and help the plant to grow well.

Table 4.38 Long term effect of fertilizer and manure on MBC, Mineralizable - N, Urease activity and phosphatase and dehydrogenase activity after 39 years of rice wheat cropping (LTFE)

Treatments	MBC (µg gm^{-1})	Mineralizable N (µg kg^{-1})	Urease activity (mg urea $gm^{-1}hr^{-1}$)	Phosphatase activity (µg p-np gm^{-1} hr^{-1})
	(0-15 cm depth)			
50% NPK+Zn	208.78	40.42	1.44	14.72
100% NPK	314.17	42.56	1.58	14.72
150% NPK	369.82	53.42	2.00	18.62
100% NPK+HW+Zn	357.76	46.66	1.91	17.84
100% NPK+Zn	356.36	49.11	1.68	17.04
100% NP+Zn	303.56	44.75	1.34	14.58
100% N+Zn	264.06	46.20	0.90	12.01
100% NPK+FYM	412.53	55.53	2.27	25.45
100% NPK-S+Zn	284.33	44.33	0.94	13.17
Control	235.06	38.26	0.80	10.92
LSD (*P*≤0.05)	36.864	4.091	0.186	1.849

Table 4.39 Effect of fertilization on biological parameters under rice-wheat cropping system on Mollisols of Pantnagar (39 th years of cropping).

Treatments	DHA (µg $gm^{-1}hr^{-1}$)	Actinomycets (No. X 10^{-4} cfu gm^{-1})	Fungi Counts No. X10^{-3} cfu gm^{-1})	Bacterial Counts (No.X10^{-6} cfu gm^{-1})
50% NPK+Zn	716.00	3.98	4.72	15.13
100% NPK	588.92	4.35	6.02	21.19
150% NPK	775.43	6.15	7.08	18.85
100% NPK+HW+Zn	621.75	5.97	7.46	20.33
100% NPK+Zn	851.62	6.06	7.62	21.89
100% NP+Zn	627.87	4.82	4.56	16.12
100% N+Zn	513.12	3.53	3.32	13.63
100% NPK+FYM	940.62	8.42	10.86	28.23
100% NPK-S+Zn	706.62	4.29	5.00	16.14
Control	510.87	2.83	2.85	12.83
LSD (*P*≤0.05)	103.431	1.127	1.066	2.224

4.5.5 Bangalore

Perusal of data (Table 4.40) revealed that application of fertilizer nutrient did not have any adverse effect on microbial population in soil rather increase in population was noted on application of nutrients. However, incorporation of FYM further increased microbial population in soil compared to other treatments. Application of lime resulted sharp increase in population of bacteria and actinomycetes. Application of nutrient irrespective of quality also resulted increase in microbial biomass nitrogen and carbon which is direct evidence in support of increase in population of soil

microorganism. It is due to the fact that microbes also require nutrients for their growth. Greater activity of dehydrogenase and acid phosphatase confirms the observations on microbial population. Thus result clearly brought out that application of nutrient enhanced the microbial activities (Table 4.41) in soil and the myth prevailed in the society that application of chemical fertilizer kill the soil organism is ruled out.

Table 4.40 Effect of long term fertilization on microbial diversity (2011 -12)

Treatments	Bacteria ($x 10^6$ cfu.g^{-1})	Fungi ($x10^3$ cfu.g^{-1})	Actinomycetes ($x 10^4$ cfu.g^{-1})
50% NPK	17.33	7.33	3
100% NPK	21.00	11.67	5
150% NPK	22.00	13.67	7
100% NPK+HW	18.00	11.67	5
100% NPK+Lime	20.67	9.00	5
100% NP	16.00	7.33	2
100% N	16.67	6.33	2
100% NPK+FYM	26.00	17.67	7
100% NPK(S-free)	18.00	7.00	5
100% NPK+ FYM+ lime	31.33	17.67	7
Control	15.33	5.33	2
LSD (*P*≤0.05)	4.47	3.33	1.80

Table 4.41 Effect of long term fertilization on enzymatic activities (2011 -12)

Treatments	MBC (µg g^{-1})	MBN (µg g^{-1})	AP (µg/PNP/g/24hr)	Dehydrogenase (µg/TPF/g/24hr)
50% NPK	229.36	24.0	88.36	56.20
100% NPK	241.06	25.1	92.43	62.00
150% NPK	264.20	26.7	94.59	64.40
100% NPK+HW	238.46	26.8	88.56	52.00
100% NPK+Lime	236.40	25.0	87.79	59.80
100% NP	204.96	23.6	88.11	42.20
100% N	206.97	23.9	85.21	43.60
100% NPK+FYM	262.50	27.2	102.37	65.80
100% NPK(S-free)	237.06	24.6	88.57	33.80
100% NPK+FYM+lime	276.53	26.1	118.77	60.20
Control	216.36	23.4	81.73	47.00
LSD (*P*≤0.05)	9.02	4.25	12.99	4.65

MBC, microbial biomass carbon; MBN, microbial biomass nitrogen ; AP, acid phosphotase.

4.5.6 Ludhiana

Soil microbial biomass carbon significantly improved with the application 100%N as compared to control (**Table** 4.42). The SMBC further improved with balance fertilization which was significantly higher than 100% N. The highest value of SMBC was recorded in 100%NPK+FYM (232 mg kg^{-1}) and difference was significant from other treatments. Similarly, application of N alone has statistically at par value of SMBN compared to control. However, long term application of balanced fertilizer significantly improved SMBN. The highest value of SMBN was recorded for 100% NPK+FYM (17.1 mg kg^{-1}) which was significantly higher than other treatments. Thus, data suggest that continuous

use of fertilizer improved the microbial activity and turn over of nutrient in soil which is responsible for higher productivity.

Table 4.42. Effect of long term application of fertilizer on biological properties of soil (2011-12)

Treatment	SMBC ($mgkg^{-1}$)	SMBN ($mgkg^{-1}$)
50% NPK	189	11.3
100% NPK+W	185	14.5
150% NPK	208	14.6
100% NPK+W	208	15.1
100% NPK+Zn	213	15.3
100% NP	187	11.7
100% N	168	8.9
100% NPK+FYM	232	17.1
100% NPK(-S)	211d	14.8
Control	139	8.4

4.5.7 Ranchi

Soil carbon fractionation study revealed that application of nutrient resulted increase in all the fractions of soil carbon (Table 4.43) compared to control. Application of fertilizer in larger quantity has positive effect on carbon fraction. However, incorporation of FYM over and above NPK brought significant improvement in all the fractions of soil carbon (Table 4.44). Through FYM also enhanced loss of carbon through respiration because of higher microbial population.

Table 4.43 Long term effect of continuous cropping, fertilization manuring and liming on active and slow pool soil organic carbon (SOC) in soybean-wheat cropping system.

Treatment	Water soluble C ($mg\ kg^{-1}$)	Water soluble Carbohydrates ($mg\ kg^{-1}$)	CO_2 Evolution (mg/100 g soil)	Soil microbial biomass C ($mg\ kg^{-1}$)	Soil microbial biomass N ($mg\ kg^{-1}$)	Particulate organic C (%)
Control	20.4	251.8	36.8	174.9	16.9	28.3
100% N	22.3	255.0	31.8	131.5	11.7	31.2
100% NP	24.4	243.8	44.8	156.1	13.9	32.1
100% NPK	26.3	277.9	39.8	185.9	18.3	33.9
100% NPK+Lime	35.5	302.3	55.0	207.2	23.0	32.3
100% NPK+FYM	44.6	327.4	65.3	236.7	24.9	41.4
150% NPK	40.5	312.5	50.0	217.0	22.8	39.2
LSD ($P \leq 0.05$)	7.3	26.3	6.5	8.8	1.4	0.0

Table 4.44 Long term effect of continuous cropping, fertilization manuring and liming on distribution of carbon in different fractions of soil humus after soybean.

Treatments	Organic carbon (%)	Humic carbon (%)	Fulvic carbon (%)	Humic+ fulvic carbon (%)	Humin carbon (%)
Control	0.32	0.062	0.091	0.153	0.167
100% N	0.36	0.039	0.076	0.115	0.245
100% NP	0.37	0.053	0.069	0.122	0.248
100% NPK	0.39	0.118	0.138	0.256	0.134
100% NPK+Lime	0.33	0.067	0.065	0.132	0.198
100% NPK+FYM	0.50	0.073	0.165	0.238	0.262
150% NPK	0.42	0.074	0.098	0.172	0.248
LSD (*P*≤0.05)	0.08	0.01	0.02	0.025	0.04

4.5.8 Coimbatore

Continuous application of inorganic fertilizers with or without FYM significantly influenced the biomass carbon and nitrogen (Table 4.45). Higher value of biomass carbon and nitrogen was noticed in INM practice whereas lower values were recorded in control. The results revealed that amongst the microbes, bacterial population was larger compared to fungi and actinomycetes. Bacterial population in soil ranged from 48 to 118 $X10^6$ cfu/g dry soil, fungi from 17 to 23 $X10^3$ cfu/g dry soil and actinomycetes from 7 to 16 $X10^4$ cfu/g dry soil. Long term integrated application of inorganic fertilizers + FYM @ 10 t ha^{-1} recorded more microbial population followed by 100% NPK, than control. Application of N alone also recorded relatively higher population than control but less than 100% NPK.

Table 4.45 Biomass carbon, nitrogen, microbial population in post harvest soil after finger millet and maize hybrid (Mean of two years 2010-12)

Treatments	Biomass carbon (mg kg^{-1})	Biomass nitrogen (mg kg^{-1})	Bacteria population ($x10^6$ CFU / g dry soil)	Fungi population ($x10^3$ CFU / g dry soil)	Actino- mycetes population ($x10^4$ CFU/g dry soil)
50% NPK	298	47.03	79	19	10
100% NPK	326	57.31	87	19	12
150% NPK	334	58.58	79	19	10
100% NPK + HW	318	45.77	87	20	12
100% NPK + $ZnSO_4$	331	56.57	81	20	10
100% NP	294	40.92	71	18	9
100% N	229	35.51	71	18	8
100% NPK + FYM	352	69.93	118	23	16
100% NPK (-S)	332	47.91	83	19	10
Control	225	32.87	48	17	7
LSD (*P*≤0.05)	6.38	0.79	1.70	0.66	0.17

4.5.9 Udaipur

Microbial population: An assessment of soil microbial population under influence of chemical fertilizer, FYM and integrated used of chemical fertilizer with FYM, and *Azotobacter* was studied at the end of fourteen cropping cycles of maize-wheat cropping relation and presented in Table 4.46. Data revealed that balanced application of nutrient maintained larger population compared to control and 100% N. Application FYM further improved the population all the three types of organisms.

Soil enzymes: Maximum values of soil enzymes were recorded on application of organic manure either alone or in combination with chemical fertilizers. On the other hand, the lowest fungal population was maintained under no application of fertilizer and manure (control). Higher activities of soil enzymes in the plots received balanced fertilizer supports the microbial population trend in soil as enzyme activity is direct indicator soil microbial population. As soil enzymes play an important role in organic matter decomposition and nutrient cycling.

Table 4.46 Long term effect of fertilizer, manure and their combination on microbial population and soil enzymes after fourteen crop cycles (cfu g^{-1} soil)

Treatment	Fungi ($x10^4$)	Bacteria ($x10^6$)	Actinomycetes ($x10^5$)	Dehydrogenase (µg TPF produced/g/h)	Acid phosphatase (µg PNP produced/g/h)	Alkaline phosphatase (µg PNP produced/g/h)
Control	6.50	6.75	5.50	0.703	58.38	117.95
100% N	6.25	6.75	5.50	0.774	68.78	116.04
100% NP	7.00	7.00	5.75	0.787	69.57	116.68
100% NPK	5.75	8.75	7.50	0.777	80.23	118.85
100% NPK + Zn	7.50	10.75	9.50	0.796	69.96	114.76
100% NPK + S	7.75	11.25	10.00	0.792	84.17	131.98
100% NPK + Zn + S	9.25	10.50	9.25	0.800	75.49	117.70
100% NPK + FYM	12.50	16.25	15.00	0.882	90.62	139.76
100% NPK – FYM	10.75	13.00	11.75	0.857	105.88	175.22
FYM	10.00	13.00	11.50	0.864	110.90	199.46
150% NPK	9.00	9.75	8.50	0.847	66.94	112.85
100% NPK + Bio	8.75	11.75	10.50	0.760	83.25	123.69
LSD ($P \leq 0.05$)	0.69	0.80	0.84	0.030	3.17	4.71

4.5.10 Pattambi

Data generated on microbial population (Table 4.47) revealed that application of fertilizer resulted increase in microbial population, however imbalanced use of nutrient led to decline in microbial population compared to control. It is strange to note that application of lime had adverse effect on bacterial and *Azospirillum* population. On the contrary, a big jump in growth of bacterial and *actinomycetes* was recorded. This could be due to sudden change in microclimate in soil which is favourable to actinomycetes and these were comparable to *Azospirillum* and bacteria. But overall effect is positive on bacterial population is considered.

Table 4.47 Long term effect of fertilizer, manure on microbial population and soil enzymes after fourteen crop cycles

	Bacteria ($x10^5$)	Fungi ($x\ 10^5$)	Azospirillum ($x\ 10^5$)	Actinomycetes ($x\ 10^5$)
50% NPK	71.1	2.7	19.4	1.7
100% NPK	61.4	2.7	19.4	1.5

150% NPK	52.0	3.0	28.3	1.1
100% NPK +Lime)	43.4	3.2	0.1	7.7
100% NPK	57.2	2.5	1.5	2.0
100% NP	51.9	2.3	4.0	1.7
100% N	38.8	1.0	6.8	2.6
100% NPK+ FYM	84.8	3.0	31.3	2.0
50% NPK+ FYM	61.6	2.0	21.9	3.8
100% NPK+GM	76.9	2.7	33.5	2.2
50% NPK +GM	63.2	2.6	29.1	1.6
Control	51.3	2.6	25.4	0.9

4.5.11 Jagtial

4.5.9.1 Enzymatic activities

Urease : In all the treatments, the urease activity showed an increasing trend with the age of the crop and exhibited maximum activity at 60 days after transplanting (DAT) and thereafter the activity decreased gradually at harvest. The activity of urease enzyme (Table 4.48) increased with increase in levels of recommended dose of fertilizer up to 150%. The urease activity with application of sub optimal dose of fertilizer (50% NPK) were 2.97, 6.14, 4.47 and 1.82 mg NH_4^+ released g^{-1} soil h^{-1}at 30, 60, 90 DAT and at harvest during *rabi* (mean values of two years) respectively. A similar trend was noted in kharif season also with almost similar magnitude.

Table 4.48 Effect of long term fertilizer application on soil urease activity (mg NH_4^+ released g^{-1} soil h^{-1}) in rice (Mean 2010-11 and 2011-12)

Treatments	Kharif				Rabi			
	30 DAT	60 DAT	90 DAT	Harvest	30 DAT	60 DAT	90 DAT	Harvest
50% NPK	2.76	6.47	2.96	2.02	2.97	6.14	4.47	1.82
100% NPK	3.48	7.45	3.30	2.49	3.01	7.06	4.64	2.20
150% NPK	3.91	7.78	3.67	3.13	3.31	7.62	5.87	2.66
100% NPK + HW	2.97	7.07	3.26	2.45	2.83	6.56	5.13	1.98
100% NPK + Zn	3.05	6.85	3.41	2.88	2.51	6.78	5.36	2.45
100% NP	3.37	6.85	2.96	3.02	2.35	6.37	5.97	2.57
100% N	2.95	6.80	2.44	2.41	2.28	5.75	3.28	2.06
100% NPK + FYM	4.31	8.52	3.97	3.30	3.46	8.56	6.54	2.77
100% NPK - S	2.78	6.74	3.24	2.45	2.54	5.96	4.99	2.10
FYM	3.40	6.66	3.38	3.20	3.31	6.38	5.38	2.62
Control	2.55	4.27	2.23	1.85	1.98	4.09	3.66	1.54
Fallow	3.74	6.51	3.62	3.34	3.06	6.42	3.81	2.72
LSD ($P \leq 0.05$)	0.29	0.45	0.20	0.33	0.18	0.53	0.47	0.27

Dehydrogenase : Similar to urease, the activity of dehydrogenase (Table 4.49) with the age attained maximum at 60 DAT and thereafter decreased at maturity of crop. Significantly higher dehydrogenase activity was observed in 100% NPK + FYM (@ 10 t ha^{-1}) compared to other treatments. The treatment with 100% N alone recorded significantly lower dehydrogenase activity than the other treatments; however, all the treatments were superior to absolute control.

Table 4.49 Effect of long term fertilizer application on soil dehydrogenase activity (mg TPF produced g^{-1} soil d^{-1}) at various growth stages of rice (Mean 2010-11 and 2011-12)

Treatments	Kharif				Rabi			
	30 DAT	60 DAT	90 DAT	Harvest	30 DAT	60 DAT	90 DAT	Harvest
50% NPK	1.81	3.56	2.72	1.58	2.67	5.46	3.81	1.73
100% NPK	2.12	4.10	3.04	1.96	2.71	6.28	4.10	2.09
150% NPK	2.14	4.28	3.38	2.46	2.98	6.79	5.19	2.53
100% NPK + HW	1.95	3.90	3.00	1.93	2.55	5.84	4.53	1.87
100% NPK + Zn	1.97	3.77	3.14	2.26	2.26	6.04	4.72	2.32
100% NP	1.71	3.52	2.73	2.37	2.11	5.68	4.90	2.35
100% N	1.60	3.37	2.24	1.90	2.05	5.12	2.90	1.95
100% NPK + FYM	2.42	4.69	3.66	2.60	3.11	7.62	5.78	2.63
100% NPK - S	1.88	3.71	2.98	1.92	2.29	5.31	4.41	2.00
FYM	1.85	3.73	3.11	2.46	2.97	5.68	4.75	2.48
Control	1.37	2.35	2.05	1.45	1.78	3.64	3.23	1.46
Fallow	1.94	3.62	3.33	2.62	2.75	5.72	3.37	2.57
LSD ($P \leq 0.05$)	0.14	0.29	0.22	0.18	0.16	0.47	0.31	0.18

Phosphatase : Similar to urease and dehydrogenase the activity of acid (Table 4.50) and alkaline phosphatase (Table 4.51) was also gradually increased with the advancement of the growth of the crop and attended maximum activity at 60 DAT and decreased at harvest.

Table 4.50 Effect of Long term fertilizer application on soil acid phosphatase activity (µg p-nitrophenol released g^{-1} soil h^{-1}) at various growth stages of rice (Average of two years 2010-11 and 2011-12).

Treatments	Kharif				Rabi			
	30 DAT	60 DAT	90 DAT	Harvest	30 DAT	60 DAT	90 DAT	Harvest
50% NPK	77	96	90	58	88	188	107	78
100% NPK	83	109	101	68	102	192	123	87
150% NPK	94	128	114	79	121	206	139	101
100% NPK + HW	84	105	99	68	102	192	127	91
100% NPK + Zn	85	105	98	68	105	194	127	90
100% NP	69	86	82	58	79	177	92	70
100% N	65	81	72	52	73	170	86	66
100% NPK + FYM	90	114	107	77	111	201	156	95
100% NPK - S	84	104	98	66	101	194	129	90
FYM	90	102	100	75	108	198	140	92
Control	74	93	83	61	84	182	94	75
Fallow	88	103	99	75	100	192	138	96
LSD ($P \leq 0.05$)	8	11	7	7	9	14	12	9

Table 4.51 Effect of long term fertilizer application on soil alkaline phosphatase activity (µg p-nitro phenol released g^{-1} soil h^{-1}) in rice (Mean 2010-11 and 2011-12)

Treatments	Kharif				Rabi			
	30 DAT	60 DAT	90 DAT	Harvest	30 DAT	60 DAT	90 DAT	Harvest
50% NPK	84	94	96	76	94	142	109	84
100% NPK	90	102	100	80	104	152	125	95
150% NPK	106	136	122	89	126	177	151	109
100% NPK + HW	87	100	100	79	102	154	122	97
100% NPK + Zn	88	98	101	82	104	150	123	94
100% NP	80	90	83	63	86	132	97	77
100% N	71	87	76	56	82	128	86	69
100% NPK + FYM	98	120	105	86	115	167	140	109
100% NPK - S	88	102	100	78	101	152	124	95
FYM	89	111	106	86	119	156	137	101
Control	83	91	87	65	88	137	97	86
Fallow	97	109	105	84	115	158	132	103
LSD (*P*≤0.05)	4.6	7.4	7.9	4.8	6.7	7.9	6.8	4.9

4.5.9.2 Organic matter fractions

The humic acid content varied from 0.29 to 0.48% in 2010 and 0.33 to 0.53% in 2011 (Table 4.52). Humic acid content increased with increased levels of fertilizer doses from 50 to 150%. The increase over control was 19.3% (50% NPK) to 45.1% (150%NPK). The highest humic acid carbon content was recorded with application of 100% NPK plus FYM which was superior over other treatments. The fulvic acid content varied significantly amongst the treatments under study. The fulvic acid ranged from 0.19 to 0.31 per cent in 2010 and 0.22 to 0.36 per cent in 2011. It is evident from the data that as like humic acid, fulvic acid content also increased with increased levels of fertilizers doses from 50 to 150% and there was 25% increase in 50% NPK and 60 per cent increase in 150% NPK (mean of two years) over control. From the data it can be concluded that application of fertilizer helps in sequestering the carbon in resistant pool as carbon exist in soil.

Table 4.52 Effect of long term fertilizer application on soil humic substances (%) at post harvest soils of rice during *rabi* 2010 and 2011

Treatments	Humic acid (%)			Fulvic acid (%)		
	2010	2011	Mean	2010	2011	Mean
50% NPK	0.36	0.38	0.37	0.23	0.27	0.25
100% NPK	0.39	0.43	0.41	0.25	0.31	0.28
150% NPK	0.44	0.47	0.45	0.30	0.35	0.32
100% NPK + HW	0.37	0.42	0.39	0.24	0.31	0.27
100% NPK + Zn	0.31	0.36	0.33	0.20	0.25	0.22
100% NP	0.32	0.38	0.35	0.22	0.26	0.24
100% N	0.36	0.43	0.39	0.23	0.28	0.25
100% NPK + FYM	0.48	0.53	0.51	0.31	0.36	0.33
100% NPK - S	0.35	0.40	0.38	0.23	0.25	0.24
FYM	0.42	0.45	0.43	0.27	0.30	0.29
Control	0.29	0.33	0.31	0.19	0.22	0.20
Fallow	0.42	0.46	0.44	0.27	0.31	0.29

LSD (*P*≤0.05)	0.041	0.061	0.041	0.020	0.041	0.020

4.5.12 Parbhani

Data (Table 4.53) indicated that application of fertilizer nutrient led to increase in all the three species of microorganism over control. Incorporation of FYM over and above NPK further improved their number. The year's variation in population of bacteria and fungi was noted that could be due to change in soil condition because of climate.

Table 4.53 Effect of organic manures and fertilizers on soil microbial properties after harvest of soybean- safflower crop sequence (2010-11 & 2011-12)

Treatment	Bacteria ($x10^7$)		Fungi ($x10^4$)		Actinomycetes ($x10^6$)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
50% NPK	92	142	24.3	6.4	37.5	34.1
100% NPK	85	153	19.3	6.9	41.1	36.9
150% NPK	79	163	13.8	8.1	39.1	44.1
100% NPK+HW	82	183	19.5	7.4	33.9	39.5
100% NPK + Zn	90	156	22.0	7.4	36.8	41.1
100% NP	93	149	15.5	6.5	37.0	35.1
100% N	90	123	20.8	6.4	37.8	32.1
100% NPK +FYM	128	255	27.8	8.9	50.5	53.1
100% NPK – S	88	162	23.5	6.6	35.0	42.8
FYM @10t/ha.	114	222	29.5	11.1	44.9	48.7
Control	71	121	14.8	5.9	23.5	29.9
Fallow	71	106	14.3	5.2	26.2	27.2
LSD (*P*≤0.05)	7.44	38.39	3.99	2.69	3.07	4.46

Soil enzymes with particular reference to acid phosphatase, alkaline phosphatase, soil dehydrogenase activites were also found significantly more in organic matter added tretments over chemical fertilizers alone (Table 4.54). Similarly, SMBC and CO_2 evolution which are the indicators of microbial activities were also noted larger in 100% NPK+FYM treatment.

Table 4.54 Effect of organic manures and fertilizers on enzymatic activity, SMBC and CO_2 evolution after harvest of Soybean-Safflower crop sequences (2011-12)

Treatment	Acid phosphatase (ug p-NP g^{-1} soil hr^{-1})	Soil dehydrogenase enzyme activity (µg TPF/g/24 hrs)	Alkaline phosphatase (ug p-NP g^{-1} soil hr^{-1})	SMBC (ug/g soil)	CO_2 evolution (mg/100g soil/24 hrs)
50% NPK	61.5	36.1	138	224	37
100% NPK	64.2	37.2	144	241	41
150% NPK	73.8	45.5	157	294	52
100% NPK+HW	66.6	39.2	145	250	43
100% NPK + Zn	68.2	40.1	150	271	46
100% NP	65.8	38.7	143	234	40
100% N	59.3	34.5	134	209	37
100% NPK+FYM	75.9	49.8	159	303	53

100% NPK –Sulphur	69.1	39.8	143	233	41
FYM@10t ha^{-1}.	67.2	43.5	147	288	51
Control	56.8	31.4	133	204	34
Fallow	54.7	34.9	130	215	31
LSD (*P*≤0.05)	2.01	1.20	3.74	11.5	5.3

4.5.13 Akola

Microbial Count

The highest population of bacteria (30.52 cfu × 10^7 g^{-1} soil), fungi (15.5 cfu × 10^4 g^{-1} soil) and actinomycetes (16.25 cfu × 10^4 g^{-1} soil) was recorded with 100% NPK + FYM @ 10 t ha^{-1} followed by treatment 150% NPK (13.5 cfu × 10^4 g soil) (Table 4.55). Though application of FYM @ 10 t ha^{-1} was not able to yield as high as 100% NPK but registered considerably higher count of bacteria, fungi and actinomycetes. Application of 100 NPK, 100% NPK along with S and NPK+Zn also found equally beneficial for proliferation of bacteria, fungi and actinomycestes.

Table 4.55 Long term effect of manures and fertilizers on microbial population at harvest of sorghum

Treatment	Bacteria (cfu ×10^7)	Fungi (cfu ×10^4)	Actinomycetes (cfu × 10^6)
50 % NPK	9.52	7.25	6.02
100 % NPK	15.54	11.25	11.75
150 % NPK	22.75	13.25	13.50
100 % NPK S free	14.75	12.02	10.52
100 % NPK + Zn @ 2.5 kg ha^{-1}	17.75	11.52	11.99
100 % NP	13.02	8.25	8.75
100 % N	8.75	6.25	5.75
100 % NPK + FYM @ 5 t ha $^{-1}$	30.52	15.54	16.25
100 % NPK + 37.5 kg S ha $^{-1}$	20.25	9.01	12.25
FYM @ 10 t ha $^{-1}$	22.53	12.55	13.04
75% NPK + 25% N through FYM	12.52	7.75	10.03
Control	6.25	4.52	5.08
LSD (*P*≤0.05)	2.05	1.94	1.74

Biological Properties

Respiration rate and enzymatic activities in soil indicate the activity of micro organism in soil. Data (Table 4.56) revealed that soil biological properties (CO_2 evolution, SMBC, DHA and soil urease) are influenced significantly with the application of 100 % NPK + FYM @ 5 t ha^{-1}. The application of 100% NPK + FYM @ 5 t ha^{-1} resulted significant increase in CO_2 evolution, SMBC, DHA and soil urease to the extent of 42.63 mg 100 g^{-1},281 mg kg^{-1}, 55.10 µg TPF g^{-1} 24 h^{-1} and 64.36 ug/g/24 hrs, respectively. Larger evolution of CO_2, higher activity of DHA and urease were under INM and organic treatment is mainly due to addition of biomass through organic residues (plant root stable) which acts as substrate for organism and stimulates the indigenous soil micro biota

Table 4.56 Long term effect of various treatments on soil biological properties under sorghum-wheat cropping sequence (2011-12) (24th cycle)

Treatments	CO_2 evolution (mg 100 g^{-1})	SMBC (mg kg^{-1})	DHA (µg TPF	Soil urease activity

			g^{-1} 24 h^{-1})	ug/g/24 hrs
50% NPK	29.98	201	43.21	48.13
100% NPK	32.45	223	46.92	55.69
150% NPK	41.25	244	52.34	59.94
100% NPK S free	30.25	219	46.07	54.96
100% NPK + Zn @ 2.5 kg ha^{-1}	33.83	239	49.04	58.09
100% NP	27.50	202	43.84	53.30
100% N	25.85	190	42.46	52.19
100% NPK + FYM @ 5 t ha^{-1}	42.63	281	55.10	64.36
100% NPK + 37.5 kg S ha^{-1}	36.58	241	50.32	57.54
FYM @ 10 t ha^{-1}	40.15	255	52.97	63.07
75% NPK + 25 % N through FYM	39.33	241	52.76	60.12
Control	19.53	125	38.53	39.65
LSD (*P*≤0.05)	4.34	15.9	1.63	4.99

4.5.14 Bhubaneshwar

Microbial Population

Post *rabi* soil sample from some selected treatments were taken to study the effect of treatments on bacteria, fungi and actinomycetes population (**Table** 4.57). In general, application of nutrients has beneficial effect on proliferations of soil microorganism. Highest bacterial population of 12.77 X 10^7 cfu $g^{-1}$was observed with the treatment receiving 100% NPK + FYM + lime but the fungal population was found to be highest in the treatment receiving 100% NPK+FYM. Application of lime had adverse effect on fungus and actionomycetes.

Table 4.57 Effect on microbial population (cfu g^{-1}) under long term treatments at Bhubaneshwar

Treatment	Bacteria (x 10^7)	Fungus (x 10^5)	Actinomycetes (x 10^5)
50% NPK	5.13	6.6	1.77
100% NPK	6.20	7.45	1.42
100% NPK +FYM	8.75	7.23	3.03
100% NPK + FYM + Lime	12.77	5.9	0.32
100% NPK +Lime	10.70	5.32	0.47
Control	5.78	4.6	0.92

Nematode population

To study the effect of treatments on nematode population post *rabi* soil samples from selected treated were taken. It was revealed that fertilizer application suppressed the nematode population (Table 4.58). Combined use of optimal dose of NPK fertilizer and FYM proved more effective in controlling the nematode population. Saprophytic nematodes were found to be more than the more harmful -parasitic nematodes. Larger number of nematodes in control plot supports that application of fertilizer helped in controlling the nematodes.

Table 4.58 Effect of manurial treatments on nematodes population (nos. 250 cc^{-1} of Soil)

Treatment	Saprophytic Nematode population	Parasitic Nematode	Total Nematode

50% NPK	684	294	978
100% NPK	987	485	1472
100% NPK + FYM	795	253	1048
100 % NPK +FYM+Lime	930	291	1221
100% NPK+Lime	449	334	783
Control	1223	626	1849

Enzymatic activities

To study the effect of manurial treatments on the activity of soil dehydrogenase, urease and phosphatase post kharif soil samples (2011) were analyzed and the results are presented in table 4.59. Data revealed that application of N alone had adverse effect on activity of dehydrogenase and urease, whereas it does not have much effect on phosphatase activity. In general, nutrient application has increased the activities of these enzymes which is due to increase in soil micro-organism count.

Table 4.59 Effect of long term manuring on soil dehydrogenase, urease and phosphatase activity

Treatment	DHA (mg TPF kg^{-1} soil 24 h^{-1})	Urease (mg.NH_4-N kg^{-1} soil 2 h^{-1})	Phosphatase (mg p-nitrophenol kg^{-1} soil 1h^{-1})
50% NPK	178	50	420
100% NPK	192	73	271
150% NPK	86	52	317
100% NPK + FYM	246	79	452
100% N	89	64	302
100% NP	240	75	316
100% NPK + Lime	159	54	436
Control	174	36	243
LSD (*P*≤0.05)	15.10	19.05	12.63

4.6 Special Studies from LTFEs

4.6.1 Jabalpur

Studies on Disease Intensity of Rhizoctonia Aerial Blight (RAB):

Observations on disease intensity of Rhizoctonia aerial blight, were recorded in the on going Long Term Fertilizer Experiment to assess the effect of various fertilizer doses. No plant protection measures were made. Data on disease severity, yield/plot and 1000 seed weight were recorded.

Calculation of Percent Disease Index (PDI)

Ten randomly selected plants in each treatment (plot) and each selected plant was approximately divided into three positions as bottom, middle and top. From each position three to five leaves were graded as per the following diseases assessment key of Mayee and Datar which is mainly based on the percent leaf area infected (0 to 9 scales).

Rating scale (Grade)	Description (visual observation)
0	No lesions/spots

1	1% of the leaf area covered with lesions/spots
3	1.1 to 10% of the leaf area covered with lesions/spots, no spots on stem.
5	10.1 to 25% of the leaf area covered no defoliation-little damage.
7	25.1 to 50% of the leaf area covered, some leaves drop, death of a few plants, damage conspicuous.
9	>50.1 % of the leaf area covered, lesions/spot vary common on all plants, defoliation common, death of plants common, damage more than 50%

These grades were then utilized for the calculation of PDI using the following formula :

$$\textit{Percent Disease Index (PDI)} = \frac{\textit{Sum of individual rating}}{\textit{No. of leaves examined}} X \frac{\textit{100}}{\textit{Max. disease rating}}$$

On the basis of PDI, the entry / variety was classified as follows:

0.1 - 1.0	=	highly resistant
1.1 – 10.0	=	moderately resistant
10.1 – 25.0	=	moderately susceptible
25.1 – 50.0	=	Susceptible
> 50.0	=	highly susceptible

Effect of fertilizer doses on disease intensity of Rhizoctonia Aerial Blight (RAB) and yield of soybean

Effect of nine fertilizer treatments on disease intensity of RAB were recorded at pod filling stage and percentage loss in yield on the basis of yield in protected and unprotected crop were recorded and presented in the table 4.60.

Table 4.60 Effect of different fertilizer doses on disease intensity of RAB and yield of soybean

Treatments	PDI	Yield (kg ha^{-1})		Loss (%)	PDC
		Protected	Unprotected		
50% NPK	15.3	3350	2138	36.2	72.6
100% NPK	20.6	3350	2490	25.7	63.1
150% NPK	30.3	3350	2513	25.0	45.8
100% NPK+HW	18.3	3350	2475	26.1	67.3
100% NPK+Zn	20.0	3350	2488	25.7	64.2
100% NP	35.1	3350	2275	32.1	37.2
100% N	45.2	3350	1625	51.5	19.1
100% NPK+FYM	20.7	3350	2665	20.4	63.0
100% NPK-S	18.5	3350	2313	31.0	66.9
Control	55.9	3350	1200	64.2	-
LSD ($P \leq 0.05$)	3.90		325		

The data (Table 4.60) indicated that PDI (Per cent disease index) ranged between 15.3 per cent to 55.9 per cent. Similarly range of percent loss was between 20.4 to 64.2%. Maximum PDI 55.9% was observed in control. Among treatments, maximum PDI 45.2% was recorded in 100% N, whereas minimum PDI 15.3% was observed in 50% NPK. Observation showed that maximum per cent loss of 64.2 per cent was recorded in control followed by 100%N of 51.5 whereas minimum per cent loss of 20.4 was recorded in 100% NPK+FYM. All the fertilizer doses tested were found significantly effective in reducing the disease severity of RAB in soybean. Per cent disease control over control ranged from 19.1 per cent to 72.6 per cent. Maximum per cent disease control of 72.6 per cent was recorded in 50% NPK followed by 100% NPK-S of 66.9 whereas minimum per cent disease control (PDC) of 19.1 per cent was recorded in 100% N. Two treatments i.e. 100% N and 100% NP had reduced 19.1 and 37.2 per cent disease control over check (no fertilizer) as compared to other treatments. In simple words balanced application of fertilizer develoed resistance in the to fight against RAB.

Effect of RAB on 1000 Seed weight

Effect of various doses of fertilizers on 1000 seeds was studied on the basis of yield in protected and unprotected crop and presented in the table 4.61 and indicated that range of PDI (percent disease index) of nine fertilizer doses was between 15.3 per cent to 55.9 per cent and range of per cent loss was between 16.3 per cent to 21.0 per cent.

PDI (45 per cent) compared to 55.9 per cent in 100% N. Control indicated that application of even N alone also developed resistance ion plant against RAB. The risk of infection further reduced to 35.1 and 20.6 percent on application NP and NPK, respectively.

Table 4.61 Effect of RAB on 1000 seed weight

Treatment	PDI	1000 Seed Weight (g)		Loss (%)
		Protected (g)	Unprotected (g)	
50% NPK	15.3	100	82.8	17.2
100% NPK	20.6	100	82.2	17.8

150% NPK	30.3	100	83.7	16.3
100% NPK+HW	18.3	100	82.3	17.7
100% NPK+Zn	20.0	100	83.2	16.8
100% NP	35.1	100	81.2	18.8
100% N	45.2	100	80.3	19.7
100% NPK+FYM	20.7	100	82.4	17.6
100% NPK-S	18.5	100	82.2	17.8
Control	55.9	100	79.0	21.0
LSD (*P*≤0.05)	3.90		1.94	

4.6.2 Raipur

4.6.2.1 Soil quality assessment

Soil respiro metric study under Rice-wheat system: Monitoring in situ CO_2 fluxes

The CO_2 fluxes were found maximum in wheat field than the rice field. In rice-wheat cropping system CO_2 flux increases till 90th DAT in rice and 77 DAS in wheat than it decreases. CO_2 fluxes were found maximum under 100%NPK + FYM followed by 50%NPK+GM. CO_2 fluxes were more under 100%N alone than balanced (100%NPK) fertilization. In rice field CO_2 fluxes were low up to 50 DAT due to continuous submerged condition. Evening fluxes were more than morning fluxes.

Effect of elevated temperature and soil moisture regimes on CO_2 production

NPK+FYM treatment showed higher CO_2 production in rice and wheat crop followed by 50% NPK+ GM. Application of N alone has higher CO_2 production than balanced application of NPK. Largest CO_2 production was observed at 45 ^oC followed by 35 ^oC and 25 ^oC for both soil moisture condition and crop growth stage. 60% soil moisture results in higher CO_2 production compared to submergence. Comparatively higher CO_2 production was observed at tillering than transplanting stage of rice. CO_2 production increases with days of incubation and was highest in 90th day of incubation than it decreases.

Structural diversity of passive pools of soil carbon:

FTIR analysis of HA of IGKV Raipur, long term fertilizers trials depicts structural variation among fertilizer treatments however analysis of FA does not reveal structural diversity between groups.

Soil microbial community diversity using sole-carbon source utilization pattern (Biolog analysis)

- Significant differences in diversity were observed among Control, 100% NPK, 100% NPK+FYM and 50% NPK+GM treatments on the basis of Shannon diversity Index and evenness, Simpson diversity Index, McIntosh diversity Index and McIntosh evenness whereas no significant differences were observed in control and 100% N alone treatment.
- Principal component analysis (PCA) based on carbon source utilization by microflora of rice field soils indicated that the presence of amendment of green manure causes significant changes in the microbial community, followed by 100%NPK+FYM, 100% NPK and 100%N respectively, as compared with control (C). Also PCA of carbon source utilization pattern showed close clustering among treatment 100% NPK, 100% N and 100% NPK+FYM whereas Control and 50% NPK+GM treatment were placed separately from each other and from the cluster at 78.58 and 8.09% on factor 1 and 2 axis.

- Substrate utilization pattern was observed in Biolog MT plates indicates FYM and GM amended soils efficiently utilizes Urea, lignin, pectin, chitin cellulose, phytic acid, ferulic acid, sodium meta silicate and silicic acid and encourages beneficial growth of microorganisms in the soil .It was also observed that polymers as carbon substrates were efficiently utilized by 100% NPK followed by 50% NPK+GM as compared to control.

C: To make an assessment of the incidence of soil borne diseases and changes in pests and pathogens under the proposed manuring and cropping programme.

Maximum egg mass count was observed in the plots where applied 100 % N (T7) (1) and 100 % NPK + FYM (T8) (1). The ascending order of effect of different fertilizer doses in terms of egg mass count is as follows T1 = T2 = T6 = T9 = T10 < T3 = T4 = T5 < T7 = T8. Maximum adult moth population was observed in the plots supplied with 100 % N (T7) (1.75). The ascending order of effect of different fertilizer doses in terms of adult moth population at tillering stage is as follows T5 < T1 < T2 = T6 = T8 < T3 = T9 = T10 < T4 < T7. Maximum white earhead percent was observed in the plots applied with 100 % N (T7) (45.51%). The ascending order of effect of different fertilizer doses in terms of white earhead percent is as follows T1 < T8 < T6 < T2 < T9 < T5 < T10 < T3 < T4 < T7. Application of N alone or higher doses of N fertilizer resulted in maximum damage to rice crop by stem borer as recorded by egg moss, larvae population, adult moth and number of white ear heads. Treatments are T_1: Control, T_2: 50%NPK; T_3:100%NPK; T_4:150%NPK; T_5:100%NPK+Zn; T_6: 100%NP; T_7:100%N; T_8:100%NPK+FYM; T_9: 50%NPK+BGA; T_{10}:50%NPK+GM.

(A) (B) (C) (D)

Plate 4.1 Showing :- A : Egg mass of stem borer. B : Larvae of stem borer. C : Adult moth of stem borer. D : White ear head

4.6.3 Ludhiana

A new experiment was started to study the effect of integrated nutrient management on crop yield in maize-wheat cropping system. The application of fertilizer significantly increased maize (4.29 t ha^{-1}) and wheat (4.94 t ha^{-1}) yield over the control (2.34 and 2.07 t ha^{-1}, respectively). The maize grain yield improved in the plot received 100% NPK+3t FYM and 75% NPK+10t FYM as compared to 100%NPK treatment (4.34 t ha^{-1}), however this increase was statistically non-significant (Fig. 4.1). Maize grain yield increased significantly with 6t of FYM along with 100% NPK compare to 3t of FYM along with 100% NPK. Similarly, it increased significantly when amount of FYM increase from 6 t to 10 t along with 100% NPK.

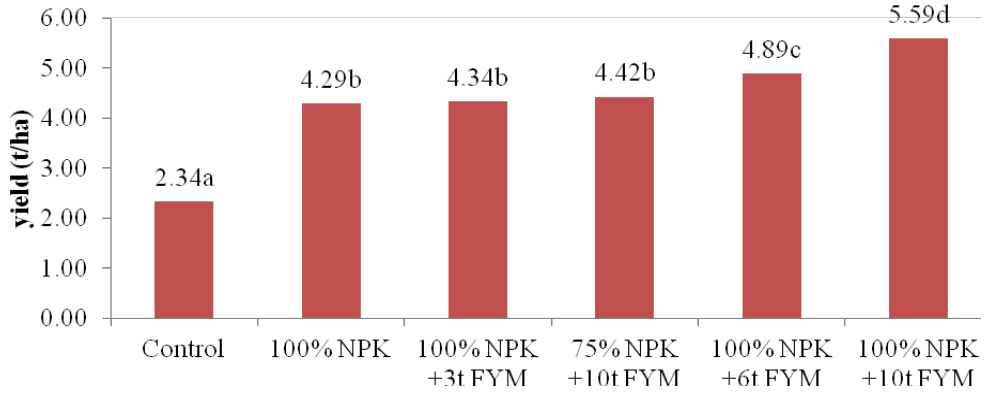


Figure 4.1 Effect of INM on maize productivity

The residual effect of FYM applied on wheat grain was also recorded. However, lower wheat yield (Fig. 4.2) obtained with 75% NPK compared to 100% NPK. The residual effect of 10 t FYM ha^{-1} along with 75% NPK to wheat on grain yield (4.29 t ha^{-1}) was significantly less than the 100% NPK (4.34 t ha^{-1}) treatment. The wheat yield under 100% NPK+ 3 t FYM and 100% NPK+6 t FYM was statistically at par, however the effect of these treatment was significantly higher than the recommended dose of NPK. The maximum wheat grain yield was recorded in 100% NPK+10 t FYM treatment which was significantly higher than the other treatments.

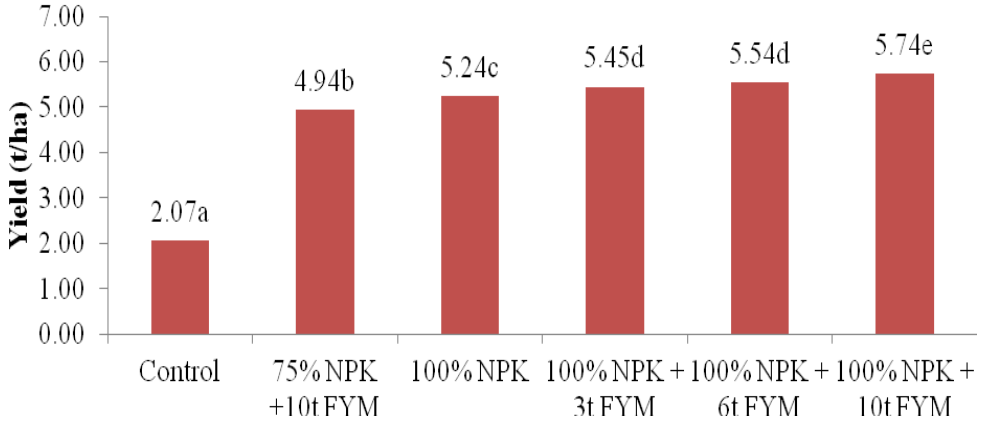


Figure 4.2 Effect of INM on maize productivity

Thus results indicate that 25% substitution of FYM with in 100% NPK does not support subsequent wheat yield with 75% NPK.

5. NUTRIENT DYNAMICS

Nutrient transformation is continuous process that occurs in soil in the presence of moisture. The process is mediated through chemical and biochemical process and change of one form of nutrient to another is termed as nutrient dynamics. Studies conducted on nutrient dynamics are given here under.

5.1 Jabalpur

5.1.1 Nitrogen

Nitrogen is most dynamic in nature which exists in several forms in soils. Nitrogen fractionation (Table 5.1 and 5.2) showed that applications of NPK along with FYM led to significant increase in total N, hydrolysable N (*i.e.,* amino acid N, hydrolyzable NH_4-N, hexose amine N) and non-hydrolysable N in both surface and subsurface soils as compared to control plot. The status of various organic N fractions was higher in surface than the subsurface soils. The results clearly indicated that the subsurface soils in addition to surface soils also substantially contributed to the N requirement of the crops. Increase in total N, available N and inorganic N in 100% NPK, 150% NPK and 100% NPK+ FYM is due to increase in soil organic carbon as a result of larger productivity. Soil Organic Carbon acted as sink to retain N in soil and responsible for maintaining productivity even after 40 years.

Table 5.1 Organic C, total N, available N and inorganic N (kg N ha^{-1}) in surface and sub surface soils under different treatments

Treatments	Total N		Available N		Inorganic-N (NH_4-N+NO_3-N)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
50% NPK	1562.1	1536.5	219.6	176.2	164.3	145.0
100% NPK	1724.8	1620.4	299.8	240.6	176.5	165.0
150% NPK	1818.9	1665.4	312.9	262.7	202.6	180.5
100% NP	1599.4	1464.1	261.6	229.6	172.6	160.3
100% N	1536.8	1357.1	204.7	161.3	169.8	157.3
100% NPK+FYM	1912.9	1780.5	324.8	288.0	219.5	206.5
100% NPK-S	1693.4	1614.6	263.6	230.9	170.0	162.3
Control	1398.1	1224.3	196.9	160.5	143.5	124.5
LSD *(P≤0.05)*	195.8	159.4	18.8	18.5	9.9	10.1

Table 5.2 Total hydrolysable, non hydrolysable and different hydrolysable N fractions (in surface and sub surface soils (kg ha^{-1}) under different treatments

Treatments	Total Hydrolysable N		Non-hydrolysable		Hydrolysable NH_4-N		Amino acid N		Hexose amine N		Unidentified Hydrolysable	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm

50% NPK	1047	935	499	479	310	299	322	311	33	25	422	297
100% NPK	1252	1070	555	533	332	320	349	332	39	32	532	383
150% NPK	1330	1167	573	560	345	335	382	357	45	41	558	434
100%NP	1197	1050	516	493	329	312	340	325	37	29	431	380
100% N	1135	1038	424	412	322	305	328	315	36	28	449	365
100% NPK+FYM	1420	1265	602	685	389	379	417	380	50	46	665	462
100% NPK-S	1194	1060	550	529	330	315	345	329	38	30	481	386
Control	979	721	415	402	291	257	276	255	28	21	385	274
LSD *(P≤0.05)*	87	92	58	44	49	39	50	49	4	6	46	43

5.1.2 Phosphorous

Due to low use efficiency of P fertilizer, it is applied in larger quantity than required by crops. The remaining amount of fertilizer P is fixed in soil and exists in several forms. To trace the path of applied P, fractionation study was carried out at Jabalpur. Perusal of data (Table 5.3) revealed that though applied P has gone to almost all fractions of P but majority of P is fixed in the form of Ca-P followed by Fe-P and Al-P. Due to continuous use significant increase in available P was also noted. Larger accumulation as Ca-P is due to calcareous nature of parent material. Majority of P is accumulated in surface soil and small amount has also gone to sub layers. This is due to churning nature of soil. Vertisols are self ploughed soil and wide cracks are developed during summer season. When the first rain is received a portion of surface soil goes down along the cracks that contribute to subsurface.

Table 6.3 Effect of different treatments on available P and its fractions in different soil depths (cm)

Treatments	Available – P (kg ha^{-1})			Saloid-P (mg kg^{-1})			Al – P (mg kg^{-1})		
	Soil depth (cm)								
	0- 20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
50% NPK	19.0	9.4	6.6	7.6	3.9	3.7	20.3	18.9	14.3
100% NPK	29.4	16.8	8.8	10.3	9.1	8.2	30.2	27.5	20.5
150% NPK	39.6	21.9	9.3	16.2	9.6	9.1	35.7	31.2	21.9
100% NP	28.8	15.9	8.1	10.1	8.3	8.1	28.4	24.0	17.3
100% N	9.7	5.3	4.8	4.0	2.3	1.9	13.2	12.9	9.0
100% NPK+FYM	39.8	22.1	10.3	16.5	11.1	11.1	36.7	31.2	24.6
100% NPK-S	27.3	14.7	7.8	6.0	4.4	3.5	22.4	16.2	10.3
Control	7.9	3.8	3.5	2.7	2.0	1.1	9.5	5.7	2.4
LSD *(P≤0.05)*	3.8	3.2	1.6	2.0	1.4	1.0	3.8	3.4	2.7
Treatments	Fe – P (mg kg^{-1})			Occl-P (mg kg^{-1})			Ca-P(mg kg^{-1})		
	0- 20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
50% NPK	30.6	26.8	18.9	7.3	3.8	3.2	138	136	135
100% NPK	48.0	39.9	34.8	10.2	6.9	5.2	188	184	184
150% NPK	57.2	49.7	47.0	11.5	7.7	5.6	219	216	214
100% NP	43.2	37.2	31.9	8.6	6.4	5.1	181	180	178
100% N	26.8	15.2	12.2	6.4	3.1	1.9	129	128	126
100% NPK+FYM	60.7	54.8	47.0	11.9	8.4	5.7	220	217	217
100% NPK-S	41.0	32.7	27.6	7.5	4.3	3.1	154	150	148
Control	19.6	12.7	8.2	5.1	2.0	1.4	115	110	109
LSD *(P≤0.05)*	6.9	5.5	4.4	1.4	1.1	0.6	29.9	26.1	34.4

5.1.3 Potassium

Like N and P, K also exists in several forms in soils which are in equilibrium with each other and availability of K influenced by these forms. Data on K fractions (water soluble-K, exchangeable-K, non exchangeable-K, lattice-K and total-K) decreased with increasing soil depth up to 60 cm (Table 5.4). The contribution of different K fractions at various soil depths studied was in order of total-K> lattice-K> non exchangeable-K> exchangeable-K> water soluble-K. In spite of application of K in less quantity than uptake, higher K content was noted in 150% NPK and 100% NPK is due to mobilization of K from non-exchangeable due to decomposition of root biomass added in larger quantity. A little decline in non-exchangeable K was noted in 50% NPK, 100% NPK and control which means that K is mined from this fraction when K is not sufficiently applied, which is also reflected in lattice and total K.

Table 5.4 Effect of different treatments on available K and its forms in soil (mg kg^{-1})

Treatments	Available – K			Water soluble – K			Exchangeable – K		
	Soil depth (cm)								
	0- 20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
50%NPK	124	119	113	18.6	16.1	15.6	105	103	97
100%NPK	135	127	120	21.9	18.3	17.6	113	108	102
150%NPK	142	138	132	22.8	20.6	19.5	119	117	112
100%NPK+FYM	148	143	138	24.9	22.8	22.0	123	120	116
Control	101	96	90	15.6	12.1	10.6	86	84	80
LSD *(P≤0.05)*	12.6	7.8	7.9	4.4	2.1	2.9	9.6	8.2	7.1
	Non exchangeable – K			Lattice – K			Total – K		
50%NPK	750	721	705	3933	3409	3132	4807	4249	3950
100%NPK	770	742	724	4035	3507	3421	4939	4375	4265
150%NPK	813	773	763	4353	3656	3447	5307	4567	4342
100%NPK+FYM	885	818	786	4366	3756	3518	5398	4716	4441
Control	736	706	694	3856	3319	2848	4693	4121	3632
LSD *(P≤0.05)*	88	114	85	588	436	437	598	419	459

5.1.4 Sulphur

The distribution pattern of sulphur fractions decreased with increasing soil depth up to 100 cm, irrespective of the treatment (Table 5.5). The organic-S form was found to be more compared to heat soluble-S. The highest concentration of all S fractions was recorded with 100% NPK+FYM followed by 150% NPK, whereas the lowest concentration was in control plot. Irrespective of fractions, concentration of all the fractions of S is higher to values obtained with NPK-S treatment. It could be due to continuous absence of S in fertilizer schedule. Data further revealed that S applied in excess than uptake in largely accumulated in organic form. This could be due to availability of carbon in soil.

Table 5.5 Effect of different treatments on S fractions in soil (mg kg^{-1})

Treatments	Organic sulphur				
	0-20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm
50% NPK	63.25	48.00	42.00	36.25	33.75
100% NPK	69.00	52.50	45.50	40.00	38.25
150% NPK	71.25	65.50	56.75	51.50	45.25
100% NP	53.00	45.25	41.25	34.75	32.50
100% N	48.25	41.50	37.00	30.75	28.50

100% NPK+FYM	79.25	63.75	58.01	51.75	47.25
100% NPK-S	49.00	42.25	38.00	31.00	27.00
Control	45.75	38.75	36.50	29.75	25.10
LSD *(P≤0.05)*	7.35	5.09	4.56	4.43	4.76
Treatments	Heat soluble sulphur (mg kg^{-1})				
50% NPK	34.50	27.25	24.00	21.25	17.75
100% NPK	36.75	29.25	25.00	22.25	19.25
150% NPK	38.00	31.00	28.75	23.25	20.75
100% NP	32.75	26.50	22.75	20.75	15.00
100% N	26.86	24.50	20.25	14.50	9.50
100% NPK+FYM	49.75	32.75	31.25	26.50	21.25
100% NPK-S	27.10	25.25	20.50	15.23	10.32
Control	26.25	23.75	19.00	14.15	8.96
LSD *(P≤0.05)*	5.68	3.85	2.79	3.50	2.73
Treatments	Total sulphur (mg kg^{-1})				
50% NPK	192.25	171.75	159.25	138.25	129.25
100% NPK	203.50	188.75	165.50	148.00	136.00
150% NPK	214.25	193.50	173.75	157.75	141.75
100% NP	198.75	176.25	152.00	140.75	131.00
100% N	153.00	137.50	121.25	109.00	98.00
100% NPK+FYM	236.75	203.25	191.75	178.75	163.75
100% NPK-S	154.25	138.50	123.75	110.75	101.25
Control	152.75	135.75	120.25	108.25	96.75
LSD *(P≤0.05)*	17.59	20.15	16.14	12.06	11.91

5.1.5 Zinc

Though Zn availability is not a problem in Vertisol of Jabalpur; however, there is need to know different fractions of Zn. The data on Zn fractions (Table 5.6) revealed increases in water soluble and exchangeable Zn on application of fertilizer in balanced form and further increase with incorporations of FYM. This is due to mobilization of Zn from non available form through root biomass. Data further indicated that majority of applied Zn is accumulated in organic and occluded form of Zn which are active source of available pool of Zn.

Table 5.6 Effect of treatments on zinc pools (mg kg^{-1}) in soil profile

Treatments	Water soluble – Zn (mg kg^{-1})					Exchangeable – Zn (mg kg^{-1})				
	Soil depth (cm)									
	0-20	20-40	40-60	60-80	80-100	0-20	20-40	40-60	60-80	80-100
50%NPK	0.072	0.056	0.044	0.037	0.034	0.19	0.17	0.17	0.16	0.16
100%NPK	0.077	0.061	0.049	0.042	0.039	0.20	0.19	0.18	0.18	0.17
150% NPK	0.084	0.069	0.056	0.049	0.046	0.21	0.20	0.19	0.19	0.18
100% NPK+Zn	0.090	0.073	0.062	0.055	0.052	0.30	0.29	0.29	0.28	0.28
100% NP	0.075	0.059	0.047	0.040	0.037	0.20	0.18	0.18	0.17	0.17
100%NPK+FYM	0.086	0.070	0.058	0.050	0.048	0.29	0.28	0.28	0.27	0.27
100% NPK - S	0.074	0.058	0.045	0.039	0.036	0.19	0.18	0.18	0.17	0.17
Control	0.071	0.055	0.043	0.036	0.033	0.18	0.17	0.16	0.16	0.15
LSD *(P≤0.05)*	0.006	0.008	0.004	0.006	0.007	0.02	0.01	0.02	0.03	0.02
	Complexed – Zn (mg kg^{-1})					Organically bound – Zn (mg kg^{-1})				
50%NPK	0.280	0.235	0.185	0.145	0.095	0.740	0.670	0.609	0.569	0.539
100%NPK	0.320	0.250	0.200	0.160	0.110	0.780	0.710	0.649	0.609	0.579
150%NPK	0.332	0.257	0.207	0.167	0.117	0.810	0.746	0.685	0.645	0.615
100% NPK+Zn	0.345	0.275	0.225	0.185	0.135	1.218	1.148	1.087	1.047	1.017
100% NP	0.318	0.248	0.198	0.158	0.108	0.770	0.700	0.639	0.599	0.569
100% NPK+FYM	0.340	0.270	0.220	0.180	0.130	1.203	1.133	1.072	1.032	1.002

100% NPK - S	0.316	0.246	0.196	0.156	0.106	0.760	0.690	0.629	0.589	0.559
Control	0.295	0.225	0.175	0.135	0.085	0.735	0.665	0.604	0.564	0.534
LSD *(P≤0.05)*	0.39	0.027	0.026	0.027	0.029	0.073	0.080	0.081	0.080	0.065
Treatments	Occluded – Zn (mg kg^{-1})					Residual – Zn (mg kg^{-1})				
50%NPK	1.310	1.260	1.230	1.220	1.190	46.66	43.60	40.26	38.12	34.98
100% NPK	1.340	1.290	1.260	1.250	1.220	48.16	46.85	43.51	41.37	38.23
150% NPK	1.390	1.340	1.310	1.300	1.270	51.41	48.35	45.01	42.87	39.73
100% NPK+Zn	1.600	1.550	1.520	1.510	1.480	55.41	52.36	49.01	46.86	43.72
100% NP	1.360	1.310	1.280	1.270	1.240	47.42	45.35	41.01	38.85	35.73
100% NPK+FYM	1.490	1.440	1.410	1.400	1.370	53.43	50.33	47.01	44.86	41.71
100% NPK - S	1.350	1.300	1.270	1.260	1.230	48.40	45.32	42.01	39.87	36.74
Control	1.270	1.220	1.190	1.180	1.150	44.41	41.35	38.01	35.87	32.73
LSD *(P≤0.05)*	0.11	0.09	0.08	0.09	0.10	5.45	5.90	5.95	5.67	5.68

5.1.6 Spatial changes in particulate organic carbon

The distribution of particulate organic carbon (POC) contents amongst different fractions of aggregates was merely uniform, however, the higher values were recorded in smaller size aggregates. The concentration of POC was relatively higher in balanced application of fertilizers and manure (Fig. 5.1). The larger proportion POC on application FYM and 150% NPK in due increase in proportion aggregation of different size as a result of addition of root biomass in larger quantity.

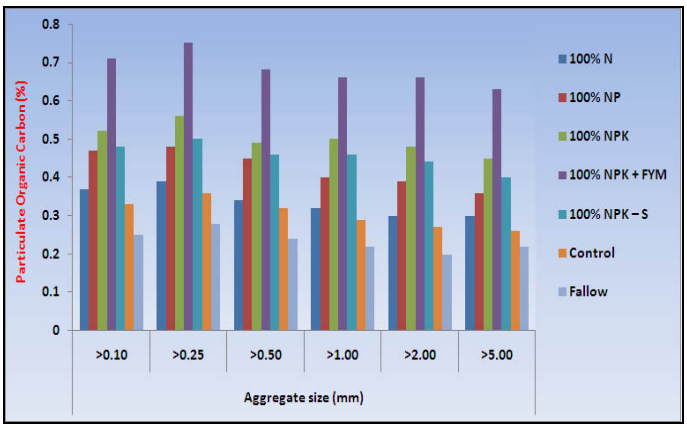


Figure 5.1 Spatial changes in particulate organic carbon

5.2 Barrackpore

Data on fractions of potassium (Fig. 5.2, 5.3, 5.4) revealed that intensive cultivation with inadequate application of potassium adversely affected K nutrition of crops. Therefore, different fractions of potassium and its changes over time were studied in jute-rice-wheat cropping system. With the application of 100% NPK; water soluble, exchangeable and non-exchangeable K in soil decreased after 41 years from initial. The depletion of all forms/fractions of K was highest under NP treatment. The depletion of non-exchangeable K indicates that there was a continuous mining of soil reserve potassium. The result revealed that although the experimental soil is rich in total K, most of the K is present as fixed potassium. Hence, regular application of potassic fertilizer is necessary to reduce the

mining of soil reserve potassium and to avoid the sudden reduction in yield due to decline in available K status.

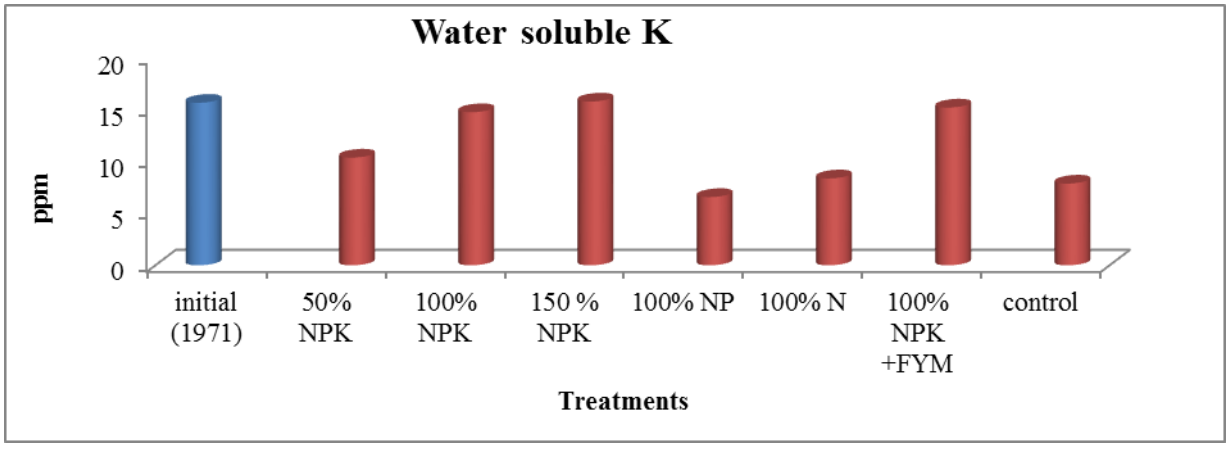


Fig. 5.2 Changes of water soluble K over years

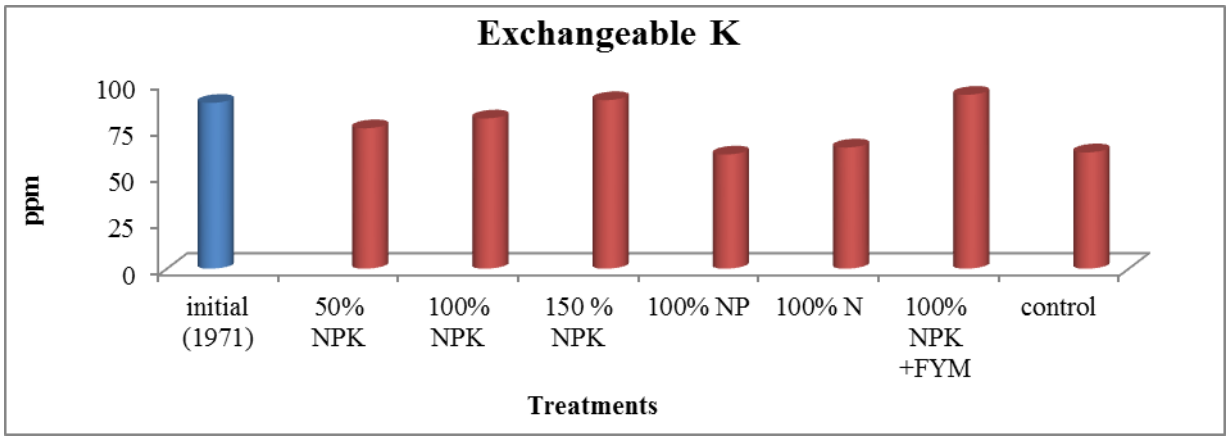


Fig. 5.3 Changes of exchangeable K over years

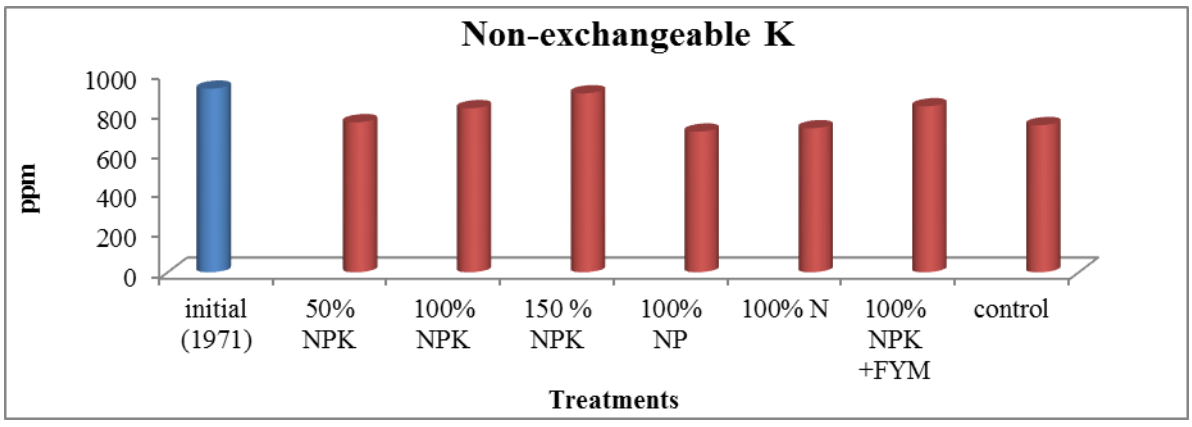


Fig. 5.4 Changes of non-exchangeable K over years

5.3 Bangalore

The initial plant available soil silicon status (Table 5.7) during 1986 was 230.8 kg ha^{-1} which reduced to 185.2, 82.8 and 64 kg ha^{-1}during 1991, 2001 and 2010, respectively. Application of FYM resisted to decline in silicon content to some extent. This could be due to addition of silica through FYM. In control plot silica content is larger than any of the treatment which appears to be due to less uptake of silica by crop because of poor growth. In these soils silica could be a threat in sustaining the productivity in near future. So regular monitoring of silica is needed. In some of the crops Si is highly beneficial element. Data on silica status with time clearly indicated declining trend.

Table 5.7 Plant-available soil silicon (kg ha^{-1}) status in different treatments of long-term fertilizer experiment, Bengaluru

Treatment	Si (kg ha^{-1}) after the harvest of maize				
	1991	1996	2001	2006	2010 (Rabi)
50% NPK	163.5	158.2	138.0	103.0	90.5
100% NPK	185.3	123.2	82.9	60.3	64.5
150% NPK	161.3	113.8	65.3	56.0	57.8
100% NPK+ HW	193.5	187.3	87.1	73.9	77.1
100% NPK+ Lime	205.0	202.1	188.4	162.6	110.7
100% NP	188.2	167.8	121.0	80.9	79.1
100% N	163.7	151.4	93.2	109.8	77.1
100% NPK+ FYM	183.9	185.3	125.7	71.5	132.6
100% NPK(S-free)	190.9	112.2	70.3	85.1	65.9
100% NPK+ FYM+ Lime	180.8	188.2	207.2	180.5	193.8
Control	251.1	203.0	186.1	189.5	194.0
LSD *(P≤0.05)*	33.1	23.3	28.7	14.9	14.6

Initial silica status (1986) = 230.8 kg ha^{-1}

5.4 Jagtial

5.4.1 Nitrogen

In soil N_2 exists in several forms but plant absorb nitrogen in inorganic forms like NH_4 and NO_3. Therefore these two forms are important as far as plant nutrition is concerned. Data (Table 5.8) revealed that low productivity in 100% N and 100% NP plots, appears to be due low content of the content NH_4-N and NO_3 N. Compared to treatment received the same amount of N along with other plant nutrient. Less content of NH_4 – N and NO_3 – N is due to less organic carbon in soil because of poor yield. Soil organic carbon helps in maintaining the equilibrium among different forms of nitrogen through mineralization/immobilization.

Table 5.8 Effect of long term fertilizer application on contents of inorganic N- fractions (mg kg^{-1}) in soil after rice during *rabi* 2010-11 and 2011-12

Treatments	Ammoniacal Nitrogen (NH_4-N)	Nitrate Nitrogen (NO_3 N)	Inorganic N {(NH_4-N)+ (NO_3 N)}
50% NPK	45.8	39.9	85.7
100% NPK	51.7	42.2	93.9
150% NPK	60.2	47.4	107.6
100% NPK + HW	48.3	43.1	91.4
100% NPK + Zn	54.4	43.2	97.6
100% NP	43.4	36.7	80.1
100% N	34.4	30.8	65.2
100% NPK + FYM	66.3	57.4	123.7
100% NPK - S	51.6	46.8	98.4
FYM	52.4	38.6	91.0
Control	37.7	21.9	59.6
Fallow	52.6	48.3	100.9
LSD *(P≤0.05)*	6.41	6.47	12.88
Inital	34.15	32.58	66.73

5.4.2 Phosphorous

Perusal of data (Table 5.9) revealed that due to application of P, accumulation of P was observed in all the four inorganic fraction of P (Saloid – P, Al –P, Fe – P and Ca – P) but majority of was fixed as calcium phosphate. Soils of Jagtial are Vertisols and developed on basaltic materials which are alkaline in nature and calcium is available in large amount which causes fixation of P and reduces the availability of applied P.

Table 5.9 Effect of Long term fertilizer application on contents of Inorganic P fractions (mg kg^{-1}) in soil after harvest of rabi-2011:

Treatments	Saloid –P	Al- P	Fe – P	Ca - P
50% NPK	4.8	77.9	33.9	348.0
100% NPK	5.6	87.2	36.4	367.1
150% NPK	6.2	92.2	40.6	402.9
100% NPK + HW	5.4	86.1	33.5	356.8
100% NPK + Zn	5.6	83.5	40.7	369.2
100% NP	4.3	72.5	36.6	366.1
100% N	3.7	60.6	23.9	232.6
100% NPK + FYM	7.0	104.0	44.2	447.6
100% NPK - S	5.1	90.0	35.2	402.9
FYM	5.5	75.5	38.3	350.8
Control	3.9	39.6	28.2	199.9
Fallow	5.3	99.7	38.3	383.8
LSD *(P≤0.05)*	0.5	7.4	3.4	21.1

5.4.3 Potassium

Data on K forms (Table 5.10) revealed that available K ranged from 72.3 to 108.5 kg mg kg, and non exchangeable K from 637.3 to 942.5 mg kg^{-1}. Application of K maintained more or less similar amount of available K in soil to that of fallow plot maintained side by side. Absence of K in fertilizer schedule resulted in significant decline in non-exchangeable (1 *N* HNO_3-K) which means crop receiving K from non-exchangeable form of K. Therefore, there is need to keep a watch on non exchangeable K in these soil otherwise sudden drop in productivity may be experienced.

Table 5.10 Effect of Long term fertilizer application on contents of K fractions (mg kg^{-1}) in soil after rice during *rabi* 2010 and 2011

Treatments	Water soluble potassium	Exchangeable potassium	Available potassium	1*N* HNO_3 extractable-K
50% NPK	35.5	50.5	85.9	748.0
100% NPK	36.6	51.8	88.4	810.3
150% NPK	35.4	62.8	98.2	838.6
100% NPK + HW	32.6	54.1	86.7	774.7
100% NPK + Zn	32.3	58.3	90.6	743.9
100% NP	28.3	52.9	81.2	704.7
100% N	27.8	44.4	72.3	637.3
100% NPK + FYM	41.6	67.0	108.5	942.5
100% NPK - S	38.0	51.3	89.2	730.4
FYM	40.5	57.2	97.6	826.9
Control	37.2	34.4	71.5	708.5
Fallow	44.6	52.0	96.6	735.3
LSD *(P≤0.05)*	5.43	12.05	10.99	114.4
Initial	55.8	25.4	81.25	964.4

5.5 Palampur

Zinc

The study was also conducted on transformation of Zn into different pools (Table 5.11). The relative contribution of Zn-I, Zn-II, Zn-III, Zn-IV, Zn-V and Zn-VI towards total Zn (Zn-VII) on an average was 0.6, 1.6, 14.4, 5.9, 11.0 and 69.4 per cent in the surface layer, respectively. Continuous application of chemical fertilizers and amendments had significant influence on the non-specifically adsorbed (Zn-I) and specifically adsorbed (Zn-II) zinc contents under various treatments. Continuous application of Zn led to the build up of both the non-specifically adsorbed and specifically adsorbed fractions of the zinc to the extent of 82 and 394 per cent in 100 per cent NPK + Zn treatment, respectively. Organically bound zinc (Zn-III) was highest under Zn treated plots followed by FYM treated plots. Application of lime induced adsorption of non specifically (Zn), specified (Zn II) and organically bound Zn (Zn III) Continuous chemical fertilizers and Zn application increased

all the fraction of Zn. However, amendments had no significant influence on the residual and total zinc content of the soil.

Table 5.11 Long-term effect of fertilizers and amendments on pools of zinc (mg kg^{-1}) in soil

Treatment	Zn-I	Zn-II	Zn-III	Zn-IV	Zn-V	Zn-VI	Zn-VII
(0 – 20 cm)							
50% NPK	0.59	0.87	10.17	5.95	10.51	63.79	91.87
100% NPK	0.68	1.02	10.81	5.69	9.69	64.67	92.56
150% NPK	0.44	1.49	13.94	4.99	9.94	64.97	95.77
100% NPK+HW	0.46	0.99	13.42	5.14	8.96	67.49	96.47
100% NPK+ Zn	0.97	5.45	17.32	6.39	15.70	67.79	113.62
100% NP	0.54	0.95	9.66	6.13	10.07	63.03	90.37
100% N	0.36	1.08	14.61	5.27	9.97	59.95	91.23
100% NPK+FYM	0.71	0.98	14.61	4.93	7.19	58.42	86.83
100% NPK(-S)	0.58	0.88	12.38	6.28	9.33	59.27	88.72
100% NPK+ Lime	0.62	0.97	15.49	4.92	7.35	62.58	91.93
Control	0.46	1.18	11.44	3.09	10.81	62.96	89.93
Buffer	0.53	1.10	14.18	6.66	9.80	66.49	98.77
LSD (P≤0.05)	0.039	0.043	0.021	0.583	1.566	NS	NS
(20 – 40 cm)							
50% NPK	0.49	0.49	8.14	4.83	8.41	55.57	77.93
100% NPK	0.54	0.84	8.96	4.60	7.76	55.76	78.47
150% NPK	0.36	0.96	10.85	3.46	7.79	58.25	81.67
100% NPK+HW	0.43	0.80	10.53	4.01	6.77	56.63	79.17
100% NPK+ Zn	0.92	4.87	15.08	5.15	13.35	60.80	100.17
100% NP	0.44	0.66	8.06	5.03	8.30	54.38	76.87
100% N	0.28	0.85	11.27	4.20	8.14	52.74	77.48
100% NPK+FYM	0.71	0.98	14.61	4.93	7.19	58.42	86.83
100% NPK(-S)	0.49	0.76	10.19	5.08	7.44	56.54	80.50
100% NPK+ Lime	0.51	0.82	13.60	3.64	7.33	52.13	78.03
Control	0.37	0.88	9.56	2.76	8.59	54.08	76.23
Buffer	0.42	0.86	11.18	5.21	7.93	61.91	87.50
LSD (P≤0.05)	0.053	0.123	0.710	0.326	0.653	NS	NS

Zn-I : Non-specifically adsorbed exchangeable; Zn-II : Specifically adsorbed exchangeable; Zn-III : Organically bound; Zn-IV : Manganese oxide bound; Zn-V : Al and Fe-oxide bound; Zn-VI : Residual; Zn-VII : Total

5.6 Akola

Potassium

Even though soils of Akola are rich in K but crop showed response to applied K at higher productivity. Therefore, fractionation study was carried out. Data for different forms of K (Table 5.12 -5.14) indicated decline in all fractions of K with depth except lattice K and total K. It is strange to note that in spite of very high K content in soil, water soluble K is

very low (4 - 7 mg kg^{-1}) that means rate of release from exchangeable to water soluble is very poor and this could be the reason for response of crop to applied K in spite of high K content. Application of K @ 100% and 150% maintained relatively higher K in soluble and exchangeable pool K. Application of FYM also maintained relatively larger amount of available K, probably due to mobilization of K from non exchangeable pool.

Table 5.12 Impact of long-term manuring and fertilization on vertical distribution of different forms of potassium

Treatment	Water soluble K (mg kg^{-1})			Exchangeable K (mg kg^{-1})		
	0-15	15-30	30-45	0-15	15-30	30-45
50% NPK	6.57	6.32	6.21	113.49	107.95	104.86
100% NPK	6.99	6.66	6.57	161.70	156.55	144.25
150% NPK	8.40	8.06	7.95	187.45	183.59	180.27
100% NPK S free	6.94	6.74	6.60	159.12	155.23	140.27
100% NPK + Zn @ 2.5 kg ha^{-1}	7.02	6.88	6.66	165.45	158.76	148.61
100% NP	4.70	4.81	4.98	95.95	100.60	105.04
100% N	4.13	4.33	4.56	93.79	98.36	101.77
100% NPK + FYM @ 5 t ha^{-1}	8.75	8.45	8.34	201.02	193.20	189.44
100% NPK + 37.5 kg S ha^{-1}	7.22	6.96	6.80	162.86	158.37	147.30
FYM @ 10 t ha^{-1}	6.33	6.21	6.05	125.63	118.68	115.26
75% NPK + 25 % N through FYM	6.88	6.63	6.43	139.24	129.25	125.22
Control	3.72	3.83	4.02	74.14	74.70	79.29
LSD *(P≤0.05)*	0.24	0.30	0.28	2.86	2.84	2.76

Table 5.13 Impact of long-term manuring and fertilization on vertical distribution of different forms of potassium

Treatment	Available K (mg kg^{-1})			Non-exchangeable K (mg kg^{-1})		
	0-15	15-30	30-45	0-15	15-30	30-45
50% NPK	120.06	114.27	111.04	769.52	745.24	763.78
100% NPK	168.69	163.21	150.82	824.43	816.78	819.72
150% NPK	192.80	191.90	188.22	912.04	909.04	908.48
100% NPK S free	166.06	161.97	146.87	836.29	832.57	833.39
100% NPK + Zn @ 2.5 kg ha^{-1}	172.47	165.64	155.27	850.52	843.88	847.89
100% NP	100.65	105.41	110.13	702.96	708.98	714.08
100% N	97.92	102.69	106.33	669.72	674.21	683.14
100% NPK + FYM @ 5 t ha^{-1}	209.77	201.65	197.78	944.94	943.60	941.77
100% NPK + 37.5 kg S ha^{-1}	170.08	165.33	154.10	793.99	788.68	791.20
FYM @ 10 t ha^{-1}	131.95	124.89	121.41	761.98	759.77	760.28
75% NPK + 25 % N through FYM	146.12	135.88	131.65	798.00	788.92	785.03
Control	77.88	78.53	83.32	622.54	640.97	657.45
LSD *(P≤0.05)*	2.89	2.86	2.84	11.23	12.13	9.62

Table 5.14 Impact of long-term manuring and fertilization on vertical distribution of different forms of potassium

Treatment	Lattice K (mg kg^{-1})			Total K (mg kg^{-1})		
	0-15	15-30	30-45	0-15	15-30	30-45
50% NPK	12864	11956	12441	13734	12816	13316
100% NPK	14166	13637	13156	15159	14617	14126
150% NPK	16762	16297	15727	17870	17398	16824
100% NPK S free	13142	12213	12748	14144	13208	13728
100% NPK + Zn @ 2.5 kg ha^{-1}	14296	13463	13832	15319	14472	14835
100% NP	7336	7617	7925	8107	8432	8749
100% N	7046	7393	7588	7814	8170	8377
100% NPK + FYM @ 5 t ha^{-1}	17078	16752	16193	18232	17897	17332
100% NPK + 37.5 kg S ha^{-1}	14625	14235	14367	15589	15189	15312
FYM @ 10 t ha^{-1}	11818	11427	10916	12712	12321	11798
75% NPK + 25 % N through FYM	14005	13613	13612	14949	14538	14079
Control	6444	6751	7070	7145	7470	7811
LSD *(P≤0.05)*	106.78	106.52	106.27	120.74	112.20	103.66

5.7 Delhi

5.7.1 Boron

Deficiency of boron is emerging very fast especially in the acidic and calcareous soil. So study on B dynamics is essential to sustain the productivity. A study on boron fraction in three contrast soil was carried out and results are summarized below.

6.7.1.1 Typic haplustept

Total B (Fig 5.5) varied significantly with the treatments ranging between 36.5 and 44.9 mg kg^{-1}. It was significantly higher under NPK+FYM as compared to rest of the treatments. Readily soluble and specifically adsorbed B varied significantly with treatments with being highest (0.82 and 0.86 mg kg^{-1}, respectively) under NPK+FYM and lowest (0.61 and 0.60 mg kg^{-1}, respectively) under N alone. Contribution of this fraction towards total B was highest (2.0%) under unfertilized control and lowest (1.56%) under 150% NPK. No significant effect of treatments was observed on the oxide bound and residual fractions of B, which varied between 1.44 and 1.62 mg kg^{-1}, and 31.0 and 35.8 mg kg^{-1}, respectively. On the other hand, organically bound B showed highest value (5.86 mg kg^{-1}) under NPK+ FYM, whereas it was lowest (2.50 mg kg^{-1}) under control, contributing 13.1 and 6.6%, respectively towards total soil B content in these treatments (Fig. 5.1). As these soils are neither B deficient, nor have excessive B adsorption sites such as $CaCO_3$, oxides or clay content, distribution of B in different fractions is mainly governed by organic matter and B removal by the crops. Higher percentage of organically bound B under NPK+FYM in LTFE-Delhi is possibly due to greater chelation of B by organic matter and subsequent release on decomposition. Substantial increase in readily soluble B under NPK+FYM also appears to be associated with high organically bound fraction.

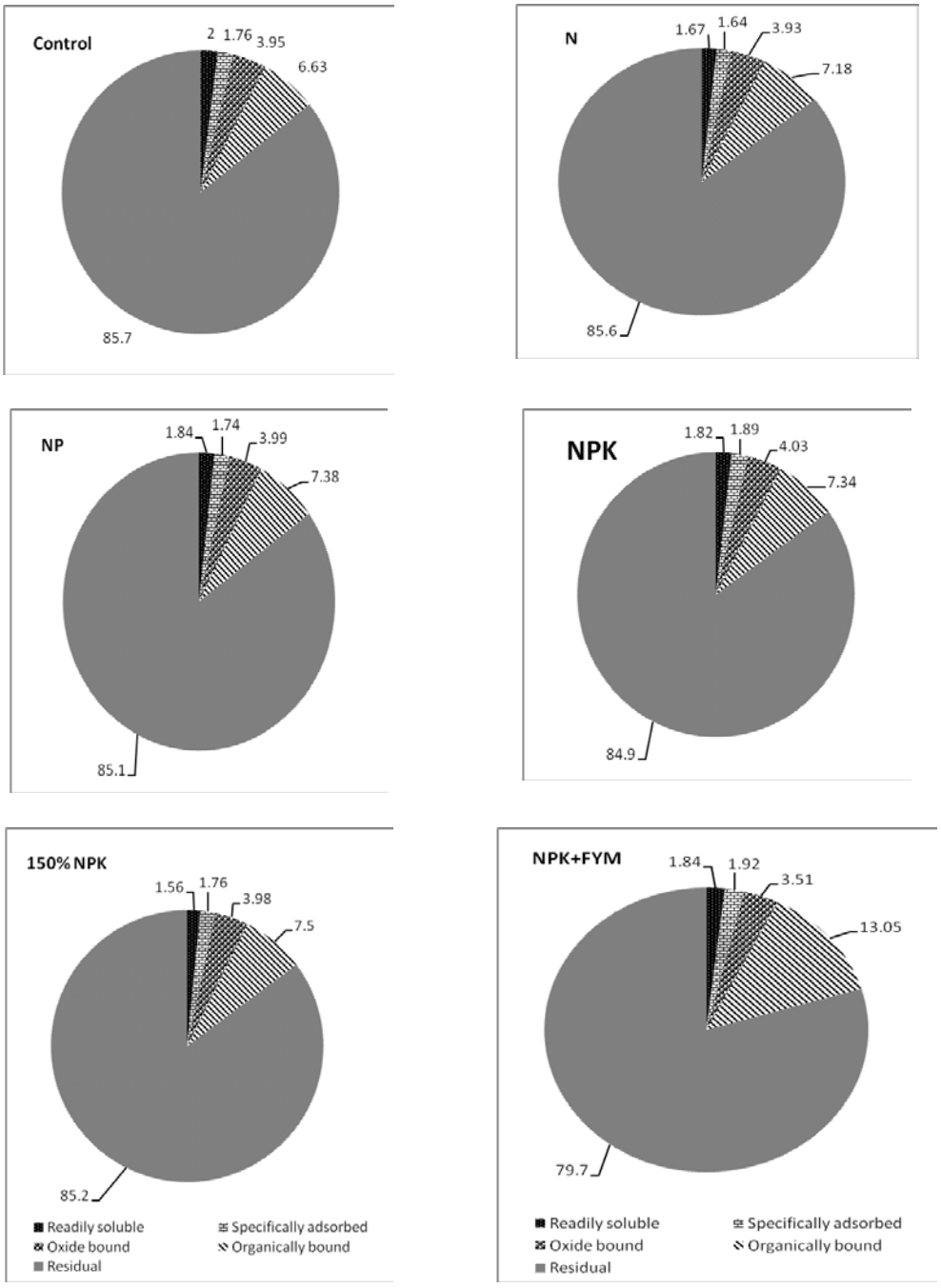


Fig. 5.5 Per cent contribution of different B fractions towards total B content of soil under different nutrient management options on a *Typic Haplustept* (Delhi)

5.7.1.2 Vertic ustochrept

At Junagadh, total B (128-136 mg kg^{-1}), residual B (121-127 mg kg^{-1}) and readily soluble B (0.49 to 0.60 mg kg^{-1}) did not vary with the treatments (Fig 5.2). However, specifically adsorbed and organically bound B fractions varied significantly with treatments and were the highest (1.34 and 4.68 mg kg^{-1}, respectively) under NPK+FYM. Per cent contribution of

organically bound B fraction to total B increased from merely 2.0% in control to 3.4% in NPK+FYM, although the effect of other treatments was not apparent (Fig. 5.6). Very high $CaCO_3$ content (38.9 to 43.0%) at this site possibly masked the treatment effect and also the distribution of B in different fractions other than residual fraction.

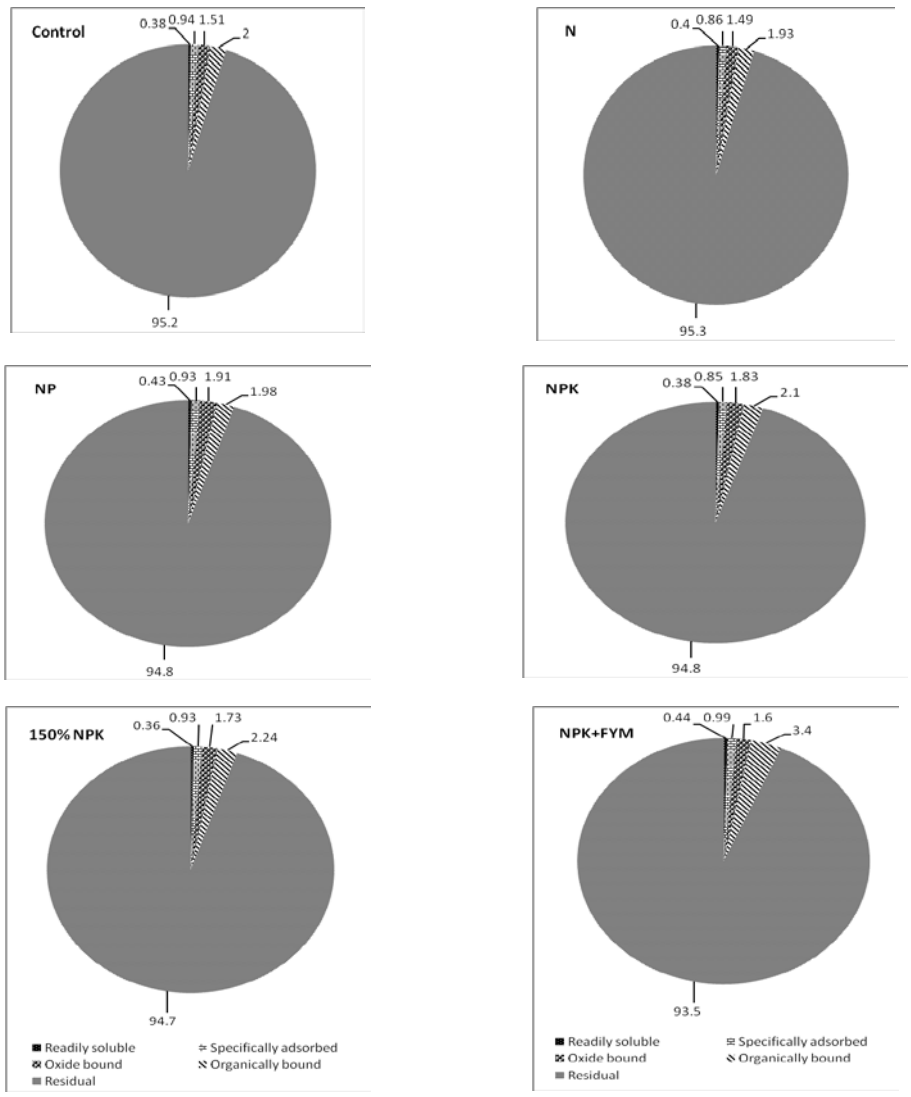


Fig. 5.6 Per cent contribution of different B fractions towards total B content of soil under different nutrient management options on a Vertic Ustochrept (Junagadh)

5.7.1.3 Typic haplustalf

Among the study sites, total B (Fig. 5.7) was the lowest in *Typic haplustalf* of Ranchi, and here also the treatments also did not affect total or residual B. Use of FYM or lime along with NPK brought significant increase in readily soluble, specifically adsorbed and organically bound B, and a significant decrease in oxide bound B compared with N alone or NPK. Increase in readily soluble and specifically adsorbed B consequent to lime

application could be explained in the light of increase in soil pH due to liming, which led to conversion of $B(OH)_3$ to $B(OH)_4^-$. These borate ions get adsorbed non-specifically on clay sites (readily soluble B), as also on specific sites of variable charge surfaces (specifically adsorbed B) which could be extracted by phosphate solution. Higher organically bound B under NPK+FYM was apparently due to high soil organic C content.

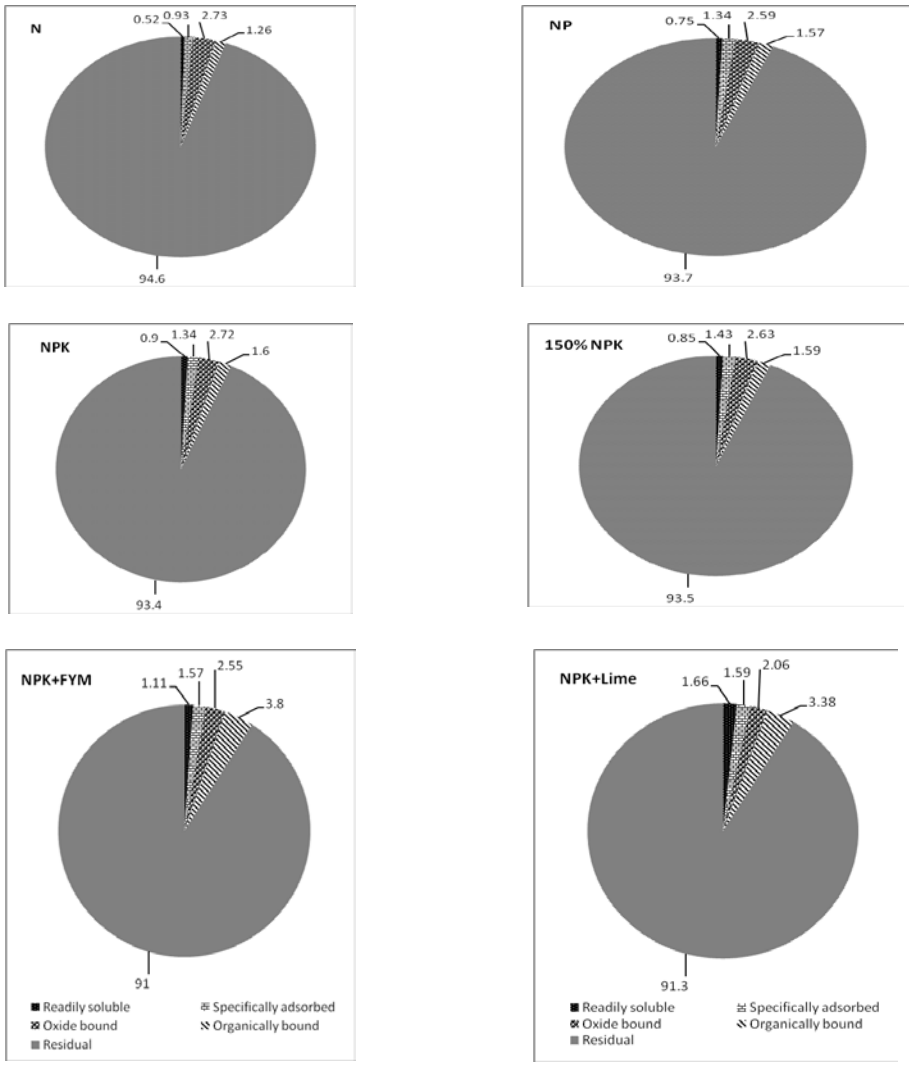


Fig. 5.7 Per cent contribution of different B fractions towards total B content of soil under different nutrient management options on a Typic Haplustalf (Ranchi)

5.7.2 Sulphur

Total S in surface soil (0-15 cm) ranged between 164 and 242 mg kg^{-1}, with highest content in NPK+S plots (Table 5.15). Organic fraction contributes 88 to 93% of total S, and appeared to be the dominant pool. Highest contents of organic and inorganic S fractions were registered in NPK+S followed by NPK+FYM plots.

Apparent S balance

Apparent balance sheet of S was computed by estimating S addition through different sources viz., fertilizers, irrigation and rainfall. Annual S addition to different treatments ranged between 29.8 and 119.3 kg ha^{-1}, whereas total S uptake by both crops ranged between 9.34 and 33.0 kg ha^{-1} (Fig. 5.4). Thus, the apparent balance was positive in all treatments, except 150% NPK. Highest positive balance of 88% kg ha^{-1} was recorded under NPK+S, which was followed by 45.2 kg ha^{-1} under NPK+FYM.

Table 5.15 Effect of long-term fertilization and manuring on S (mg kg^{-1}) distribution in the soil

Treatment	Inorganic S	Organic S	Total S
100% NPK	12.7	172	185
150% NPK	11.5	152	164
100% NP	12.8	172	185
100% N	13.2	177	190
100% NPK+FYM	23.8	199	223
100% NPK+S	29.5	212	242
Control	14.1	179	193
LSD *(P≤0.05)*	1.4	11	12

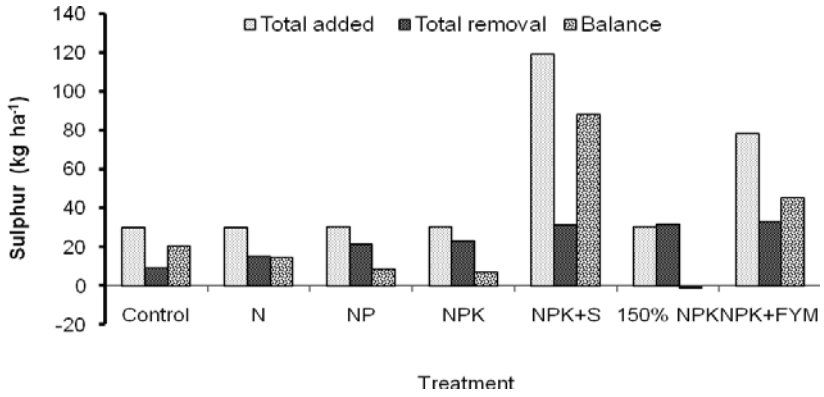


Fig. 5.8 Annual apparent balance of S in soil under long-term fertilization and manuring

6. SUPERIMPOSITION

6.1 Barrackpore

Superimposition of treatments has been started from rice crop in 2011. In one of the replications of four treatments, superimposition of P was undertaken by dividing the phosphorus doses (S_1 = 100% P, S_2 = 2/3rd P and S_3 = 1/3rd P). The grain yield of rice and wheat obtained with the superimposition treatments are shown in Table 6.1. This needs to be continued for at least 5 years before coming to any conclusion. From the result it was observed that highest grain yield of both rice and wheat were recorded where 100% phosphatic fertilizer was added.

Table 6.1 Grain yield (kg ha^{-1}) of rice and wheat of superimposition treatments

Treatments Original	Super imposed	Rice	Wheat
100% NPK	S_1	3061	2785
	S_2	2748	2475
	S_3	2418	2060
150% NPK	S_1	3527	3120
	S_2	3392	2923
	S_3	2934	2677
100% NP	S_1	3093	2515
	S_2	2742	2202
	S_3	2476	1793
100% NPK + FYM (FYM in jute)	S_1	3223	2860
	S_2	2895	2563
	S_3	2602	2342

6.2 Bangalore

6.2.1 Crop yield

Few treatments were superimposed with FYM and lime to achieve the maximum yield. The yield data of finger millet and maize (Table 6.2) revealed that incorporation of FYM and lime over and above 150% NPK and 100% NPK resulted in marginal increase in productivity of finger millet but resulted significant increase in yield of subsequent maize. It is interesting to note that superimposition of FYM and lime on imbalance treatment like 100% N and 100% NP did miracle as far as yields are concerned in both the crops. It could be due to supply of nutrients through FYM and increase in availability of native P and K with lime application. Reduction in P dose to half in the plot having high P due to continuous P application in the past did not have any adverse effect on productivity of both the crops. Thus results indicated that application of nutrient in balance form is the best option to get the potential yield.

Table 6.2 Grain yield (kg ha^{-1}) of finger millet and maize in superimposition treatments at GKVK Bangalore

Treatments	Finger millet			Maize		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean
150% NPK	4647	2577	3612	6085	4199	5142
150% NPK, 5 t ha-1 FYM	4820	2873	3847	7356	4694	6025
150% NPK, 10 t ha-1 FYM	4980	3113	4047	7489	5608	6549
100% NPK	4160	2238	3199	5664	3287	4476
100% N, 50% P, 100% K, FYM	4270	2368	3319	6909	3969	5439
100% N, 50% P, 100% K, FYM, lime	4440	2699	3570	7577	4503	6040
100% NP	808	1091	949	1956	1896	1926
100% N, 50% P, 100% K, FYM	3213	2173	2693	4613	4508	4561
100% N, 50% P, 100% K, FYM, lime	3533	2498	3016	5747	5350	5549
100% N	780	1074	927	1498	1212	1355
100% NPK, FYM	3150	2388	2769	4264	3663	3964
100% NPK, FYM, lime	3650	2665	3158	4734	4285	4510
LSD (*P*≤0.05)	853	194	-	1655	653	-

6.2.2 Soil properties

Perusal of data (Table 8.3) revealed that application of both FYM and lime resulted in improvement of soil properties and moderated soil condition. Data further indicated that little increase in soil organic carbon (SOC) on balanced application of nutrient. However, application of FYM and lime did not show any additional favourable effect on SOC. This is probably due to loss of carbon through respiration due to entrance in activity of microbes due to improvement in soil environment. So far there in no limitation as far as micronutrients status is concerned. However, the content of Ca and Mg is below the critical level. This is the reason why application of lime improved the productivity of maize

Data on soil properties (Table 6.7) indicated that superimposition of FYM moderates soil pH and improved soil organic carbon but did not have any impact in treatment received 150% NPK. Though application of P is reduced to half during past ten years of experimentation but still decline in P was not noted probably due to application of FYM which not only adds but also mobilizes P from reserve sources. A similar trend was also recorded in other nutrient including micronutrient cations.

Table 6.7 Soil properties after harvest of maize in super imposed treatments (2011 -12)

Treatments	pH	EC dSm^{-1}	OC (gkg^{-1})	Av. N (kg/ ha)	Av. P (kg/ ha)	Av. K (kg/ ha)	Av. Ca (kg/ ha)	Av. Mg (kg/ ha)	Av. S (kg/ ha)
T_3 (Imposed in 2005-06)									
150% NPK	5.15	0.14	5.35	366.50	121.88	209.20	5.65	1.85	83.50
150% NPK, 5t/ha FYM	5.30	0.13	5.49	398.05	132.38	210.85	6.15	2.17	108.50
150% NPK, 10t/ha FYM	6.09	0.11	5.43	398.50	132.23	211.00	6.15	3.07	123.00
T_4(Imposed in 2002-03)									
100% NPK	6.16	0.12	5.02	394.00	75.92	151.10	5.42	0.75	82.00
100% N+50%P+100K, FYM	6.16	0.11	5.26	418.50	88.25	167.50	6.70	2.22	88.25
100% N+50%P+100K, FYM, lime	6.18	0.16	5.27	395.00	94.26	172.50	7.20	2.30	84.25

T_6(Imposed in 2002-03)									
100% NP	5.02	0.11	4.97	296.10	81.50	62.75	5.82	2.30	79.50
100% N+50%P+100K, FYM	5.34	0.14	5.27	320.25	85.10	113.15	5.92	2.37	87.00
100% N+50%P+100K, FYM, lime	5.55	0.15	5.29	331.30	98.34	114.00	7.10	3.07	96.00
T_7(Imposed in 2002-03)									
100% N	5.22	0.12	5.10	290.65	49.60	58.00	5.50	1.95	61.00
100% NPK, FYM	5.75	0.10	5.26	314.50	114.00	104.75	6.20	2.95	65.50
100% NPK, FYM, lime	5.77	0.08	5.33	292.27	128.95	109.00	6.80	2.85	73.00
LSD (*P*≤0.05)	0.20	0.030	0.10	4.53	3.87	3.47	0.86	0.92	3.45

Table 6.8 Soil properties after harvest of maize in super imposed treatments (2011 -12)

Treatments	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
T_3 (Imposed in 2005-06)				
150% NPK	34.25	62.00	2.45	2.25
150% NPK, 5 t/ha FYM	35.50	64.00	3.00	2.25
150% NPK, 10 t/ha FYM	38.50	66.50	3.95	2.40
T_4 (Imposed in 2002-03)				
100% NPK	25.95	56.07	2.05	2.55
100% N+50% P+100K, FYM	31.05	62.00	2.15	2.55
100% N+50% P+100K, FYM, lime	36.35	64.00	3.25	2.70
T_6 (Imposed in 2002-03)				
100% NP	29.55	55.00	2.70	2.15
100% N+50% P+100K, FYM	32.90	56.00	3.75	2.45
100% N+50% P+100K, FYM, lime	34.45	64.50	3.90	3.10
T_7 (Imposed in 2002-03)				
100% N	28.75	63.50	2.16	2.10
100% NPK, FYM	31.70	65.00	2.85	3.40
100% NPK, FYM, lime	32.05	69.50	3.70	3.45
LSD (*P*≤0.05)	3.31	3.58	0.083	0.036

6.3 Ludhiana

With the continuous P application, the available P content of soil increased from initial low to high and very high. Therefore, to find out how many crops with optimum yield could be taken with reduced amount of P application on the existing level of residual P, new treatments were superimposed in the one of the previous four replications. By increasing the level of N from present 50% to 100% of the optimum level, the grain yield of both maize and wheat (Table 6.4) increased significantly although the dose of P and K remained at 50% of the optimum level. The reduction of P dose from 100% and 150% to 50% of the optimum level did not have any adverse effect either on maize or wheat yields there by suggesting that the fertilizer P could be saved by 50- 66% (Table 8.4). Maize and wheat grain yield were reducedsignificantly when P was not applied during the ninth crop season.

Table 6.4 Effect of fertilizer application on grain yield of maize and wheat (kg ha^{-1}) under superimposed treatment

Treatment	Maize		Wheat	
	2010	2011	2010-11	2011-12
50% NPK	3590	3740	5150	5230
100% N+50% PK	4310	3930	5020	4970
100% N+50% PK+Zn	4390	4220	4850	5020
100% NPK	4790	4150	5540	5590
100% NK+50% P	4600	4400	5800	5510
100% NK+50% P+Zn	4460	4080	5890	5640
150% NPK	4680	4550	4330	4250
150% NK+50% P	5450	4340	4860	5000
150% NK+50% P+Zn	4950	4530	4730	5110
100% NK	2420	3980	4100	5240
100% NPK(DAP)	4460	4100	3750	4120
100% NPK(DAP)+Zn	4630	4230	4060	5550
LSD (*P*≤0.05)	870	470	1130	

6.4 New Delhi

Superimpositions were made with the objective to provide organics in place of chemical fertilizers partially and completely. Even after 8 years, substitutions of 100% N through FYM and 50% N through FYM could not keep the pace with 100% NPK in none of the treatments (Table 6.5). Less yield on substitution of FYM is probably an availability of nutrients in less quantity due to less mineralization rate of FYM particularly during winter season. The larger yield of both maize and wheat in 100% N plot support the hypothesis.

Table 6.5 Grain yields (kg ha^{-1}) of maize and wheat in super-imposed treatments (2011-12)

Treatment*		Yield (kg ha^{-1})	
Original	Super-imposed	Maize	Wheat
100% NPK +HW	S_1	3480	4790
	S_2	2480	3750
	S_3	2730	3940
	Mean	2900	4160
100% N	S_1	2280	3520
	S_2	2000	2190
	S_3	2150	2360
	Mean	2140	2690
Control	S_1	1400	1950
	S_2	1500	2180
	S_3	1630	2340
	Mean	1520	2160

*S_1= Original treatment; S_2 = 100% N as FYM in both crops; S_3 = 50% NPK + 50% N as FYM to both crops.

6.5 Ranchi

To study impact of lime and FYM in under nourished treatment, the treatments were modified by superimposing FYM and lime. Application of both lime and FYM resulted in improvement in soybean and wheat yield (Table 6.6) but magnitude of increase was more in application of FYM compared to lime because of additional supply of P and K through FYM. A very good positive impact of FYM and ineffectiveness of lime in increasing the yield in 100% N treatment supports the above hypothesis. Lime application moderate soil condition by raising the pH. If P and K availability is less then lime will not work. Whereas FYM not only moderate the soil condition but also supply P and K which is responsible for relatively better yield. The increase productivity on superimposition of both lime and FYM in the plot received nitrogen through ammonium sulphate is due to availability of P and K. Effectiveness of lime is dictated by the P and K content of soil. This treatment is getting P and K continuously and the reduction in yield was due to decline in availability of P and K due to reduction in pH.

Table 6.6 Grain yield (kg ha^{-1}) of soybean and wheat in superimposed treatments

Superimposed treatments	Soybean				Wheat			
	2010-11	2011-12	Mean (2002-11)	% change Mean 2002-11	2010-11	2011-12	Mean (2002-11)	% change Mean 2002-11
100% NP (Original)	591	732			2718	3487	2985	
100% NP+Lime	1210	1265	941	66.98	3556	4171	3639	21.89
100% NP+FYM	2137	1863	1752	210.97	3641	4103	3915	31.15
100% N (Original)	632	109	192		212	376	237	
100% N + Lime	694	684	797	315.71	561	444	641	170.95
100% N + FYM	1863	1638	1668	770.50	1983	2188	1624	586.27
100% N(S)PK	1402	1665	644		2137	2633	1429	
100% N(S)PK +Lime	2308	2034	1979	207.49	3966	4393	3340	133.74
100% N(S)PK +FYM	2359	2325	1723	167.73	3453	3932	2714	89.95
150% NPK	1870	2058	2103		2451	3932	2075	
150% NPK+2.5 t FYM	2154	2017	2335	11.03	2701	4068	2410	16.17
150% NPK+10.0 t FYM	2410	1949	2298	9.25	3231	4410	2646	27.54
LSD ($P \leq 0.05$)	443	259						

7. TECHNOLOGY DEMONSTRATION ON FARMERS' FIELD

Information generated from Long Term Fertilizer Experiment (LTFE) conducted at different locations were synthesized and transformed into technology palatable to farmers. These technologies were demonstrated on farmer's field and the outcome has been given in this section.

7.1 Jabalpur

7.1.1 Soil status

In LTFE at Jabalpur accumulation of P due to continuous use of P fertilizer and hidden hunger of S due to use of DAP was recorded which resulted in decline of productivity, so demonstrations were carried out to reutilize accumulated P and rule out hidden hunger of sulfur. The data (Table 7.1) revealed that the soils of selected FLD's at Jabalpur district are neutral and slightly alkaline in reaction (soil pH), normal in EC, medium to high in organic carbon and available N, medium to high in available K and also high in available P.

Table 7.1 Soil test values at various locations of farmer's fields (2010-11 and 2011-12)

Name of Farmer	Village	pH	EC (dS m^{-1})	OC (g kg^{-1})	Available nutrients (kg ha^{-1})				Zn (mg kg^{-1})
					N	P	K	S	
Magan Patel	Padariya	7.2	0.22	5.9	243	41.3	256	21.8	0.67
Kalu R. Patel	Mahgava	7.3	0.18	5.6	209	20.9	331	19.6	0.63
Bhagwat P. Villoha	Andhua	7.5	0.18	9.36	318	57.0	223	13.6	0.97
Deep Chandra Patel	Singledeep	7.7	0.43	6.27	234	61.8	295	16.2	0.86

7.1.2 Crop yields and B:C ratio

The data revealed that the treatment 100% NPK + FYM resulted in the highest mean yield of both soybean and wheat (Table 7.2), whereas, the lowest mean yield was recorded in farmers' practice. The data further showed that even with 50% P application there was no reduction in yield and yields were better than 100% NPK–S treatment and farmer's practice. The B:C ratio obtained was maximum in 100% NK+50% P and better than rest of treatment. Thus, it is advisable that farmers could go for 50% P with 100% N and K when soil is high in available phosphorous. The practice saved input cost on P fertilizer which adds to the profit of the farmers. Integration of FYM is resulted in highest productivity in all the cases. Lower yield in farmers' practice is due to application of fertilizer in imbalanced form and less quantity of N fertilizer.

Table 7.2 Grain yields (kg ha^{-1}) and B:C ratio of soybean and wheat (2010-11 and 2011-12)

Treatments	Farmer 1		Farmer 2		Farmer 3		Farmer 4	
	Yields	B:C ratio	Yields	B:C ratio	Yields	B:C ratio	Yields	B:C ratio
	Soybean							
	2010-11				2011-12			
100% NPK + 5 t FYM ha^{-1}	2260	2.24	2100	2.01	1975	2.48	1930	2.40
100% NPK+ S	2130	2.31	2062	2.21	1810	2.46	1805	2.45
100% NK + 50% P	2100	2.49	1995	2.32	1780	2.63	1778	2.63
100% NPK-S	1880	2.06	1810	1.95	1750	2.50	1725	2.45
Farmer's Practice (13 : 34)	1480	1.43	1390	1.28	1230	1.48	1183	1.39

	Wheat							
100% NPK + 5 t FYM ha^{-1}	5440	3.21	5380	3.16	5563	3.54	5876	3.36
100% NPK	5250	3.06	5190	3.01	5286	3.24	5489	3.17
100% NK + 50% P	5040	3.15	5050	3.16	5224	3.48	5435	3.39
100% NPK-S	4825	2.93	4930	3.01	5113	3.31	5294	3.23
Farmer's Practice (70 : 34)	4030	2.27	3950	2.21	4127	2.55	4375	2.45

Farmer 1: Magan Patel; Farmer 2: Kalu R Patel ; Farmer 3: Bhagwat P Villoha; Farmer 4: Deep C Patel

100% NPK as 25 kg N, 50 kg P_2O_5 and 30 kg K_2O in soybean and 120 kg N, 58 kg P_2O_5, 30 kg K_2O in wheat

7.2 Barrackpore

Emerged out treatments (balanced and imbalanced) of long term fertilizer experiments viz., 100% NPK + FYM, 100% NPK, 150% NPK and 100% N were taken to the farmers' fields in Goaldaha village of Swarupnagar (Dist. Basirhat) and Karimpur (Dist. Nadia) during 2010-2011 and 2011-12. Trials were taken with jute and rice. It was observed that imbalanced treatment and farmers' practice recorded lower jute fibre and rice grain yield as compared to 100% NPK + FYM, 100% NPK and 150% NPK treatments (Figs. 7.1 and 7.2).

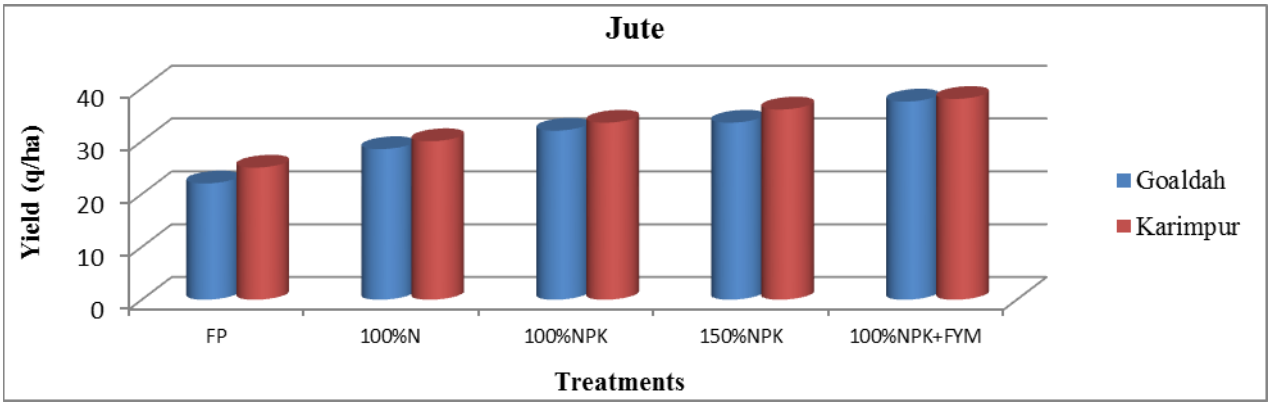


Fig. 7.1 Effect of treatments on jute fibre yield in farmers' field (2010-2011)

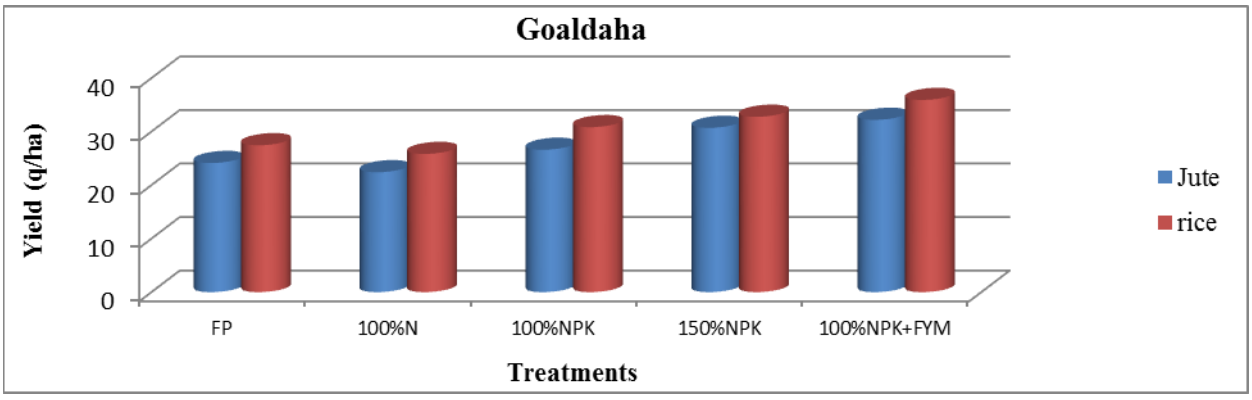


Fig. 7.2 Effect of fertilizer and manure on yield of jute and rice in farmers' field (2011-2012)

7.3 Coimbatore

Field demonstrations were carried out in three villages (Lakshiminagar, Vattamalai palayam, Kareecha-palayam) of Coimbatore district. The soil of experimental site was alkaline in reaction (8.1-8.00), medium to high organic carbon (0.65-0.75%) and phosphorus (18 to 25 kg ha^{-1}) and very

high in K status (600 to 900 kg ha^{-1}). Grain yield data (Table 7.3) revealed that balanced use of nutrient resulted in high yield compared to imbalanced use of nutrient in farmers' practice. The less yield in farmers' practice is due to application of less amount of N and absence of K. Though soils are high in K but because of very high productivity soil is not able to meet out the demand of K in limited growth period of maize is limited and sufficient K is not made available to plant in that short period. In spite of higher cost of cultivation under balanced nutrition compared to imbalanced use of nutrient is due to higher productivity after absorbing the higher cost of cultivation.

Table.7.3 Grain and straw yield (kg ha^{-1}) of maize with application of balance and imbalance nutrients at farmer field.

Demonstration Plots	Farmer 1		Farmer 2		Farmer 3	
	Grain	Straw	Grain	Straw	Grain	Straw
INM (250:75:75)	8765	10215	9143	10824	9336	10999
Farmers Practice (FP) (135:58:0)	4622	7351	5012	7985	5189	8090

Table.7.4 Cost of cultivation, net return and B:C ratio under balance and imbalance use of nutrient

Particulars	Farmer 1		Farmer 2		Farmer 3	
	INM	FP	INM	FP	INM	FP
Cost of cultivation (Rs.)	49414	34032	49414	34032	49414	34032
Total income (Rs.)	101523	54518	105985	59125	108196	61124
Net return (Rs.)	52109	20486	56571	25093	58782	27092
B:C ratio	2.05	1.60	2.14	1.74	2.19	1.80

7.4 Bangalore

Field demonstrations were conducted at farmer's field to evaluate the nutrient management practices compared to farmer's practice. The data (Table 7.5) observed at different locations of rural Bangalore district, it was noted that application of 150% NPK integration of FYM with fertilizer (NPK+FYM) and STCR based fertilizer application resulted in almost at par yield of finger millet which found better than farmers' practice. The lower production in 100% NPK treatment indicated that amount supplied is not sufficient to harness the potential yield of finger millet. Therefore, there is need to revise the fertilizer recommendation for finger millet which is now emerging as one of the special crop in the area because of its high nutritive value.

Table 7.5 Evaluation of efficiency of most sustainable fertilizer practice on yield of finger millet (q ha^{-1}) on farmer's field

Treatments	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Mean
150% NPK	48.1	48.6	55.1	37.3	47.3
100% NPK+ FYM @ 15 t ha^{-1}	47.8	44.8	57.7	35.5	46.5
STCR Recommendation C	48.7	47.4	52.0	31.8	45.0
Farmers' Practice C	40.2	41.2	28.3	30.3	35.0
100% NPK (Control)	48.1	43.5	46.0	30.9	42.4

Farmer 1: Ranganath (Mallonahally; DB pura); Farmer 2: Ramegowda (SonnenaHalli ; DB pura); Farmer 3: Nagaraj (Bycha pura ; Devanahalli); Farmer 4: Topaiah (Vaddarahalli; DB pura)); (100% NPK 100 kg N, 50 kg P, 50 kg K ha^{1} Farmer Practice 60 kg N, and 58 kg P; STCR 125 kg N, 40 kg P, 50 kg K)

Perusal of data (Table 7.6) revealed that increase in K dose to double invariably resulted increase in yield of finger millet at all the four places where reduction in P dose to half did not have adverse effect on two locations out of four. Positive effect of lime was seen where the availability of native P and K was less other wise lime did not improve the yield over higher dose of K (100%). Application of FYM irrespective of sites resulted increase in productivity. Thus results indicated that to harness the potential yield of hybrid finger millet FYM is an essential input which rules out hidden hunger of micro and secondly nutrient.

Table 7.6 Evaluation of alternate strategies of fertilizer use and their impact on yield of finger millet crop in farmer's field

Treatments	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Mean
100% NPK (Control)	48.1	43.5	46.0	30.9	42.1
100% N :50% P: 100% K	50.7	33.6	46.8	33.9	41.2
100% N :50% P: 200% K	60.3	46.8	58.1	35.3	50.1
100% N :50% P: 100% K + Lime	56.7	43.6	58.4	32.7	49.4
100% N :50% P: 100% K + FYM @ 7.5 t ha^{-1}	53.6	47.4	62.0	40.6	50.9

Perusal of economic data revealed that benefit: cost (B: C) ratio ranged from 4.41 to 3.02 in various treatments (Table 7.7). The highest B: C ratio was obtained in 100% NPK treatment and declined was noted with increase in amount of fertilizer and incorporation. Reduction in P dose to half led to increase in B: C ratio by 0.2 unit, which is due to reduction in input cost on P fertilizer though net profit was less than 100% NPK

Table 7.7 Cost of cultivation on Evaluation of efficiency of most sustainable fertilizer practice on yield of finger millet on farmers' field

Treatments	Grain yield (q ha^{-1})	Gross return (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
150% NPK	47.3	99330	20418	78912	3.86
100% NPK+ FYM@ 15 tha^{-1}	46.5	97650	26782	70868	2.65
STCR Recommendation	45.0	94500	26500	68000	2.66
Farmers, Practice	35.0	73500	18253	55247	3.02
100% NPK (Control)	42.4	89040	17010	72030	4.23
100% N :50% P:100%K	41.3	86730	16010	70720	4.41
100% N :50% P:200%K	50.1	105210	19768	85442	4.32
100% N :50% P:100%K+Lime	49.4	103740	20072	83668	3.20
100% N :50% P:100%K+FYM @ 7.5 t ha^{-1}	50.9	106890	26572	80318	3.02

1 kg N = 11.50 (Urea), 1kg P=20.00 (SSP), 1kgP=21.60 (DAP), 1 kg K=16.56, Ragi seeds 1Kg=Rs.21.00, FYM 1kg=1.00

7.5 Jagtial

Field demonstrations conducted on farmer's field during 2010-11 and 2011-12 revealed that farmer's are using fertilizer in fairly large amount and getting good yield (Table 7.8 and 7.9). On an average farmer's are getting yield of rice to the tune of 6.2 to 6.4 t ha^{-1}. However, increase in fertilizer quantity to 150% further increased the yield by 2 q in kharif and 4 q ha^{-1} during rabi. The data indicated that there is a need to increase the dose of N by keeping P and K at the level (100%) to enhance the productivity. As far as gross return is concerned, there is no change with increasing the dose of fertilizer in spite of increase in yield (150% NPK). However, increase in gross return in

possible by withholding P and K application especially during rabi season. Increase in net return as a result of increase in productivity is offset by fertilizer cost.

Table 7.8 Pooled rice yield (kg ha^{-1}) at Jagtial (ANGRAU Hyderabad) during kharif 2010-11 and 2011-12

Treatment	N-P_2O_5-K_2O (kg ha^{-1})	Grain yield (q ha^{-1})	% Yield increase over FP	Fertilizer cost (Rs. ha^{-1}) (A)	Gross returns (Rs. ha^{-1}) (B)	Net returns (Rs. ha^{-1}) (B-A)
Farmers' practice	109-58-38	6219	-	4,490	68,720	64,230
RDF	100-50-40	6294	1.2	4,896	69,549	64,653
150% RDF	150-75-60	6451	3.7	6,877	71,284	64,407
150% N + 100% PK	150-50-40	6374	2.5	5,332	70,433	65,101

Grain cost in Rs. 1105 per q

Table 7.9 Pooled rice yield (kg ha^{-1}) during rabi 2010-11 and 2011-12

Treatment	N-P_2O_5-K_2O (kg ha^{-1})	Grain yield (q ha^{-1})	% Yield increase over FP	Fertilizer cost (Rs. ha^{-1}) (A)	Gross returns (Rs. ha^{-1}) (B)	Net returns (Rs. ha^{-1}) (B-A)
Farmers' practice	109-58-38	64.15		4,833	70,565	65,732
RDF	120-60-40	64.67	0.8	5,014	71,137	66,123
150% RDF	180-90-60	68.63	7.0	7,522	75,493	67,971
150% N + 100% PK	180-60-40	73.72	14.9	5,781	81,092	75,311

Grain cost in Rs. 1100 per q

7.6 Raipur

Field demonstrations were conducted in Durg. Dhamtari, Mahasamund and Janjgir-Champa districts of Chattsgarh. Rice (*cv* MTU 1010, Swarna, HMT etc) was planted on different farmers fields during June to August, 2011. The FLDs were conducted on farmers' field with treatments namely: T_1 - Farmer's practice (FPD); T_2 - Application of sole N source; T_3 - Application of fertilizer as per RDF; T_4 - Application of fertilizer as per RDF + FYM.

Data (Table 7.10) revealed that farmer's are getting less yield in general because of use of fertilizer in less quantity than required. Many of the farmer's are using only urea which further declined the productivity of rice. The use of fertilizer in balanced amount resulted harassing the potential yield. On an average 15 to 20 quintal increase in productivity can be achieved by normally application of fertilizer nutrient in right quantity. In all the three targeted district 31 to 47 percent increase in productivity rice over farmer's practice may be enhanced. Incorporation of 5 t FYM further increased the productivity 13 to 20 per additionally. Thus result clearly showed that there is good scope to enhance the productivity in the area by managing the nutrients. Increase in productivity will improve the economic condition of farmer's of the region in addition to national food security.

Table 7.10 Mean grain yield of rice in relation to different treatments at farmers at different district

Treatments	Farmer 1	Farmer 2	Farmer 3	Mean	% increased over FPD
	Durg District				
FPD (65:40:15)	36.45	33.78	-	35.11	-
Sole N 120 K	27.24	24.95	-	26.09	(-)25.69
RDF (120:60:40)	46.44	45.71	-	46.07	31.23
RDF+FYM (5 t FYM)	50.56	51.15	-	50.85	44.84
	Dhamtari District				
FPD (65:40:15)	37.50	36.25	35.16	36.30	-
Sole N 120 K	25.33	28.20	26.58	26.70	(-)26.43
RDF (120:60:40)	47.50	45.50	55.13	49.37	36.00
RDF+FYM (5 t FYM)	53.25	55.00	56.87	55.04	51.62
	Janjgir-Champa District				
FPD (65:40:15)	30	32	28	30	-
Sole N 120 K	25.00	28.00	27.00	25.66	(-)14.46
RDF (120:60:40)	45.50	44.00	43.13	44.21	47.36
RDF+FYM (5 t FYM)	50.25	49.00	51.87	50.37	67.9

7.7 Palampur

In order to demonstrate the technology generated under this experiment, ten field demonstrations were laid out at farmers' fields under irrigated conditions, five each in district Hamirpur and Bilaspur on maize and wheat on integrated nutrient management package during 2010-11 and 2011-12. In total, twenty demonstrations were laid out per year.

The average yield data (Table 7.11) revealed that INM treatment (100% NPK + FYM) recorded higher maize yield compared to farmers' practice at both the districts during both years. Per cent increase in maize yield due to INM treatment over farmers' practice was 106 and 69 at Hamirpur and Bilaspur, respectively during 2010. Similarly, in both the districts the INM treatment out yielded farmers' practice in case of wheat. The per cent increase in wheat yield due to INM treatment over farmers' practice at Hamirpur and Bilaspur was 116 and 110%, respectively, during 2010-11 and during 2011-12 the respective per cent increase was to the tune of 92.4 and 140.2.

Table 7.11 Effect of integrated nutrient management on productivity of maize at farmers' fields

District	Maize grain yield (kg ha^{-1}) (2010) (*Average of five farmers*)		Maize grain yield (kg ha^{-1}) (2011) (*Average of five farmers*)	
	Farmers' Practice	INM (100% NPK+ FYM)	Farmers' Practice	INM (100% NPK+ FYM)
Hamirpur	19.5	40.1	22.50	41.81
Bilaspur	21.4	36.2	24.57	45.38
Average	20.5	38.2	23.54	43.60
B:C Ratio	1.15	2.02	1.32	2.32

In order to calculate B:C ratio, total returns for each crop were also calculated during both the years (Table 7.12). The INM treatment comprising of 100% NPK + FYM demonstrated higher B:C ratio in

both the crops. In maize crop, the B:C ratio in this treatment was 2.02 against 1.15 in Farmers' practice during 2010, whereas in 2011 the B:C ratio in case of INM treatment was 2.32 against 1.32 in case of farmers' practice.

Table 7.12 Effect of integrated nutrient management on productivity of wheat at farmers' fields

District	Wheat grain yield (q/ha) (2010-11) (*Average of five farmers*)		Wheat grain yield (q/ha) (2011-12) (*Average of five farmers*)	
	Farmers' Practice	INM (100% NPK+ FYM)	Farmers' Practice	INM (100% NPK+ FYM)
Hamirpur	11.6	25.1	13.88	26.63
Bilaspur	12.4	26.1	12.56	30.17
Average	12	25.6	13.22	28.40
B:C Ratio	0.96	1.94	1.05	2.15

In case of wheat crop the B:C ratio for the INM treatment was 1.94 and for Farmers' practice it was 0.96 during 2010-11. The values of B:C ratio were 2.15 for INM treatment and 1.05 for Farmers' practice during 2011-12. It is clear from the results that for both the crops B:C ratio was higher for INM treatment compared to Farmers' practice during both the years. The farmers' practice was not found economically viable.

7.8 Akola

7.8.1 Crop Yield

Application of recommended dose of NPK along with FYM @ 5 t ha^{-1} to sorghum and recommended dose of NPK to wheat recorded higher sorghum yield (3973 kg ha^{-1}) and wheat (2588 kg ha^{-1}) in sorghum - wheat cropping sequence (Table 7.13). The adoption of farmers' practice, in which application of K was skipped, resulted in 36.74 and 30.4% decrease tha RDF + FYM @ 5 t ha^{-1} in sorghum and wheat, respectively, indicating role of potassium in the sequence. Inclusion of DAP as a source of P in the fertilizer schedule, also considerably reduce the yield of sorghum and wheat, such decrease in the yield was reported to the extent of 12.86 and 5.88%, respectively as compared to SSP as a source of P. The results indicated that application of K and S are essential to get the potential yield.

Table 7.13 Effect of various treatments on grain yield of sorghum and wheat under sorghum-wheat cropping sequence

Treatments	Yield (q ha^{-1})			
	Sorghum		Wheat	
	Grain	Fodder	Grain	Straw
Farmers' practice (control) (-K)	25.13	59.41	18.00	29.91
RDF (P through DAP) -S	31.10	72.71	21.75	31.97
RDF (P through SSP) + S	35.10	83.87	23.03	33.03
RDF + FYM @ 5 t ha^{-1}	39.73	92.43	25.88	37.56
75% RDF + 25% N through FYM	36.17	86.36	24.94	34.78
LSD ($P \leq 0.05$)	2.82	8.00	0.77	0.43

FYM applied to sorghum only: Farmer Practice: Half the dose of RDF (-K)
Recommended Dose of Fertilizer; 1) Sorghum: 100: 50 : 50; 2) Wheat: 120:60:60 kg N, P_2O_5 and K_2O ha^{-1}.

7.8.2 Soil Properties

The highest contents of organic carbon (Table 7.14) were observed with the application of RDF + FYM @ 5 t ha^{-1} (5.97 g kg^{-1}) followed by 75% RDF + 25% N through FYM (5.62 g kg^{-1}). The available N, P and K after harvest of sorghum were significantly higher in the treatment where, 100% NPK was applied along with FYM @ 5 t ha^{-1}.

Table 7.14 .Effect on fertility status of the soil after harvest of sorghum (2012-13)

Treat.	pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	Available nutrients (kg ha^{-1})		
				N	P	K
Farmers' practice (control)	8.13	0.386	5.02	207	18.97	334
RDF (P through DAP)	8.05	0.389	5.35	215	20.92	347
RDF (P through SSP)	8.14	0.395	5.48	222	22.47	355
RDF + FYM @ 5 t ha-1	8.21	0.394	5.97	238	25.70	370
75% RDF + 25% N through FYM	8.13	0.398	5.62	228	23.80	358
LSD (*P* ≤ 0.05)	0.099	0.0043	0.16	5.02	1.09	6.30

7.8.3 Economics

Data generated on economics indicated better B:C ratio than the application of nutrient (Table 7.15) at farmer's rate. So farmer should take care of nutrient management very precisely to get larger return for invested each rupee.

Table 7.15. Effect of various treatments on net monetory return and B: C ratio

Treatments	NMR (Rs.)			B:C Ratio		
	Sorghum	Wheat	Sorghum + Wheat	Sorghum	Wheat	Sorghum + Wheat
Farmers' practice (control)	40223	22887	63111	1.98	1.08	1.52
RDF(P through DAP)	51004	27116	78120	2.15	1.06	1.59
RDF(P through SSP)	60129	29341	89471	2.43	1.12	1.75
RDF+ FYM @ 5 t ha^{-1}	67476	35878	103355	2.43	1.34	1.90
75% RDF + 25% N through FYM	61230	31466	92696	2.33	1.10	1.69

Plate 7.1 Demonstration of soybean on farmers field at Akola

7.9 Bhubaneshwar

To study the performance of the best LTFE treatment at the research station at fermers' filed, a trial was conducted with four treatments during the kharif season 2012. Experimental sites were acidic in nature low in SOC and K and medium in nitrogen and phosphorus.

Data recorded on paddy yield (Table 7.16) revealed that application of nutrient in balanced and integrated way resulted in higher productivity of paddy at both the location. Less yield with farmer's practice is due to use of less quantity of fertilizer nutrient. The larger return with INM treatment is due to larger yield.

Table 7.16 Yield and yield attributing characters in farmers plot

Treatment	No. of tillers per hill	Yield (q/ha)	% increase over RDF	B:C Ratio
	Village: Dova			
Farmers Practices (50:25:25- N : P_2O_5 : K_2O kg ha^{-1})	11.2	26.3	- 31.51	
100% RDF NPK (80:40:40- N : P_2O_5 : K_2O kg ha^{-1})	14.3	38.4	-	4.2:1
100% RDF + 5 t ha^{-1} FYM	21.6	45.2	+ 17.71	5.9:1
Soil Test Recommandation (80:40:60- N : P_2O_5 : K_2O kg ha^{-1})	16.8	41.7	+ 7.19	4.3:1
	Village: Gaudapatna			
Farmers Practices (50:25:25- N : P_2O_5 : K_2O kg ha^{-1})	10.6	24.5	-32.69	
100% RDF NPK (80:40:40- N : P_2O_5 : K_2O kg ha^{-1})	12.9	36.4	-	4.1:1
100% RDF + 5 t ha^{-1} FYM	19.2	43.2	+ 15.74	5.8:1
Soil Test Recommandation (80:40:60- N : P_2O_5 : K_2O kg ha^{-1})	14.8	39.6	+ 8.08	4.2:1

N.B: Cost of fertilizer (`) per kg urea-6, DAP-26,MOP-17,transportation of FYM-150 & Paddy- 500/qt

The B:C ratio has been calculated on the basis of extra yield obtained on extra expenditure incurred for fertilizers over the farmers practice.

7.10 Pantnagar

To demonstrate the technology generated out of experiment conducted at Pantnagar research farm, demonstrations were conducted with few treatment. Before conducting the demonstrations soil samples were collected from Udham Singh (US) Nagar district. Soils are alkaline in nature and non saline. Soil organic carbon ranged from 0.40 to 1.72 percent. Soils are low in available N, medium to high in available P and K. Except few sample, Zn Content was low (Table 7.17)

The results of demonstration conducted in different villages revealed good response of rice to applied Zn and sulfur almost at all the farmer's field during both the years (Table 7.17 to 7.20). It is interesting to note that yields obtained in treatment supplied with NPK and FYM are at par with the yield obtained on application of NPK + Zn + S at most of the farmer's field. This indicates if FYM in applied along with NPK then hidden hunger of Zn and S can be ruled out.

As far as yield of subsequent wheat in can corned, data little residual effect of both S and Zn but may not be statistically significant. The yields recorded under farmer's practice are invariable low because of non supply of nutrient in proper quantity and number. Some time farmer does not supply S and many times organic manure (Table 7.21). The economic analysis carried out revealed that application of both S and Zn resulted in benefit: Cost 1: 36 over farmer's practice. However, in case of FYM this ratio comes out to be very poor because of very high cost of FYM. If the benefit of individual nutrient is considered then Zn was superior than S and obviously FYM in always better as far as productivity is concerned but found poor with respect to net profit (Table 7.20) Almost similar scenario was recorded at Kichha as far as economics in concerned (Table 7.21)

Table 7.17 Soil health analysis of soil samples taken from the farmer's fields of Udham Singh district (2010-11)

Village Name	pH, (:2.5)	EC, (dS/ m)	OC, (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})	Ex Ca (mg kg^{-1})	Ex Mg (mg kg^{-1})	Zn (mg kg^{-1})
Bara	8.14	0.079	1.30	112.89	94.67	220.64	37.14	9.0	8.0	1.0
Sirsa Farm	8.18	23.6	0.44	150.52	106.03	67.72	24.28	11.2	6.0	0.5
Madlopur	7.64	87.72	0.71	100.35	103.60	115.36	25.71	8.4	8.0	0.5
Pipaliya	8.15	37.2	0.40	137.98	38.22	151.20	24.28	8.0	9.4	0.7
Kisanpur	7.78	10.4	1.33	100.35	56.08	211.68	31.42	9.6	9.6	0.8
Deoria	7.70	49.6	1.49	137.98	62.52	115.36	34.28	10.2	7.8	0.4
Kichha (Bandia)	7.95	39.6	0.83	112.8	35.01	98.56	28.57	10.0	7.0	0.5
Shimla pistor	7.80	62.6	1.72	112.8	63.59	296.80	34.28	9.4	6.6	0.6
Jawahar Nagar	7.40	88.6	1.57	87.8	30.36	36.64	25.71	8.0	7.6	0.4
Kali Nagar	7.65	19.8	0.98	100.35	58.94	70.56	22.85	8.2	7.6	0.3
Kundan Nagar	6.95	13.9	1.41	75.2	89.31	81.76	21.42	8.6	8.0	0.3
Vijay Nagar	7.54	32.1	1.49	87.8	100.03	144.48	22.85	10.4	7.8	0.2
Zafar Pur No.1	6.75	31.0	1.45	100.35	104.67	118.72	20.0	9.6	8.2	0.4
Zafar Pur No.2	7.55	37.0	0.87	87.8	31.43	98.56	24.28	8.0	8.0	0.5

Table 7.18 Effect fertilizers application on rice yield (kg ha^{-1}) on farmer's field

Treatments	Deoria	Kichha	Kali Nagar	Kundan nagar
NPK+S+Zn	57.00	59.50	54.20	52.20
NPK-S+Zn	53.40	56.30	52.00	48.00
NP30K+Zn	56.20	59.80	55.80	47.70
NPK-Zn	46.60	44.40	48.20	42.50
FP	46.80	47.20	46.00	49.60
NPK+FYM	58.10	58.40	56.60	53.30

FP = Farmer's practice

Table 7.19 Effect fertilizers application on wheat yield (kg ha^{-1}) on farmer's field

Treatments	Deoria	Kichha	Kali Nagar	Kundan nagar
NPK+S+Zn	47.00	42.50	48.20	45.20
NPK-S+Zn	44.40	40.30	46.00	43.00
NP30K+Zn	46.20	43.80	46.80	43.70
NPK-Zn	39.60	38.40	42.20	36.50
FP	40.80	38.00	39.00	40.60
NPK+FYM	48.10	44.40	49.60	46.30

FP = Farmer's practice

Table 7.20 Economical benefits obtained with the technological interventions (a) over farmers' practice and (b) over NPK-Zn at Deoria (Dist Pantnagar)

Technological interventions	Rice (Extra yield q ha^{-1}) G. + S	Wheat (Extra yield q ha^{-1}) G. + S	Total extra Income (Rs)	Cost of extra production–Extra expenditure	Additional benefit over FP and -Zn (Rs)
(a) Benefits over FP					
NPK+ S+ Zn	10.2+ 12.0	6.2+10.2	8000+6200+ 1200+2400	17,400 -3,000	14,400
NPK- S+ Zn	6.6+ 7.8	3.6+6.8	5280+3600+ 780+ 1720	11,380- 3,000	8,380
NP30K+Zn	9.4+ 11.1	5.4+8.6	7500+5400+ 1110+1720	15,700-1500	14,200
NPK+FYM	11.3+ 10.8	7.3+11.2	9040+7300+ 1080+2240	19660-15000	4,660
(a) Benefits over NPK-Zn					
NPK+ S+ Zn	10.4+ 11.1	7.4+9.4	8320+7400+ 1110+1880	18,710 -3,000	15,710
NPK –S +Zn	6.8+ 6.9	4.8+6.0	5440+4800+ 690+ 1200	12,130-3,000	9,130
NP30K+Zn	9.6+ 10.2	6.6+7.8	7680+6600+ 1020+1560	16,860-1500	15,360
NPK+FYM	11.5+ 9.9	8.5+10.4	9200+8500+ 990+2080	20770-15000	5,770

Note: G=Grain S=Straw FP – Farmer Practice. FYM was applied in Kharif; Cost of FYM Rs. 2500 / t

Table 7.21 Economical benefits obtained with the technological interventions (a) over farmers' practice and (b) over NPK-Zn at Kiccha (Dist Pantnagar)

Technological interventions	Rice (Extra yield q ha) (G+S)	Wheat (G+S)	Total extra Income (Rs)	Cost of extra production– Extra expednditure	Additional Benefit (Rs)
(a) Benefits over FP					
NPK+ S+ Zn	12.3+ 6.7	4.5 + 7.1	840+4500+ 670 +1420	16430 - 3000	13430
NPK- S+ Zn	9.1+5.3	2.3+ 0.7	7280+2300+ 530+1400	11510-3000	8510
NP30K+Zn	12.6+ 6.9	5.8 + 4.3	10080+5800+ 690 + 860	17430-1500	15930
NPK+FYM	11.2+ 8.1	6.4 + 7.5	8960+6400+ 810 + 1500	17670-15000	2670
(a) Benefits over NPK-Zn					
NPK+S+Zn	15.1+ 8.9	4.1 + 4.9	12080+4100 +890 +980	18050-3000	15050
NPK-S+Zn	11.9 + 7.5	1.9 + (-1.5)	520+1900+ 750 + (-300)	11870-3000	8870
NP30K+Zn	15.4 +9.1	5.4+ 2.1	2320+5400 +910+ 420	19050-1500	17550
NPK+FYM	14.0 +10.3	6.0 + 5.3	11200+600+ 1030+1060	19290-15000	4290

Note: G=Grain S=Straw *FFP – Farmer Fertilizer Practice*

7.11 Ludhiana

Eight field experiments were conducted in maize-wheat cropping system to study the effect of inorganic fertilizers and integrated use of organics and fertilizer under different agro ecological situations.

7.11.1 Soil fertility status (2010-11)

The soil samples were taken before sowing of crops and analyzed for chemical properties like pH, EC, organic carbon and available N, P and K status (Table 7.22). The soils were normal in reaction (6.9-7.5) and salt content (0.25 -0.37 dS m^{-1}) and low in organic carbon content (0.24- 0.36%) The soil samples tested low in available nitrogen (112.9-150.5 kg ha^{-1}), high in available phosphorus (23.4-71.9 kg ha^{-1}) and were low to medium in available potassium (97.4-178.1 kg ha^{-1}) content.

Table 7.22 Chemical properties of the soils under maize-wheat cropping system

Properties	Location			
	L1	L2	L3	L4
pH	7.5	6.9	7.1	7.5
EC (dS m^{-1})	0.36	0.25	0.26	0.37
OC (%)	0.24	0.32	0.35	0.36

Available N (kg ha^{-1})	112.9	125.4	145.1	150.5
Available P (kg ha^{-1})	41.9	71.9	30.1	23.4
Available K (kg ha^{-1})	112.0	97.4	145.1	178.1

7.11.2 Crop Productivity (2010-11)

The maize grain yield ranged from 1.55 to 4.37, 1.70 to 4.58, 1.75 to 5.29 and 1.74 to 5.38 t ha^{-1} (Table 7.23) and wheat crop yield varied from 1.80 to 5.10, 1.87 to 5.75, 1.85 to 5.25 and 1.78 to 5.35 t ha^{-1} (Table 7.24) under various treatments at different locations. At all the sites, the grain yields of both maize and wheat crops were significantly higher in all the treatments over control. The application of 100%N+50% PK recorded non-significant improvement in maize yield compared to application of 100%N alone and significantly less than 100% NPK. It means reduction of P dose to half did not work here because out of four farmers three fields with medium in P status. The maize yield with 75% NPK+FYM treatment was statistically at par with the maize yield of 100% NPK treatment. The highest yield of maize (4.91 tha^{-1}) was recorded in 100% NPK+FYM treatment plot which was significantly higher from NPK, however, the residual effect of FYM application was not significant in wheat. There was non-significant difference in wheat yield of 100% NPK and 100% NPK+FYM treated soils indicating the no residual effect of organic manure. The incorporation of FYM before maize in addition to 75 per cent NPK dose to both the crops resulted in grain yields comparable to recommended dose (100NPK) to both the crops. The increase in grain yield of wheat may be due to carry over effect of FYM. The highest and lowest value of B:C ratio was calculated for control (no fertilizer) and 100NPK+FYM, respectively.

Table 7.23 Effect of organic and inorganic fertilizers on maize grain yield (t ha^{-1}) (2010-11)

Treatment	Location				Mean	B:C ratio
	L1	L2	L3	L4		
Control	1.55	1.70	1.75	1.74	1.69a	1.91
100% N	2.51	3.27	3.22	3.38	3.10b	3.01
100% NPK	3.80	4.17	4.42	4.20	4.15c	3.13
100% N+50% PK	2.96	3.80	4.11	2.88	3.44b	2.92
75% NPK+FYM	3.65	4.10	4.41	4.55	4.18c	2.88
100% NPK+FYM	4.37	4.58	5.29	5.38	4.91d	3.15

Table 7.24. Effect of organic and inorganic fertilizers on wheat grain yield (t ha^{-1}) in different locations (2010-2011)

Treatment	Location				Mean	B:C ratio
	L1	L2	L3	L4		
Control	1.80	1.87	1.85	1.78	1.83	2.87
100% N	3.90	4.01	3.80	3.80	3.88	5.21
100% NPK	4.79	5.50	4.75	5.12	5.04	5.23
100% N+50% PK	4.25	5.00	4.45	4.55	4.56	5.65
75% NPK+FYM	4.45	5.32	5.00	5.15	4.98	5.57
100% NPK+FYM	5.10	5.75	5.25	5.35	5.36	2.87

8.11.3 Soil fertility status (2011-12)

Effect of differential dose of chemical fertilizers with and without organic manure in maize-wheat and rice-wheat cropping system were studied in seven field trials at different locations (L1, L2, L3, L4 and L5). The soil samples were taken before sowing of crops and analyzed for chemical properties like pH, EC, organic carbon and available N, P and K status (Table 7.25). These soils were normal in pH (7.0-7.6) and salt content (0.12 -0.35 dS m^{-1}) and low to medium in organic carbon content (0.30- 0.58%). The soil samples were tested low in available nitrogen (106.6-150.2 kg ha^{-1}), high in available phosphorus (29.6-72.3 kg ha^{-1}) and were low to medium in available K (100.2-248.6 kg ha^{-1}) content.

Table 7.25 Chemical properties of the soils of farmer fields under maize-wheat cropping system (2011-12)

Location	pH	EC (dS m^{-1})	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
L1	7.3	0.30	0.58	131.7	70.4	168.0
L2	7.0	0.25	0.33	127.3	72.3	100.2
L3	7.2	0.24	0.31	109.8	46.2	248.6
L4	7.2	0.12	0.36	150.2	29.6	148.3
L5	7.6	0.35	0.30	106.6	45.7	123.2

8.11.4 Crop Productivity (2011-12)

There was significant increase in maize and wheat grain yield with the use of fertilizer over the control (no fertilizers) at all the locations (Table 7.26 and 7.27). The positive effect of fertilizer application on grain yield further improved with the conjunctive use of chemical fertilizers and FYM. Grain yield of maize (1.81 t ha^{-1}) and wheat (1.90 t ha^{-1}) of control plot was significantly increased to 4.12 t ha^{-1} and 4.36 t ha^{-1}, respectively with the application of nitrogenous fertilizer (Table 13). The grain yield of both the crops was further incremented with the conjunctive use of N and P fertilizers. However, the positive effect of P application was non-significant on maize grain yield. This emphasized the low response of phosphatic fertilizer on maize grain yield grown in high P status soils. These results are in corroborating with the findings of Long-term fertilizer Experiment on maize-wheat cropping system. The effect of potassium application was also not significant both on maize and wheat crops due to high K status of experimental soils. In contrary to rice, application of P in wheat resulted increase in yield from 4.1 to 5.2 tha^{-1} (Table 7.27). Which means we can only reduce P dose in rice and wheat should be grown with rild dose. Moreover, higher dose of chemical fertilizer (150% NPK) had statistically lower maize and wheat grain yield as compared to integrated chemical fertilizers and FYM. This demonstrated that application of fertilizers in excess to recommended dose is not profitable both economically and environmentally.

The possibility of reducing recommended dose of chemical fertilizers when applied along with FYM was also demonstrated. The maize grain yield under 100%NPK and 75% NPK+FYM was statistically at par. However, the residual effect of FYM applied to maize crop could not sustain the wheat grain yield as compared to 100%NPK application. The effect of FYM application along with

100%NPK on both the crops was significant. The integrated use of chemical fertilizer and FYM significantly improved grain yield of maize (5.54 t ha^{-1}) and wheat (5.64 t ha^{-1}) crops over the 100%NPK treatment (4.66 and 5.34 t ha^{-1}, respectively).

Table 7.26 Effect of different fertilizers combination on maize grain yield (t ha^{-1}) at different locations (2011-12)

Treatment	L1	L2	L3	L4	L5	Mean	B:C ratio
Control	2.1	1.9	1.5	1.9	1.6	1.8	2.0
100% N	4.6	4.1	4.1	4.4	3.4	4.1	4.0
100% NP	4.7	4.1	4.2	4.6	3.5	4.2	3.2
100% NPK	5.0	5.0	4.5	4.8	4.1	4.7	4.0
150% NPK	5.2	5.1	4.7	5.0	4.3	4.9	3.1
75% NPK+FYM	4.8	4.9	4.4	4.9	4.2	4.6	3.2
100% NPK+FYM	5.9	5.7	5.4	5.7	5.0	5.5	3.6

Table 7.27 Effect of different fertilizers combination on wheat grain yield (t ha^{-1}) at different locations (2011-12)

Treatment	L1	L2	L3	L4	L5	Mean	B:C ratio
Control	2.0	1.8	1.9	2.0	1.9	1.9	3.0
100% N	4.5	4.3	4.3	4.4	4.3	4.4	5.9
100% NP	5.4	5.1	5.1	5.3	5.1	5.2	5.7
100% NPK	5.5	5.2	5.2	5.5	5.3	5.3	5.5
150% NPK	5.6	5.4	5.3	5.5	5.4	5.5	4.9
75% NPK+FYM	4.8	4.4	4.5	4.7	4.6	4.6	5.2
100% NPK+FYM	5.8	5.5	5.5	5.7	5.6	5.6	5.9

7.12 New Delhi

On-farm trials were conducted to demonstrate to the farmers the performance of promising treatments during 2009-10 and 2010-11 in Lohtaki village (Distt. Gurgaon). As hybrid pearlmillet-wheat was the dominant cropping system in the adopted village, on-farm trials were conducted with cropping system only. During 2011-12 in Kumbhawas village of Gurgaon district of Haryana the treatments were evaluated in wheat. Application of super-optimal NPK or NPK+FYM invariably out yielded 100% NPK in all the trials (Table 7.28 & 7.29) indicating the need for improvement in nutrient application rates in this exhaustive cereal-cereal system. Magnitude of yield increase in the above treatments was much greater when compared with farmers' fertilizer practice (FFP). As far B : C ratio is concerned application of nutrient did not show improvement in B : C ratio but net return was more. This is due to use of fertilizer in sufficient quantity in this region. Decline in net return and B: C ratio on application of FYM is due to very high cost of FYM (Table 7.29)

Table 7.28 Effect of nutrient supply options on the productivity of pearlmillet and wheat in on-farm trials

Treatment	Grain yield (t ha^{-1})			
	Pearlmillet	Wheat	Pearlmillet	Wheat
	(2009-10)		(2010-11)	
1. *Shri Likhiram*				
100% NPK	2.96	4.81	3.06	4.76
150% NPK	3.18	5.35	3.32	5.18
100% NPK+FYM	3.09	5.12	3.29	5.02
FFP	2.68	4.56	2.84	4.39
2. *Shri Nathiram*				
100% NPK	2.88	4.69	3.21	4.73
150% NPK	3.22	5.22	3.38	5.19
100% NPK+FYM	3.16	5.16	3.26	5.21
FFP	2.79	4.37	2.93	4.33
3. *Shri Hirdayram*				
100% NPK	3.15	4.85	2.93	4.64
150% NPK	3.35	5.19	3.29	5.32
100% NPK+FYM	3.26	5.04	3.25	5.17
FFP	3.24	4.18	3.14	4.27
4. *Shri Chandiram*				
100% NPK	2.88	4.71	2.90	4.77
150% NPK	3.42	5.29	3.38	5.32
100% NPK+FYM	3.31	5.18	3.23	5.14
FFP	2.72	4.33	2.43	4.46
5. *Shri Satpal Singh*				
100% NPK	2.57	4.68	2.86	4.70
150% NPK	3.32	5.28	3.47	5.27
100% NPK+FYM	3.13	5.13	3.24	5.23
FFP	2.39	4.16	2.59	4.28
6. *Shri Omkar Singh*				
100% NPK	2.79	4.75	2.83	4.88
150% NPK	3.31	5.44	3.57	5.49
100% NPK+FYM	3.09	5.16	3.36	5.26
FFP	2.42	4.71	2.53	4.64

Farmer Practice N- P- K

Table 7.29 Effect of nutrient supply options on the productivity and economics of wheat in on-farm trials during 2011-12.

Treatment	Grain yield	Straw yield	Gross returns	Net returns	B:C Ratio
	(t ha^{-1})		(Indian Rupees)		
1.Shri. Shamsher Singh					
FFP	5.33	7.90	96141	70612	3.77
100% NPK	5.62	8.20	100917	75388	3.95
100% NPK+FYM	5.91	8.10	64803	47074	3.66
150% NPK	6.05	8.40	107143	81614	4.20
2.Shri Chanderhas					
FP	5.24	7.70	94284	68755	3.69
100% NPK	5.54	8.00	99189	73660	3.89
100% NPK+FYM	5.82	7.90	63751	46022	3.60
150% NPK	5.95	8.20	105158	79629	4.12
3. Shri Vidhya Sagar					
FP	4.91	7.30	88644	63115	3.47
100% NPK	5.45	7.90	97683	72154	3.83
100% NPK+FYM	5.64	7.70	61817	44088	3.49
150% NPK	5.75	7.90	101538	76009	3.98
4.Sh. Satyavir Singh					
FP	5.12	7.40	91692	66163	3.59
100% NPK	5.61	8.10	100439	74910	3.93
100% NPK+FYM	5.73	7.60	62614	44885	3.53
150% NPK	5.80	7.90	102180	76651	4.00

7.13 Junagadh

On the basis of recommendation of the LTFE experiments on groundnut-wheat cropping sequence at Junagadh Centre a set of treatments was selected to conduct the satellite experiment on the farmer's fields. The field experiments were conducted with the objectives (i) To evaluate most suitable and sustainable fertilizer practices and (ii) To monitor changes in soil fertility as result of fertilization and manuring.

Average yield of ground nut and wheat of three years is given in table 7.32. Yield data revealed that application of Zn resulted improvement in yield of groundnut as well as wheat. Demonstration conducted further revealed that application of N half through fertilizer and half with 10 t FYM found to be best option as far as productivity of both the crop is concerned. Application of S also has positive effect on yield of ground nut and wheat as well. Five locations were selected on the farmers' fields

Name of the cultivator	Village	Tahsil	District
Satodia Hanshrajbhai Popatbhai	Hadmatia	Bhesan	Junagadh
Gajera Nitinbhai Sambhubhai	Chokali-2	Bhesan	Junagadh

Maravia Jentibhai Devrajbhai	Mendapara	Bhesan	Junagadh
Paghdar Dilipbhai Karamsibhai	Ranpur	Bhesan	Junagadh
Movalia Madhubhai Chhaganbhai	Parab	Bhesan	Junagadh

The uptake of nutrient in groundnut and wheat increased with increase in productivity which is obvious (Table 7.33 and 7.34)

Table 7.30 Nutrient status of soil at Farmers' field

Soil property	Hadmatia	Chokali-2	Mendapara	Ranpur	Parab
O.C.(g/ kg)	5.26	6.42	7.11	6.54	5.42
N (kg/ha)	148	174	210	172	155
P_2O_5 (kg/ha)	22.5	27.2	30.3	24.3	22.1
K_2O (kg/ha)	182	212	292	218	240
S (kg/ha)	14.7	18.5	21.8	18.0	19.2
Micronutrients					
Fe (ppm)	7.53	5.35	5.08	7.19	6.8
Zn (ppm)	0.33	0.44	0.52	0.55	0.39
Cu (ppm)	1.2	1.62	1.75	2.73	5.59
Mn (ppm)	7.7	8.58	9.2	8.9	8.62

Table 7.31 Recommended dose of crops at Farmers' field

Treatments	N, P_2O_5, K_2O rate (kg ha^{-1})		Fertilizer source
	Groundnut	Wheat	
100% NPK	12.5:25.0:0.0	120:60:60	Urea, DAP, MOP
100% NPK + 50 kg ha^{-1} $ZnSO_4$	12.5:25.0:0.0 Zn 50 kg	120:60:60	Urea, DAP, MOP $ZnSO_4$
50 % NPK in G nut & 100% NPK in Wheat +10 t ha^{-1} FYM	12.5:25.0:0.0 FYM 10 t ha^{-1}	120:60:60 FYM 10 t ha^{-1}	Urea, DAP, MOP FYM
100% NPK (P as SSP)	12.5:25.0:0.0	120:60:60	Urea, SSP, MOP
Farmers' practice	10 : 20 : 0	100 : 50 : 40	Urea, DAP, MOP, FYM

Note: *Recommended NPK dose for the groundnut 12.5:25.0:0 and Wheat 120:60:0*

Table 7.32 Effect of various treatments on pod yield of groundnut and yield of grain wheat crops under groundnut-wheat cropping sequence

Treatments	(kg ha^{-1})			
	2009	2010	2011	Pooled Mean
Groundnut Pod Yield *(Kharif)*				
100% NPK	1317	1244	1238	1266
100% NPK + 50 kg $ZnSO_4$ ha^{-1}	1439	1376	1410	1408
50% NPK + 10 t FYM ha^{-1}	1670	1607	1671	1649
100% NPK (P as SSP)	1509	1417	1442	1456
Farmer practices	1385	1233	1143	1254
LSD ($P \leq 0.05$)	143	187	155	89
Wheat Grain Yield *(Rabi)*				
100% NPK	3748	3544	4966	4086
100% NPK + 50 kg $ZnSO_4$ ha^{-1}	4197	3941	5057	4398
100% NPK + 10 t FYM ha^{-1}	4585	4419	5941	4981
100% NPK (P as SSP)	3740	4053	5090	4294
Farmers' practice	3694	3855	4392	3980
LSD ($P \leq 0.05$)	517	544	753	337

Table 7.33 Effect of various treatments on total uptake of nutrients by groundnut crop under groundnut-wheat cropping sequence

Treatments	N	P	K	S	Zn
	kg ha^{-1}				g ha^{-1}
Pooled Mean					
100% NPK	81.3	7.52	20.23	7.96	374
100% NPK + 50 kg $ZnSO_4$ ha^{-1}	94.3	8.98	23.44	9.22	468
50% NPK + 10 t FYM ha^{-1}	113.4	10.92	28.17	10.75	532
100% NPK (P as SSP)	97.3	9.39	23.57	9.58	423
Farmers' practice	84.2	7.91	20.54	7.98	354
LSD ($P \leq 0.05$)	5.5	0.54	1.32	0.53	33.71

Table 7.34 Effect of various treatments on total uptake of nutrients by wheat crop under groundnut-wheat cropping sequence (Pooled mean 2010-11 & 2011-12)

Treatments	N	P	K	S	Zn
	……..kg ha^{-1}…….				g ha^{-1}
100% NPK	102.61	12.78	72.1	16.75	835
100% NPK + 50 kg $ZnSO_4$ ha^{-1}	116.13	14.83	85.1	19.73	1083
50% NPK + 10 t FYM ha^{-1}	135.88	17.37	92.2	21.87	1173
100% NPK (P as SSP)	109.79	14.75	80.4	20.87	928
Farmers' practice	100.97	13.59	73.6	17.23	792
LSD ($P \leq 0.05$)	9.49	1.26	7.1	1.69	81

Table 7.35 Effect of various treatments on fertility status of the soil under groundnut-wheat cropping sequence after wheat crop (2011-12 and Pooled mean)

Treatments	O.C	N	P	K	S	Zn
	g ha^{-1}	……..kg ha^{-1}……				(ppm)
Rabi 2011-12						
100% NPK	6.50	187.2	31.54	248.8	19.12	0.47
100% NPK+50 kg $ZnSO_4$ ha^{-1}	6.50	191.2	31.64	255.2	19.08	0.61
50% NPK + 10 t FYM ha^{-1}	7.66	215.8	39.32	290.2	23.75	0.55
100% NPK (P as SSP)	6.62	190.2	29.60	251.8	21.72	0.44
Farmers' practice	6.60	186.6	30.04	257.0	20.21	0.48
LSD ($P \leq 0.05$)	0.24	11.4	3.09	15.7	1.38	0.05
Pooled Mean						
100% NPK	6.40	184.2	31.11	246.5	18.53	0.46
100% NPK+50 kg $ZnSO_4$ ha^{-1}	6.41	188.0	31.26	252.7	18.52	0.60
50% NPK + 10 t FYM ha^{-1}	7.55	212.3	38.81	287.4	23.05	0.54
100% NPK (P as SSP)	6.53	187.1	29.26	249.1	21.05	0.44
Farmers' practice	6.49	183.9	29.59	254.5	19.59	0.47
LSD ($P \leq 0.05$)	0.16	7.5	1.77	9.7	0.97	0.03

7.14 Pattambi

In situ green manuring (Daincha) identified and popularized as a cost effective and farmer friendly technology as is clear from the graph given below. The graph shows the average grain yield (averaged for kharif and rabi) of Paddy along years.

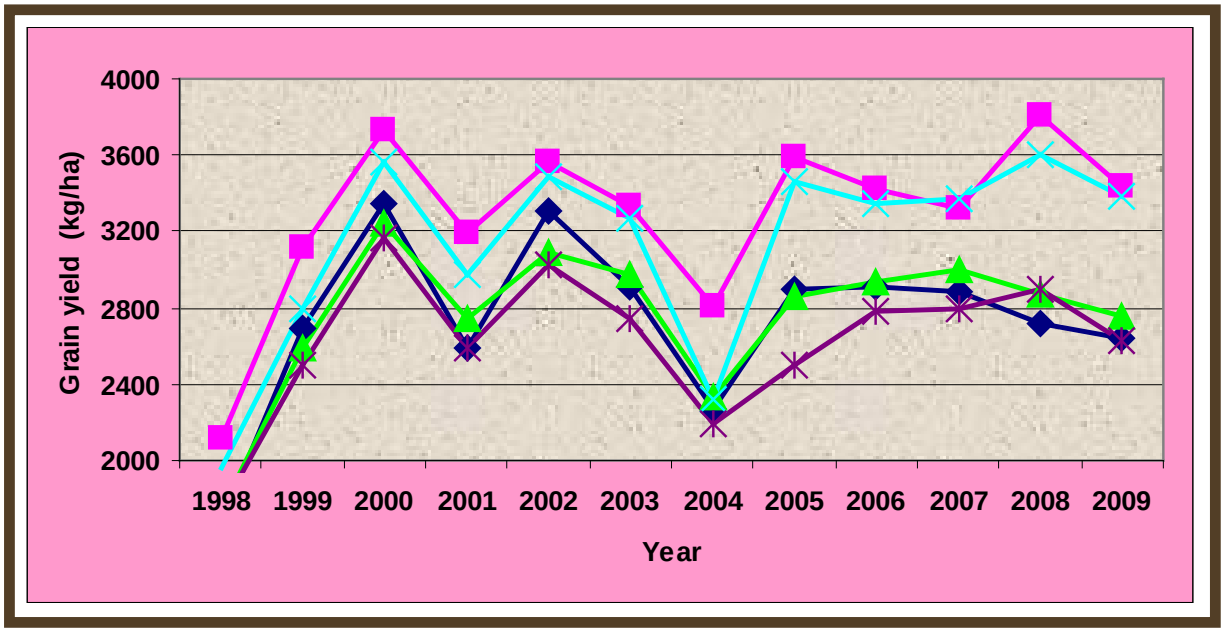


Fig. 7.1 Yield trends at Pattambi

Technology demonstrations were conducted in farmers' fields also (2010 and 2011). Demonstration is being done in rice (Table 7.36) with following 4 treatments viz. 1. 100% N,P,K (90:45:45), 2. *In situ* green manuring + 100% N,P,K (90:45;45), 3. *In situ* green manuring with Daincha + 50% N,P, K (90:45:45) and 4. FYM 5 t + 100% NPK. The demonstration was done in an area of 35 acres with 22 participant farmers in kharif 2010 and 15 acres with 8 farmers in kharif 2011. The result in terms of economic advantage obtained during kharif 2010 and 2011 are given below:

Table 7.36 Treatment effect on farmers field (Pattambi)

Year 2010	100% NPK	100%NPK+ 5t FYM	50% NPK+ 5 t FYM	100% NPK+ in situ GM	50% NPK+ in situ GM
Cost of cultivation	39900	49900	48450	43150	40700
Grain yield kg/ha	3300	4200	3880	4050	3750
Return in Rs.	49500	63000	58200	60750	56250
B:C ratio	1.24	1.26	1.20	1.41	1.38

GM, green manuring

Table 7.38 Treatment effect on farmers field (Pattambi)

Year 2011	100% NPK	100%NPK+ 5t FYM	50%NPK+ 5t FYM	100% NPK+ IN SITU GREEN MANURING	50% NPK+ IN SITU GREEN MANURING
Cost of cultivation	39900	49900	48450	43150	40700
Grain yield kg/ha	3180	3850	3620	3700	3540
Return in Rs.	47700	57750	54300	55500	53100
B:C ratio	1.20	1.16	1.12	1.29	1.30

In situ green manuring with Daincha produces on an average 35mt green matter per hector and it is a widely accepted soil health management practice with respect to addition of organic matter. The results show in situe green manuring is more benifical to FYM because of very high cost of FYM. Through not return with FYM seightly better than green manuring because of higher productivity. So farmer have option to green manuring FYM application.

Plate 7.1 Green manuring on farmers field (KAU Pattambi)

8. SOIL QUALITY INDICATORS

8.1. Soil Quality Index

It is essential to pinpoint the soil properties sensitive to management practices to evaluate the soil quality which are called soil indicators. In this context several studies at different LTFE locations were undertaken by analyzing chemical, physical and biological properties. Total 25-30 soil attributes were determined depending upon soil type at different centres. These attributes were subjected to principal component analysis (PCA) to find out soil indicators and soil quality index using the equation. The Soil Quality Index (SQI) is expressed as:

$$SQI = \sum_{i=1} WiSi$$

where, S is the score for the subscripted variable and wi weighted factor derived from PCA.

Higher is the score better is the soil quality.

SQI is relative numerical figure which indicate the condition of soil at that point of time under a particular management and how it has affected by your management practice. More is the SQI better is the soil quality. By using this concept, soil indicators were identified through principal component analysis (PCA) and using their relative contribution in productivity. SQI was calculated for some of the sites of long term fertilizer experiment.

9.1.1 Pantnagar

The principal components analysis (PCA) was performed on standardized measured 20 soil attributes. The first seven principal components (PC) accounted for 91.6% of the variability of data. These PCs were subjected to varimax rotation to maximize the relationship between interdependent variables by distributing the variance of each PC. The PCs which accounted for more than 5% of the total variance were examined. For each PC, rotated loadings of each attribute on components were obtained.

- The first PC, which explained 29.84% of the variance had high positive loading on Bacterial counts (BACT).
- The second PC, which explained 13.53% of the variance had high positive loading on Mineralizable- N (Min_N)
- The third PC, which explained 12.58% of the variance had high positive loading on De-hydrogenase activity (DHA)
- The fourth PC, which explained 12.27% of the variance had high positive loading on Available Copper (Cu)
- The fifth PC, which explained 8.18% of the variance had high positive loading on Available Manganese (Mn)

- The six PC, which explained 7.61% of the variance had high positive loading on Water holding capacity (WHC)
- The seventh PC, which explained 7.58% of the variance had high positive loading on Available Zinc (Zn)

Thus all together seven soil factors were identified as soil indicator at Pantnagar.

9.1.2 Akola

There are 17 soil attributes for PCA analysis. Out of these 17 attributes one attributes (pH) was dropped for principal component analysis as treatment were not significantly affecting pH. Thus, principal component analysis (PCA) was performed on standardized 16 soil attributes (Figure 8.1). The first two principal components (PC) showed 77.21% of variability of data. The PCs for which eigen values were equal or greater than 1 were retained. For each PC, loadings of each attribute on components were obtained. The findings of the analysis are: The first PC explained 69.33% of the variance had high positive loadings on SMBC followed by available Fe, available Mn, DHA, Co_2, soil urease activity, HC and available P within 10% of the highest loading (0.934). The second PC, which explained 7.88% of the variance, had high positive loadings on EC followed by available S within 10% of the highest loading (0.433). Amongst the variable S the significant contributor's are SMBC, Fe, DHA, SC and available sulfur.

Total Variance Explained

Component	Initial Eigen values			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.093	69.333	69.333	11.093	69.333	69.333
2	1.260	7.877	77.210	1.260	7.877	77.210

Component	SMBC	AVMN	DHA	SURCT	HC	AVP	OC	AVZN	AVK	AVN	AVS	BD
1	0.934	0.911	0.904	0.86	0.859	0.858	0.832	0.803	0.795	0.78	0.741	-0.672
2	-0.1	-0.116	-0.279	-0.246	-0.308	0.356	-0.263	0.006	0.345	0.365	0.396	0.32

SMBC, soil microbial biomass carbon; AVMN, available mineral nitrogen ; DHA, dehydrogenase activities; **SURCT, surface,** HC, hydraulic conductivity; AVP, available phosphorus; OC, organic carbon; AVZN, available zinc; AVK, available potassium; AVN, available nitrogen; AVS, available sulphur; BD, bulk density.

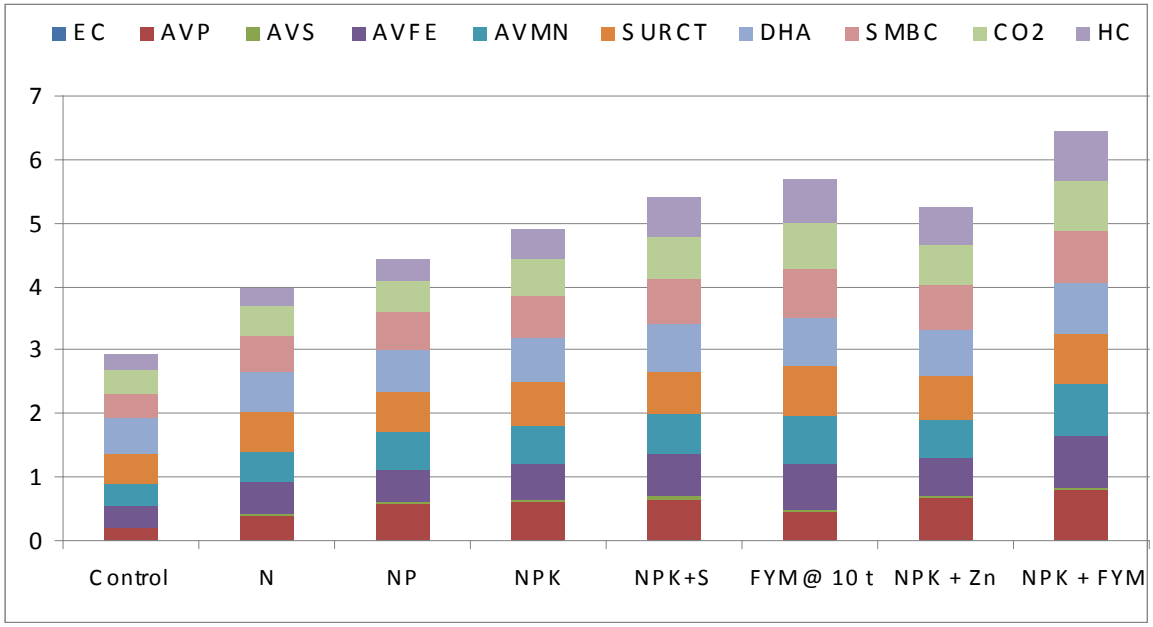


Figure 8.1 Impact of long term fertilizer and manure treatments on SQI (Akola)

9.1.3 Bhubaneshwar

For all the attributes treatments were found to be significantly affecting all the soil parameters. First two principal components (PC) were taken for the study as the eigen values of these two PCA were more or equal to 0.98. These first two principal components (PC) showed 82.07% of variability of data. The first PC explained 68.07% of the variance had high positive loadings on Available P followed by Organic carbon, Available S, Available N and Available K within 10% of the highest loading (0.909). The second PC, which explained 14.01% of the variance, had high positive loadings on pH. No other component was observed within the range of 10%. Thus, the most significant soil indicator could be available P, SOC, available N, K and pH.

	Initial Eigen values			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.765	68.069	68.069	4.765	68.069	68.069
2	.980	14.005	82.074	.980	14.005	82.074

Component	AVP	OC	AVS	AVN	AVK	EC	PH
1	0.909	0.908	0.888	0.872	0.842	0.744	0.551

2	0.228	0.112	-0.247	-0.135	-0.063	-0.47	0.782

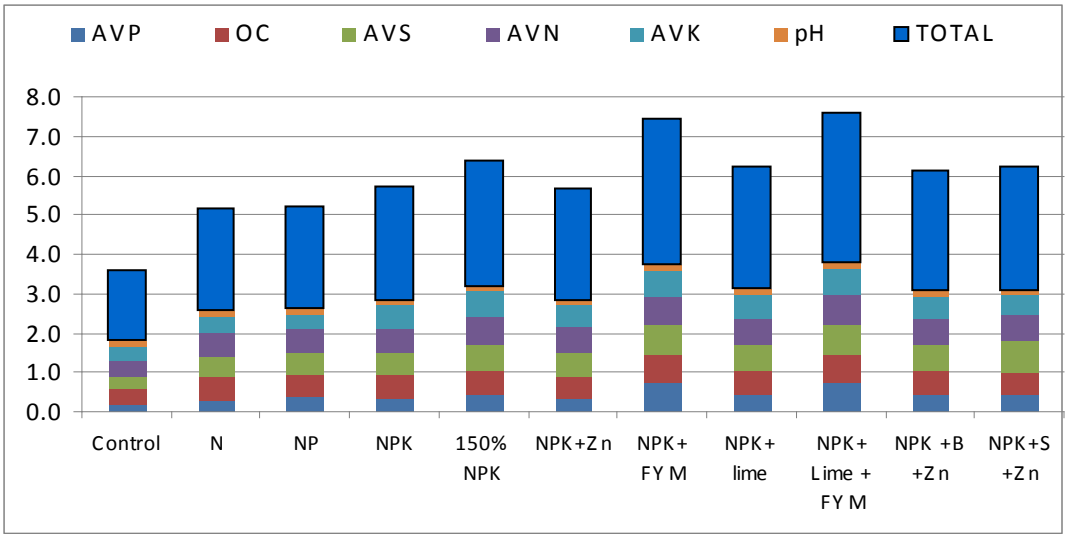


Figure 8.2 Impact of long term fertilizer and manure treatments on SQI (Bhubaneshwar)

9.1.3 Parbhani

There are 35 soil attributes for the analysis. Out of these 35 attributes one attributes (EC) was dropped for principal component analysis as treatment were not significantly affecting EC. Thus, principal component analysis (PCA) was performed on standardized 34 soil attributes. First three principal components (PC) were taken for the study as the eigen values of these three PCA was more or equal to 1. These first three principal components (PC) showed 82.88% of variability of data.

The first PC explained 71.99% of the variance had high positive loadings on Alkaline Phosphatase followed by Available Ni, Acid Phosphatase, Exch Mg, Available Pb, Available Cu, Availavle B, Available Fe, Available Mn, Co_2, Hydraulic Conductivity, SMBC, DHA, Exch K, Infiltration Rate, Exch Na, SMBN, Actinomycetes and CEC within 10% of the highest loading (0.978). Among these some of them are correlated and could be dropped either of one For example: Activity of enzymes has good correlation with SMBC and CO_2 release, So all the enzymes can also be dropped. Available of Pb, N, Fe, Mn and Cu is not a problem in acid soils so these are redundant variable and can also be dropped. The second PC, which explained 6.08% of the variance, had high positive loadings on CaCO3. No other component was observed within the range of 10%. The third PC, which explained 4.81% of the variance, had high positive loadings on pH.

Thus, after using expert's opinion significant indicator could be SMBC, available B, K, N, infiltration rate and soil pH in Alfisols of Bhubaneshwar which are responsible for sustainability.

Component	Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	24.476	71.987	71.987
2	2.068	6.084	78.071
3	1.636	4.812	82.882

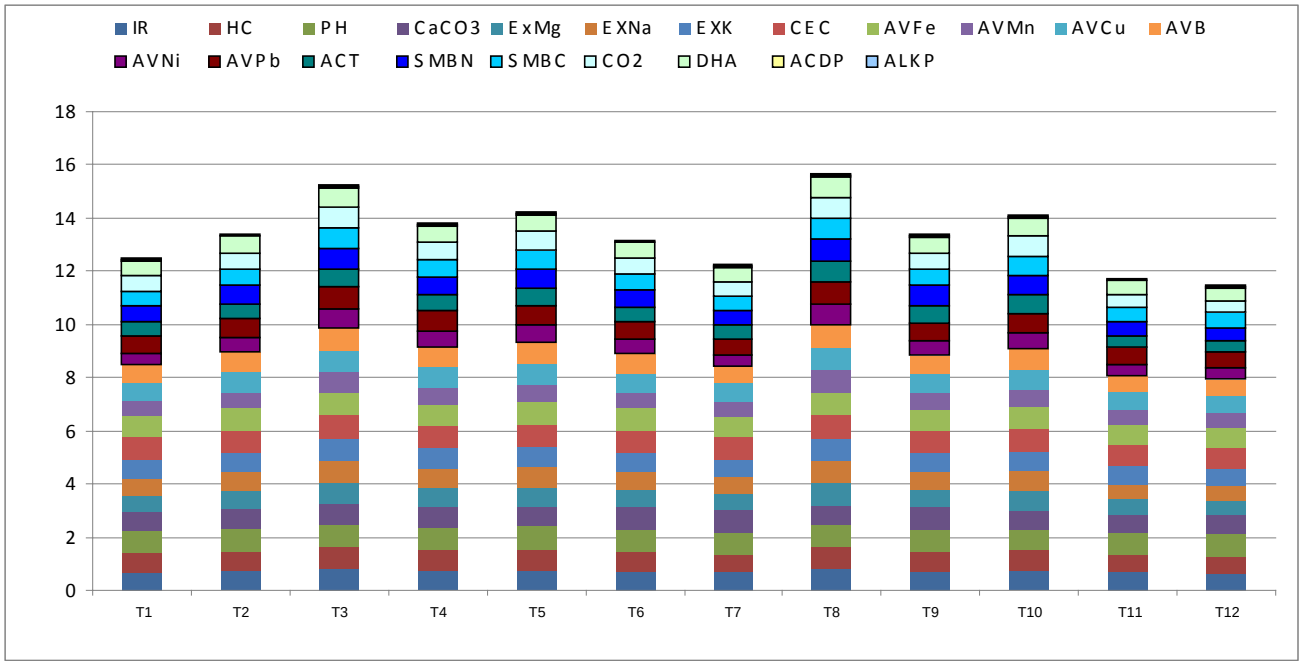


Figure 8.3 Impact of long term fertilizer and manure treatments on SQI (Parbhani)

T_1= 50 % NPK; T_2= 100 % NPK; T_3= 150 % NPK; T_4= 100 % NPK + HW; T_5= 100 % NPK + Zinc;T_6= 100 % NP; T_7= 100 % N; T_8= 100 % NPK + FYM; T_9= 100 % NPK - Sulphur; T_{10}= Only FYM 10t/ha.; T_{11}= Absolute Control; T_{12}= Fallow

Through PCA, it was noted that in different soil there are different soil indicators (properties) which are responsible for sustainability. Therefore, for all types of soil, common soil properties may not work as soil indicator.

8.2 Sustainable Yield Index (SYI)

The sustainable yield index (SYI) is also one of the ways to evaluate soil quality. More SYI value implies better soil quality.

8.2.1 Parbhani

Sustainability Yield Index (SYI): Sustainability yield index was computed for soybean-safflower crop sequence using following equation.

$$SYI = \frac{Y-\sigma}{Y_{max}}$$

where, Y = Average yield of the treatment; σ = Treatment standard deviation; Y_{max} = Maximum yield in the experiment over the year

The data given in Table 8.1 indicated highest SYI in 150% NPK followed by 100% NPK + FYM treatment but the differences between these two treatments were marginal and both the treatments are comparable with each other. The SYI values for N, NP and 5 t FYM are low and the yield can't be sustained under these nutrient management options.

Table 8.1. Effect of manures and fertilizers on SYI at Parbhani (2011-12)

Treatment	Soybean	Safflower	Total
50% NPK	0.648	0.604	0.643
100% NPK	0.733	0.720	0.741
150% NPK	0.784	0.825	0.814
100% NPK+HW	0.746	0.741	0.757
100% NPK + Zn	0.760	0.774	0.779
100% NP	0.694	0.668	0.697
100% N	0.255	0.429	0.338
100% NPK + FYM 5t/ha	0.788	0.802	0.807
100% NPK - Sulphur	0.703	0.649	0.694
FYM @ 5 t/ha.	0.517	0.592	0.560
Control	0.235	0.427	0.325

8.2.2 Udaipur

A perusal of data (Table 8.2) indicated that the indices were lowest in control plot for both the crop i.e. maize (0.33) and wheat (0.27). Application of N increased the value of sustainability index which was further increased by application of NP and NPK. The highest values of sustainability index 0.78 for maize and 0.72 for wheat were observed on conjoint use of fertilizer and manure (100%NPK+FYM @ 10 tha^{-1}). The study concluded that integrated use of fertilizer and manure is must for sustainable crop production. Application of FYM could not maintained SYI equal or at par with 100% NPK. Thus, it may be concluded that yield can't be sustained exclusively on FYM application.

Table 8.2 Long term effect of fertilizers on sustainability yield index (SYI) of maize and wheat in maize-wheat cropping system (2011-12)

Treatment	Sustainability yield index (SYI)	
	Maize	Wheat
Control	0.33	0.27
N	0.49	0.46
NP	0.62	0.56
NPK	0.69	0.62
NPK + Zn	0.72	0.64

NPK + S	0.70	0.63
NPK + Zn + S	0.74	0.65
150% NPK	0.75	0.69
NPK + FYM	0.79	0.72
NPK - FYM	0.70	0.64
FYM	0.49	0.42
NPK + Bio	0.71	0.63

8.2.3 Junagadh

Sustainability yield index (SYI) revealed lower SYI value compared to wheat (Table 8.3). This is probably due to poor yield of ground nut because it is rainfed crop and productivity depends on rainfall and its distribution, whereas, wheat is irrigated and productivity in not governed by rainfall.

Table 8.3 Impact of long term fertilizer, manure and biofertilizer on productivity (kg ha^{-1}) of groundnut and wheat at Junagadh (Gujarat) (Average 1997-2012)

Treatments	Crop productivity		Sustainable yield index	
	Groundnut pod	Wheat	Groundnut	Wheat
50% NPK	837	2093	0.25	0.31
100% NPK	906	2603	0.27	0.40
150% NPK	946	2699	0.30	0.43
100% NPK+ Zn	918	2527	0.28	0.38
100% NPK (Soil Test)	895	2578	0.26	0.39
100% NP	788	2458	0.21	0.37
100% N	749	1527	0.20	0.23
50% NPK + FYM @ 10 t ha^{-1}	1002	3168	0.31	0.47
FYM @ 25 t ha^{-1}	915	2853	0.28	0.39
50% NPK + Rhizobium + PSM	882	2453	0.26	0.36
100% NPK (P as SSP)	879	2577	0.25	0.39
Control	727	1785	0.22	0.27

100% NPK+ Zn : Indicates 100% NPK+Zn SO_4 @ 50 kg ha^{-1} once in three year to g'nut (i.e.'99, '02, '05, '08, 11 etc) & 100% NPK to wheat
50% NPK + FYM @ 10 t ha^{-1}: 50% NPK+10 t ha^{-1} FYM to g'nut & 100% NPK to wheat
50% NPK + Rhizobium + PSM : 50% NPK +Rhizobium +PSM to g'nut & 100% NPK to wheat

Thus, from sustainability index data it is concluded that balanced application of nutrient resulted in higher SYI irrespective of crop and soil type which means management of nutrients appropriately is responsible for sustainability and soil quality as well.

Table 8.4 Sustainability yield index of crops at different AICRP LTFE Centres

Centre	Crop	Control	N	NP	50% NPK	100% NPK	150% NPK	NPK +Zn	NPK+ FYM	NPK -S/+S	NPK +HW	NPK +Lime	FYM/ BGA / BF
Barrackpore	Rice	0.15	0.29	0.33	0.27	0.34	0.40	0.29	0.40	0.28	0.34		
	Wheat	0.08	0.19	0.22	0.24	0.24	0.29	0.24	0.23	0.24	0.23	-	-
Pantnagar	Rice	0.14	0.38	0.42	0.35	0.42	0.38	0.47	0.50	0.42	0.43	-	-
	Wheat	0.15	0.46	0.50	0.41	0.51	0.51	0.55	0.61	0.51	0.54	-	-
Ludhiana	Maize	0.03	0.18	0.23	0.21	0.28	0.32	0.36	0.43	0.42	0.34	-	-
	Wheat	0.14	0.44	0.64	0.47	0.70	0.77	0.74	0.78	0.73	0.73	-	-
Palampur	Maize	0.07	-0.07	0.14	0.20	0.34	0.35	0.33	0.52	0.21	0.35	0.47	-
	Wheat	0.04	-0.04	0.15	0.18	0.28	0.28	0.26	0.40	0.15	0.28	0.39	-
Ranchi	Soybean	0.10	0.01	0.20	0.36	0.48	0.46	-	0.61	0.09^{+S}	0.48	0.60	-
	Wheat	0.03	0.01	0.28	0.25	0.35	0.35	-	0.42	0.16^{+S}	0.36	0.40	-
Bangalore	F. Millet	0.06	0.05	0.07	0.32	0.51	0.62	-	0.57	0.50	0.53	0.50	0.54^{L+FYM}
	H. Maize	0.00	-0.02	0.01	0.10	0.21	0.22	-	0.28	0.15	0.21	0.25	0.27^{L+FYM}
New Delhi	Maize	0.25	0.34	0.38	0.37	0.44	0.50	0.47	0.51	0.46	0.43	-	-
	Wheat	0.38	0.58	0.67	0.62	0.74	0.81	0.76	0.82	0.76	0.74	-	-
Coimbatore	F. Millet	0.08	0.12	0.36	0.30	0.37	0.41	0.36	0.46	0.36	0.35	-	-
	Maize	0.12	0.09	0.36	0.32	0.39	0.43	0.41	0.47	0.39	0.38	-	-
Junagadh	Groundnut	0.26	0.25	0.25	0.28	0.31	0.34	0.33	0.36	0.30^{+S}	0.31^{STCR}	0.31^{R}	0.32^{F25}
	Wheat	0.37	0.20	0.33	0.29	0.36	0.40	0.35	0.42	0.39^{+S}	0.36^{STCR}	0.36^{R}	0.35^{F25}
Udaipur	Maize	0.37	0.52	0.63	-	0.69	0.74	0.72	0.77	0.70^{+S}	0.69^{FYM}	0.71^{A}	0.53^{F20}
	Wheat	0.26	0.45	0.54	-	0.60	0.67	0.62	0.69	0.61^{+S}	0.62^{FYM}	0.61^{A}	0.40^{F20}
Raipur	Rice	0.28	0.42	0.61	0.48	0.61	0.68	0.62	0.66	-	-	0.57^{GM}	0.49^{BGA}
	Wheat	0.25	0.36	0.64	0.40	0.63	0.77	0.65	0.72	-	-	0.42^{GM}	0.48^{BGA}
Jagtial	Kharif Rice	0.31	0.44	0.48	0.43	0.52	0.54	0.51	0.54	0.51	0.50	0.39^{F10}	-
	Rabi Rice	0.23	0.29	0.43	0.34	0.44	0.47	0.44	0.45	0.42	0.43	0.31^{F10}	-
Jabalpur	Soybean	0.12	0.14	0.25	0.25	0.31	0.29	0.29	0.34	0.27	0.29	-	-
	Wheat	0.13	0.15	0.49	0.40	0.53	0.56	0.52	0.58	0.49	0.51	-	-
Akola	Sorghum	0.01	0.15	0.21	0.17	0.29	0.40	0.33	0.40	0.27	0.08^{+S}	0.15^{F10}	$0.02^{75\% NPK}$
	Wheat	0.00	0.13	0.18	0.16	0.31	0.41	0.31	0.40	0.27	0.30^{+S}	0.00^{F10}	$0.22^{75\% NPK}$
Parbhani	Soybean	0.23	0.25	0.36	0.33	0.41	0.44	0.39	0.44	0.38^{+S}	0.38	0.32^{F10}	
	Safflower	0.29	0.35	0.37	0.42	0.45	0.49	0.44	0.49	0.43^{+S}	0.46	0.38^{F10}	

Denotation : **F= 50% NPK + 10 t ha^{-1} FYM at Junagadh; F^{10} = FYM 10 t ha^{-1} at Jagtial (to each kharif and rabi rice), Akola & Parbhani; F^{20} = FYM 20 t ha^{-1} at Udaipur; F^{25} = FYM 25 t ha^{-1} at Junagadh; BF= Biofertilizer alone; R= 50% NPK+ Rhizobium; A= 100% NPK+ Seed treatment with Azotobacter; GM= 50% NPK+ Green Manuring at Raipur; BGA= 50% NPK+ BGA at Raipur; L+FYM at Bangalore; +S= 100% NPK(+S) Ranchi, Junagadh, Udaipur, Akola & Parbhani; -S= 100% NPK(-S) at all centres except $^{+S}$; STCR= NPK as per soil at Junagadh.**

9. HERBICIDE RESIDUES

9.1 Herbicide Study

9.1.1 Jabalpur

Half life and Dissipation Constant of Imazethapyr :

The dissipation constant of Imazethyper was highest in 100% NPK + FYM and the lowest in 100% N treatment. However, the half life period recorded was minimum in 100% NPK+FYM and maximum in 100% N alone. Further, Imazethapyr content decreased with passage of time (Fig. 9.1 and 9.2). Results indicated that incorporation of FYM persists herbicide for longer period may be because of absorption of herbicidal residues.

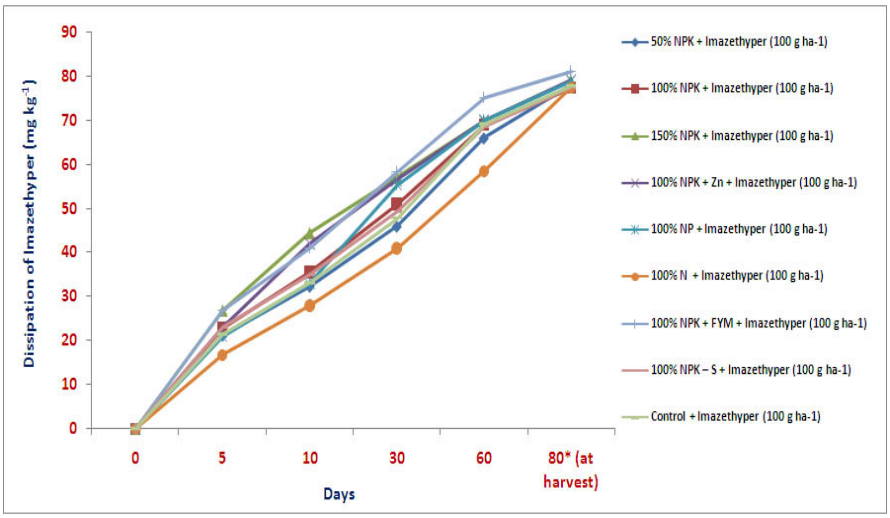


Fig. 9.1 Dissipation of Imazethaper on Soil at Different Interval

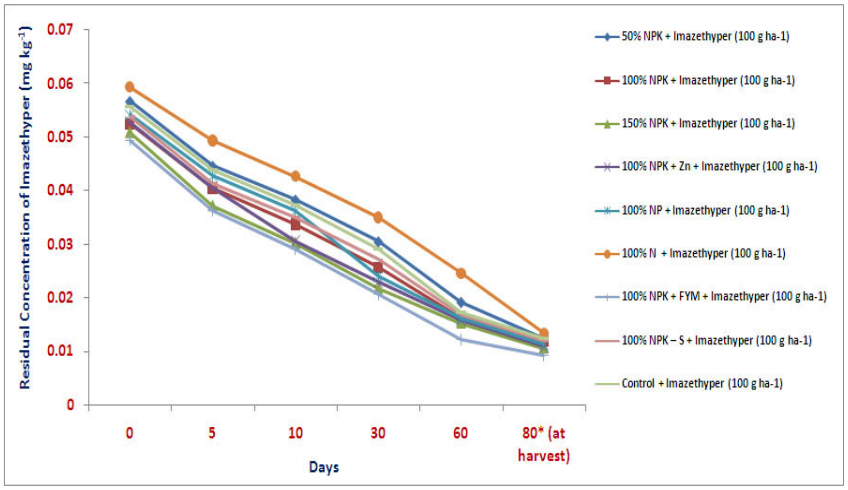


Figure 9.2 Residue of Imazethaper on Soil at Different Interval

9.1.2 Barrackpore

Degradation of herbicide/study related to herbicide and microbial activites.

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

9.3 Bangalore

Persistence of herbicide - Isoproturon in soil with drill sown finger millet crop

The persistence of isoproturon in the field experiment in Bangalore soil revealed that the residue of isoproturon in soils ranged from 0.10 to 0.63 µg g^{-1}. The rate of degradation is maximum in 100% NPK+ FYM+ lime treatment followed by 150% NPK treatment and 100% NPK+ FYM treatment and least degradation is observed in control followed by 50% NPK treatment Addition of lime to 100% NPK enhanced the rate of degradation which is almost similar with the treatment receiving FYM + 100% NPK. As the rate of nitrogen application increases the degradation rate also increased whereas the application of phosphorus and potassium along with nitrogen has no additional beneficial effect on the degradation of isoproturon.

Table 9.1 Persistence of isoproturon in soil of LTFE in drill sown finger millet

Treatments	Residues (µg g^{-1}) in different days							
	0	3	5	10	20	30	40	60
50% NPK	0.60	0.58	0.56	0.49	0.40	0.34	0.11	BDL
100% NPK	0.58	0.43	0.34	0.27	0.19	0.06	BDL	BDL
150% NPK	0.50	0.48	0.42	0.36	0.31	0.11	0.09	BDL
100% NPK+ HW	ND	ND	ND	ND	ND	ND	ND	ND
100% NPK+ Lime	0.54	0.59	0.43	0.34	0.30	0.14	0.07	BDL
100% NP	0.58	0.41	0.36	0.21	0.18	0.07	BDL	BDL

100% N	0.56	0.53	0.50	0.43	0.37	0.22	0.09	BDL
100% NPK+ FYM	0.61	0.53	0.51	0.36	0.27	0.09	BDL	BDL
100% NPK(S-free)	0.57	0.54	0.43	0.39	0.31	0.22	0.10	BDL
100%NPK+ FYM+ Lime	0.50	0.40	0.31	0.25	0.17	0.05	BDL	BDL
Control	0.63	0.60	0.55	0.43	0.41	0.32	0.22	BDL

BDL- Below detectable level, ND- Not detected

The dissipation parameters ($t_{1/2}$) were calculated from the best fit line of logarithms of residual concentration versus time for soil suggested that dissipation of isoproturon follows first order kinetics as shown in the Table 9.2.

The half life of isoproturon in field ranged from 9.9 to 20.8 days. The maximum half life was observed in control followed by 50% NPK and 100% NPK(S-free). The maximum half life was found in 100% NPK+ FYM+ lime followed by 100% NPK+ FYM and 100% NPK(S-free). The K_{deg} day^{-1} of isoproturon in field study ranged from 0.0197 to 0.0701 and the determination coefficient (r^2) ranged from 0.914 to 0.994. Decline in half life on application of balanced nutrient and organic manure is probably due to larger population of microbial which degrade the pesticide. Greater half life in control and 100% N plot support the hypothesis. In both the plots biological activity is poorest because of poor biological yield.

Table.9.2 First order kinetics of K_{deg}, r^2 and half life ($t_{1/2}$) of the soils collected from LTFE experiment with different treatments - Dissipation of isoproturon in soil

Treatments	K_{deg} day^{-1}	$t_{1/2}$ days	r^2
50% NPK	0.0197	18.0	0.994
100% NPK	0.0680	17.6	0.955
150% NPK	0.0459	15.1	0.942
100% NPK+ Lime	0.0443	15.6	0.931
100% NP	0.0638	10.8	0.914
100% N	0.0417	16.6	0.913
100% NPK+ FYM	0.0582	10.5	0.948
100% NPK(S-free)	0.0393	10.6	0.948
100% NPK+ FYM+ Lime	0.0701	9.9	0.970
Control	0.0290	20.8	0.9704

10. AWARDS, RECOGNITION & VISITS

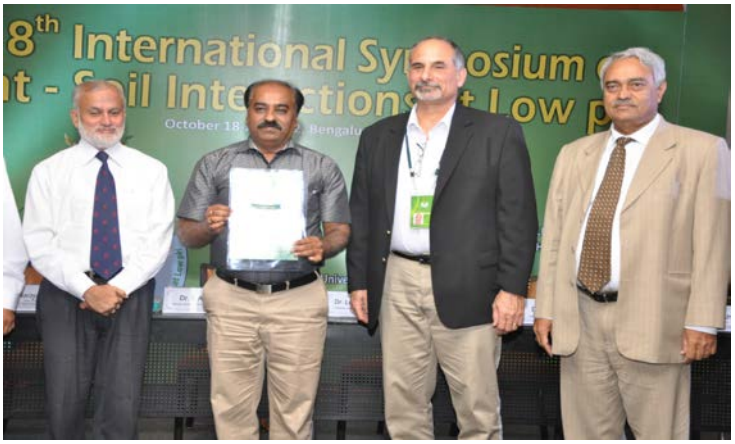
10.1 Award

10.1.1 FAI Golden Jubilee Award

Drs K.S Reddy, A Subba Rao, Muneshwar Singh and M. Mohanty received the FAI Golden Jubilee Award for excellence for the best work done in the field of 'Nutrient Management in Wheat'

10.1.2 R.C. Gowda (Bangalore)

Received Best poster presentation award for the research paper on Long term application of fertilizers and manure on soil acidification in an Alfisol (by RC Gowda, T Bhagyalakshmi, DC Hanumanthappa, K Sudhir and Singh Muneshwar). In: the "8th International Symposium on "Plant-Soil Interactions at Low pH" held during October 18-22, 2012, Bengaluru, India.



Best poster presentation award for "Long term application of fertilizers and manure on soil acidification in an Alfisol".

L-R : Dr.S.Ayyappan ,DG (ICAR), Dr.R.C.Gowda recipient of the Award Dr.Leon Koschien, President 8th PSLIPH ,Dr.K.Narayana Gowda,Vice Chancellor,UAS,Bangalore,

10.1.3 Thulasi V. (Pattambi)

Dr Thulasi V. received Dr Satish Memorial Young Scientist Award at Kerala Environment Congress 2012 (16-18, August, 2012), Best among the 15 presentations from different fields such as Agriculture, Engineering, Environmental Sciences, Genetics etc representing various universities and institutes.

10.1.4 Raj Pal Sharma, Surya Prakash Sharma and Gayatri Verma (Palampur)

They received the Second Best Paper Award for Poster Presentation in National Seminar on Indian Agriculture: Present situation, challenges, remedies and road map held on 04-05 August, 2012 at CSK HPKV, Palampur for the topic entitled 'Crop productivity and soil fertility as influenced by long-term use of chemical fertilizers and amendments in maize-wheat system in Western Himalayas'..

10.1.5 K. Arulmozhiselvan (Coimbatore)

- K. Arulmozhiselvan, Professor (SS&AC) and Scheme-in-charge (LTFE) received "Award of Appreciation for the 25 years of unblemished service in TNAU" on Foundation day of TNAU held on 1.7.2011.
- K. Arulmozhiselvan, Professor (SS&AC) and Scheme-in-charge (LTFE) received "Research Award for obtaining funds for research from DST" on Foundation day of UNAU held on 1.7.2012.

10.1.6 Udaipur

- Received Appreciation Award from Hon'ble Vice-Chancellor Prof. S.S Chahal,MPUAT, Udaipur for his outstanding work on Republic Day (26 th January, 2010)
- Best Poster presentation by PROM society to Dr S. K. Sharma(2011).

10.2 Visits

10.2.1 Bangalore

- Dr. Eva Liisa Viskari Senior Lecturer, Tampere University of Finland (23rd February 2010)
- Dr. Chikkadevaiah, Vice Chancellor, UAS, Bangalore visited the project and reviewed the work (22nd April 2010)
- Muneshwar Singh, Project Co-ordinator visited the project and reviewed the work (21st February 2011).

10.2.2 Pattambi

Dr Muneshwar Singh visits Pattambi centre (2010)

Dr Muneshwar Singh visits Pattambi centre (2013)

10.2.3 Coimbatore

Dr AK Singh, former DDG NRM, Dr Muneshwar Singh, PC (LTFE) visited Coimbatore centre

11. SEMINARS/TRAININGS ORGANIZED AND PARTICIPATED

11.1 Bangalore

Training Programmes for Extension Functionaries

- As resource person on the topic "Integrated nutrient management of agricultural crops for sustainable food security –rice, wheat, sugar cane and oil seed crops at International Institute of Horticulture Management, White Field ,Bangalore on 12-1-2010.Officers from NGO's, Scientists from agricultural Universities, Agricultural Officers and Assistant Directors of Agriculture, Govt of Karnataka.
- As resource person in the training programme on "Analysis of available sulphur and boron to the Officers of KS DA from 17-19-March, 2010, on topic- Research findings of sulphur and boron in Agricultural Officers and Assistant Directors of Agriculture, Govt of Karnataka - 30

Training Programmes for Farmers / Farm Women

- Millet improvement programme on nutritional security (Topic: Impact of long term fertililizer usage on soil and crop quality on 13-3-2012 and 28-3-2012 at Framers Training Institute, GKVK, Bangalore - 30 farmers in two batches.
- Under RKVY Project on Revalidation of fertilizer dose to crops a field day was organized with maize and finger millet crops in Doddaballpur taluk of Bangalore rural District and was attended by 50 farmers during October 2010.
- Krishi mela was organized in November at GKVK an posters with lessons learnt from LTFE Project were displayed and interacted with large number of farmers

Participation

- R.C. Gowda: Attended 75th Annual Convention of ISSS held at Bhopal, November 14-17, 2010.
- R.C. Gowda: As resource person on the topic "Integrated nutrient management of agricultural crops for sustainable food security – Rice, Wheat, sugarcane and oilseed crops" at International Institute of Horticultural Management, White field Bangalore on 12-01-2010.
- R.C. Gowda: Organized and attended "Indo US workshop on silicon in Agriculture during February 2010 at UAS, Bangalore
- D.C Hanumanthappa: Organized XIX National Symposium on "Resource management approaches towards livelihood security" December 2-4, 2010, organized by Indian Society of Agronomy, IARI, New Delhi at UAS, GKVK, Bengaluru-65
- D.C Hanumanthappa: Organized National Seminar on "Contemporary Approaches to Crop Improvement" 22nd-23rd, April 2011, held at UAS, GKVK, Bengaluru-65
- D.C Hanumanthappa: Attended National oral training programme on "Crop Micrometeorolgy" by ICAR, New Delhi organized and conducted by CAFT in Agricultural Meteorology, College of Agriculture, Pune on 8th December to 28th December 2011.
- D.C Hanumanthappa: Attended National conference on "Appropriate Technologies for Indian food processing industries" held at GKVK, Bangalore March 5-6, 2012, organised by IICPT, Thanjavur.

11.2 Palampur

Trainings Organized

Organized six one day trainings on Balanced Fertilization at six villages of Tribal Districts viz., Lahaul Spiti and Kinnaur wherein 550 farmers participated.

Location	Date	No. of farmers attended
Vill. Losar Distt. Lahaul Spiti (HP)	28.9.2012	101
Vill. Tabo Distt. Lahaul Spiti (HP)	29.9.2012	92
Vill. Leo Distt. Kinnaur (HP)	30.9.2012	81
Vill. Telangi Distt. Kinnaur (HP)	1.10.2012	57
Vill. Katgaon Distt. Kinnaur (HP)	2.10.2012	62
Vill. Nigulsari Distt. Kinnaur (HP)	3.10.2012	157

Participation

- Sharma R.P. : Attended meeting of In-charges of Co-operating centres of AICRP's, HOD's of Soil Science, Scientists of IISS and stake-holders along with Chairman of QRT & RAC held at IISS, Bhopal (MP) on January 5-6, 2012.
- Sharma R.P. : Attended QRT meeting and presented the work done in AICRP on LTFE held at GBPUA&T, Pantnagar on June 28-30, 2012.
- Sharma, Raj Pal., Sharma, Surya Prakesh and Verma, Gayatri.2012 Crop Productivity and Soil Fertility as Influenced by Long-term Use of Chemical Fertilizers and Amendments in Maize-Wheat System in Western Himalayas. In National Seminar on Indian Agriculture: Present situation, challenges, remedies and road map held at CSK HPKV, Palampur on 04-05 August, 2012.
- Jintu Dutta, N.K. Sankhyan, Sanjay K. Sharma, S.P. Sharma and Pardeep Kumar. 2012. Studies on long-term effect of chemical fertilizers and soil amendments on sulphur nutrition and crop productivity under maize-wheat cropping system. *In National Seminar on Indian Agriculture: Present Situation, Challenges, Remedies and Road Map, held on August 4-5, 2012* at CSK HP Krishi Vishvavidyalaya, Palampur (H.P.) – 176062
- Jintu Dutta, Narender K. Sankhyan, S.P. Sharma and Sanjay K. Sharma. 2012.Sulphur Transformation under maize-wheat cropping in an acid Alfisol of Western Himalaya as influenced by continuous use of chemical fertilizers and amendments. *In* 'The 8th International Symposium on Plant-Soil Interactions at Low pH' held on October 18-22, 2012 at University of Agricultural Sciences, Bengaluru, India
- Dutta, Jintu; Sankhyan, NK; Sharma, SP and Sharma, GD 2011. Sulphur sorption under maize-wheat cropping system as influenced by long-term effect of chemical fertilizers and soil amendments. *In* 76th Annual Convention of Indian Society of Soil Science during November 16-19, 2011, Organised by Dharwad Chapter of Indian Society of Soil Science, University of agricultural Science, Dharwad.
- Jintu Dutta, Narender K. Sankhyan, S.P. Sharma and Sanjay K. Sharma 2012. Sulphur transformation under maize-wheat cropping in an acid Alfisol of Western Himalayas as influenced by continuous use of chemical fertilizers and amendments. *In* The 8th International Symposium on Plant – Soil Interactions at Low pH at University of agricultural Science, Bengaluru, Karnataka, India.during October 18-22, 2012

- Sharma, RP, Sharma, SP and Verma Gayatri 2012 Effect of long-term application of fertilizers and amendments on soil health in Western Himalayas. *In* 77th Annual Convention of Indian Society of Soil Science held at PAU Ludhiana on Dec. 3-6, 2012.
- Verma, Gayatri, Sharma, RP and Sharma S. P. 2012 Changes in soil fertility status of maize-wheat cropping system due to long-term use of chemical fertilizers and amendments in an alfisol of Western Himalayas". *In* 77th Annual Convention of Indian Society of Soil Science held at PAU Ludhiana on Dec. 3-6, 2012.

11.3 Akola

Training Programme organized

- Training programme at Shetkari Sadan, Dr.PDKV, Akola on 21/02/2012, 22/02/2012 and 25/02/2012 Ninteen farmers each participated

Field Day Organized

- Ghusar Tq. &Dist. Akola , 200 farmers participated on 25/03/2012
- Aapatapa, Tq. & Dist. Akola, 250 farmers participated on 25/03/2012
- Tamshi, Tq. Balapur, Dist. Akola, 247 farmers participated on 29/03/2012
- Palodhi, Tq. & Dist. Akola 285 farmers participated on 29/03/2012
- Alanda Tq Barshi Takli Dist Akola, Akola 149 farmers participated on 16/02/2013
- Umari (Bk) Tq Manora Dist Washhim, Akola 155 farmers participated on 26/02/2013
- Loni Tq and Dist Akola, Akola 190 farmers participated on 28/02/2013

11.4 Barrackpore

- Delivered a lecture on “Nutrient Management of Jute’’ to a group of farmers in a meeting on “Improved jute retting method” for their knowledge upgradation from Palassey, Nadia district on 10/3/2010 at CRIJAF, Barrackpore.
- Delivered a lecture to a group of farmers regarding “Soil and nutrient management for better jute growth” at Santoshpur, Tarakeswar, Hooghly district on 25/03/2010.
- Delivered a lecture to a group of farmers regarding “Soil and nutrient management for better jute growth” at GauribatiTarakeswar, Hoogly district on 27/03/2010.
- Delivered a lecture to a group of farmers regarding “Soil and nutrient management for better jute growth” at Goaldaha village under Swarupnagar block of North 24 Parganas district on 12/05/2010.
- Delivered a lecture to a group of farmers regarding “Soil and nutrient management for better jute growth” at Goaldaha village under Swarupnagar block of North 24 Parganas district on 14/05/2010.
- Delivered lecture on 29/07/2010 in National Level Training Programme conducted at CRIJAF, Barrackpore on “Nutrient management for jute and allied fibres”
- Delivered lecture to farmers on 26/11/2010 in a training programme on “Scientific method of soil fertility management for enhancing jute productivity”. The training programme was held at CRIJAF, Barrackpore in collaboration with Department of Science & Technology, Government of West Bengal, Kolkata. The topic of the lecture was “Nutritional management (both macro and micro nutrient) for healthy jute crop.
- Delivered a lecture on “Nutrient management of jute with special reference to long term fertilizer experiment” in ICAR sponsored short course on “Fibre crop production, seed production and quality evaluation”during August 3-12, 2011 at CRIJAF, Barrackpore.

- Delivered a lecture in National training on “Technological advances in production of jute and allied fibres” during October17-21, 2011 at CRIJAF, Barrackpore.
- In the farmers training programme held on 24/08/2010 and 30/7/2011 long term fertilizer experimental plots were demonstrated to farmers and described different treatment effects (balanced and imbalanced) on crop yield.

11.5 Coimabatore

- A press meet was organized to disseminate the finding of 100 years of experience of Permanent Manurial Experiment PME to media. The Vice-Chancellor (TNAU) explained to Press and Media about the balanced fertilization and the performance of INM treatment in PME on 17.9.2010 (Press Meet organized)
- One-day training programme was organized to the Agricultural Officers working in STLs of State Department of Agriculture on “Assessment of Fertilizer requirements based on the Soil Fertility Status and Crops grown” on 1.12.2010. 48 Agricultural officers attended the training. Computer software for calculating fertilizer doses as per soil test values was demonstrated (Trainings organized)
- DAC-TNAU-National Seminar on “Soil Health improvement for enhancing Crop Productivity” was conducted during March 17-18, 2011. Around 242 scientists/ scholars participated. . A total of 199 abstracts, 18 lead papers were presented. Overall 242 participants from various parts of the country registered for seminar (Seminars/ Symposium / Workshops organized)

11.6 Pantnagar

Trainings/Seminar/Symposium/workshop organized and participated

- Shri Ram, Associate Professor : Attended a group meeting of AICRPs held on 5-6 Jan. 2012 at Indian Institute of Soil Science, Nabibagh Berasia Road, Bhopal (MP).
- Shri Ram, Associate Professor : Attended a national seminar on “Strategies to Rationalize and reduce consumption of water soluble phosphrus and potassium in the country to minimize import” held on 18-19 Dec., 2012 at Indian Institute of Soil Science, Nabibagh Berasia Road, Bhopal (MP).
- Shri Ram, Associate Professor : Attended a national consultation meeting on “Developing Roadmap for Soil Research of India” held on 20 Dec.2012 at Indian Institute of Soil Science, Nabibagh Berasia Road, Bhopal (MP).
- Shri Ram, Associate Professor : Participated in the “AICRP (STCR) ICAR Northern Regional workshop cum training on soil testing” held on 22-23 March, 2013 held at G. B. Pant University of Agriculture & Technology, Pantnagar-263145 (Uttrakhand)
- Shri Ram, Associate Professor : Participated in the workshop of “Preparation of GPS & GISP based Model Soil Fertility maps of selected districts of India to precise fertilizer recommendations” held on 22-23 April, 2013 held at Indian Institute of Soil Science, Nabibagh Berasia Road, Bhopal (MP).

Trainings / Seminar / Symposium /Workshop organized

- Shri Ram, Associate Professor : was member of organizing committee to organize“ QRT meeting of AICRPs; LTFE, STCR and Micronutrients (ICAR Northern Region)held on 22-

23 March, 2013 held at G.B.Pant University of Agriculture & Technology, Pantnagar-263145 (Uttrakhand)

- Shri Ram, Associate Professor : I was member of organizing committee to organize"AICRP (STCR) ICAR Northern Regional workshop cum training on soil testing" held on 22-23 March, 2013 held at G.B.Pant University of Agriculture & Technology, Pantnagar-263145 (Uttrakhand)

11.7 Parbhani

- Shirale S.T., Asstt. Professor: Attended training programme on Advances in agro-technologies for improving soil, plant and atmosphere systems on 11 to 31 October, 2012 at Dept. of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur (M.P.).

11.8 Pantnagar

- Shri Ram, Associate Professor: Presented Progress Report before the QRT meeting held from 29 and 30 Nov. ,2007 at Lucknow.
- Shri Ram, Associate Professor: Presented progress report in the workshop of LTFE held at IGKVV, Raipur (Chattishgarh) on 7.8.9 Nov.2009
- Shri Ram, Associate Professor: Presented progress report in the workshop of LTFE held at IGKVV, Raipur (Chattishgarh) on 7.8.9 Nov.2009
- Shri Ram, Associate Professor : Presented progress report in the workshop of LTFE held at IGKVV, Raipur (Chattishgarh) on 7.8.9 Nov.2009

11.9 New Delhi

- Workshop on "Implementing Site-Specific Nutrient management (SSNM) for Rice, Maize, and Wheat", 22-26 March 2010, International Rice Research Institute, Los Banos, Philippines.
- 5th International Nitrogen Conference on "Reactive Nitrogen Management for Sustainable Development - Science, Technology and Policy", 3-7 December 2010, The Ashok, New Delhi.
- 75th Annual Convention of ISSS at IISS, Bhopal from Nov. 21-24, 2010.
- 76th Annual Convention of ISSS at UAS, Dharwad from Nov. 16-19, 2011.

11.10 Pattambi

- Thulasi V- 2012 -Summer school 21 days- Natural Resource Management at TNAU, Coimbatore, 2-23, February 2012
- Moossa PP- 2012- 5 days training on Assessment of quality and resilience of soils at IISS, Bhopal, 9-13, January 2012.

12. PUBLICATION

12.1 PC LTFE (IISS, Bhopal)

Research Papers
National

- Singh Muneshwar, RH Wanjari (2012) Potassium responses and requirement of crops grown in Vertisols: Experiences from Long Term Fertilizer Experiment. *Indian Journal of Fertilisers* **8**(3): 26-32.
- Singh Muneshwar, RH Wanjari (2013) Measures to sustain and restore declined productivity in Alfisols under Long Term Fertilizer Experiments. *Indian Journal of Fertilisers* **9**(2): 24-32.
- Sawarkar, SD, NK Khamparia, Risikesh Thakur, MS Dewda and Singh Muneshwar (2013) Effect of long-term application of inorganic fertilizers and organic manure on yield, potassium uptake and profile distribution of potassium fractions in Vertisol under soybean-wheat cropping system. *Journal of the Indian Society of Soil Science* **61**(2): 94-98.
- Singh Muneshwar, Shri Ram, RH Wanjari and Pankaj Sharma (2013) Balance and forms of potassium in 40 years old rice-wheat long term experiment in Mollisols of Pantnagar (In Press).
- Singh Muneshwar, BK Agarawal, RH Wanjari and Pankaj Sharma (2013) Biological nitrogen fixation in soybean and contribution to soil in 40 year's old experiment on Alfisols of Ranchi (In Press).

International

- Singh Muneshwar, RH Wanjari, Anil Dwivedi and Ram Dalal (2012) Yield response to applied nutrients and estimates of N_2 fixation in 33- year-old soybean-wheat experiment on a Vertisol. *Experimental Agriculture* **48**(3): 311-325.
- Manna MC, P Bhattacharyya, TK Adhya, Muneshwar Singh, RH Wanjari, S Ramana, AK Tripathi, KN Singh, KS Reddy, A Subba Rao, RS Sisodia, M Dongre, P Jha, S Neogi, KS Roy, KS Rao, SD Sawarkar and VR Rao (2013) Carbon fractions and productivity under changed climate scenario in soybean–wheat system. *Field Crops Research* **145** (2013): 10-20.
- Wanjari RH, Muneshwar Singh, SD Jadhao, Prabhakar Mahapatra, AR Saha, RK Nayak, AK Dash, K Arulmozhiselvan and M Elayarajan (2013) Soil microbial diversity in long term fertilizer experiments in different agroecological zones in India. *International Journal of Bioresource and Stress Management*. **4**(2):169-172.
- Jha Promad, Arpen De, Lakaria BL, Biswas AK, Singh Muneshwar, Reddy KS and Rao AS (2012) Soil carbon pools, mineralization and pluxes associated with land use change in Vertisols of central India. *National Academy Science Letters – India* (DOI 10.1007/s40009-012-0082-2).
- Lakaria BL, Singh Muneshwar, Reddy KS, Biswas AK, Jha Promod, Choudhary RS, Singh AB and Rao AS (2012) Carbon Addition and storage under integrated nutrient management in soybean-wheat sequence in a Vertisols of Central India. *National Academy Science Letters – India* **35**:131-137.
- Jha P, Rashmi I, Patel NS, Lakaria BL, Biswas AK, Singh Muneshwar and Rao AS (2012) Effect of calcium salts on mineralisation of organic residue soil. *Agrochimica* **LVI** - N.O.
- Mohanty SR, Bharati Kollah, Sharma Vineet K, Bahadur Amar Singh, Singh Muneshwar & Rao AS (2013) Methane oxidation and methane driven redox process during sequential reduction of a flooded soil ecosystem. *Annals of Microbiology* DOI 10.1007/s13213-013-0633-x.

Technical / Popular article

- Muneshwar Singh and RH Wanjari (2013) अम्लीय मृदाओं में टिकाऊ खेती व उत्पादकता बढ़ाने हेतु तकनीक खाद पत्रिक– अक्टूबर 2013. pp. 14-17.
- Muneshwar Singh, RH Wanjari and Pankaj Kumar Sharma (2010) उर्वरकों से अम्लीय मृदाओं की उत्पादकता पर प्रभाव. *Krishi Chaynika* October-December 2010. pp. 17-19.
- Muneshwar Singh and RH Wanjari (2011) रासायनिक खादों का उपज और मिट्टी पर प्रभाव *Kheti* June 2011. pp. 20-22.

Technical Bulletins

- Singh Muneshwar and RH Wanjari (2012) Annual Report 2010-11. All India Coordinated Research Project on Long Term Fertilizer Experiments to Study Changes in Soil Quality, Crop Productivity and Sustainability. p. 1-114.

Scientific / Teaching Reviews

- Singh Muneshwar and Wanjari RH (2012) Conservation Agriculture: Biomass Recycling and Nutrient Dynamics. *In*: Model Training Course (8 days) on 'Conservation Agriculture for Sustaining Soil Carbon, Quality and Productivity in Rainfed Region'. Indian Institute of Soil Science, Bhopal. September 10-17, 2012.
- Wanjari RH (2011) Crop Diversification for Enhancing Soil, Water and Nutrient Use Efficiency in Different Regions of the Country. *In*: Model Training Course (MTC) on 'Best Soil and Water Management Practices for Resource Use Efficiency'. Indian Institute of Soil Science, Bhopal. October 17-24, 2011.
- Wanjari RH (2012) Importance of Crop Diversification in Climate Resilient Agriculture. *In*: Model Training Course (MTC) on Soil Organic Matter Management for Climate Resilient Agriculture'. Indian Institute of Soil Science, Bhopal. February 14-21, 2012.
- Singh Muneshwar, AK Biswas, AB Singh, AK Tripathi, RH Wanjari, K Ramesh, Sanjay Srivastava and A Subba Rao (2013) (Eds) *In* Souvenir : Soil Health for Sustainable Productivity. Western Region Agriculture Fair, Indian Institute of Soil Science. p. 1-160.
- Sharma Sunil, Arvind Verma, PC Kanthaliya, Muneshwar Singh and RH Wanjari (2012) Research Bulletin on Impact of Long Term Fertilizer Application on Soil Quality Crop Productivity and Grain Quality of Maize and Wheat Grown on Loamy Soils of Southern Rajasthan. AICRP LTFE, Indian Institute of Soil Science, Bhopal. pp. 1-76.
- मुनेश्वर सिंह एवं रवि वंजारी (2013) अम्लीय मृदा में टिकाऊ खेती व उत्पादकता बढ़ाने हेतु तकनीक। *In* स्मारिका–टिकाऊ उत्पादकता के लिए मृदा स्वास्थ्य (संपादक– मुनेश्वर सिंह, ए.के. विश्वास, ए.बी. सिंह, ए. के. त्रिपाठी, आर. एच. वंजारी, के. रमेश, संजय श्रीवास्तव, एवं ए. सुब्बा राव), पश्चिमी क्षेत्र कृषि मेला, भारतीय मृदा विज्ञान संस्थान, भोपाल, पृष्ठ 20–25.
- रवि वंजारी एवं मुनेश्वर सिंह (2013) दीर्घकालीन उर्वरक प्रयोगों में मृदा की गुणवत्ता का आकलनः एक अनुभव *In* स्मारिका– टिकाऊ उत्पादकता के लिए मृदा स्वास्थ्य (संपादक– मुनेश्वर सिंह, ए.के. विश्वास, ए.बी. सिंह, ए. के. त्रिपाठी, आर. एच. वंजारी, के. रमेश, संजय श्रीवास्तव, एवं ए. सुब्बा राव) पश्चिमी क्षेत्र कृषि मेला, भारतीय मृदा विज्ञान संस्थान, भोपाल, पृष्ठ 32–37.

Presentations in Conferences/Symposia/Seminars/other for a

- Wanjari RH (2011) Crop diversification for enhancing soil, water and nutrient use efficiency in different regions of the country. *In* Model Training Course (MTC) on Best Soil and Water Management Practices for Resource Use Efficiency. October 17-24, 2011.
- Wanjari RH (2012) Importance of crop diversification in climate resilient agriculture. *In*: Model Training Course (MTC) on Soil Organic Matter Management for Climate Resilient Agriculture. Indian Institute of Soil Science, Bhopal. February 14-21, 2012.

- Wanjari RH and Muneshwar Singh (2012) Impact of long term fertilizer and manure use on crop productivity and soil fertility in rice-rice cropping system in contrast soils. *In* Proceedings on Food and Environmental Security through Resource Conservation in Central India: Challenges and Opportunities. Agra. September 16-19, 2009. pp. 207-210.
- Wanjari RH (2012) Role of crop rotation in conservation agriculture. *In*: Summer School (21 days) on 'Engineering Interventions in Conservation Agriculture for Enhancing Agricultural Productivity and Climate Change Mitigation'. Central Institute of Agricultural Engineering, Bhopal. June 22- July 12, 2012.
- Wanjari RH (2012) Weed management in conservation agriculture. *In*: Model Training Course (8 days) on 'Conservation Agriculture for Sustaining Soil Carbon, Quality and Productivity in Rainfed Region'. Indian Institute of Soil Science, Bhopal. September 10-17, 2012.
- Wanjari RH (2012) Crop diversification in context to climate change. *In*: Short Course (10 days) on 'Use of Simulation Modeling in Climate Change Research: Special Reference to Natural Resource Management'. Indian Institute of Soil Science, Bhopal. October 3- 12, 2012.
- Wanjari RH (2012) Green manuring for sustainable agriculture. *In*: Model Training Course (8 days) on 'Organic and Agricultural Waste Management for Enhancing Nutrient Use Efficiency'. Indian Institute of Soil Science, Bhopal. October 15- 22, 2012.
- Behera, SK, AK Shukla, RH Wanjari and M.V.Singh (2011) Influence of different sources of zinc fertilizer on yield and zinc nutrition of maize (*zea mays* L.) *In*: 3rd International Zinc Symposium on 'Improving Crop Production and Human Health', Hyderabad, October 10-14, 2011
- Brij Lal Lakaria, AK Biswas, RH Wanjari, NK Lenka, Deepak Chhetri (2012) Assessment of integrated nutrient management modules for rice in acid soils of Nagaland. *In*: The 8th International Symposium on Plant–Soil Interaction in Low pH Soil' in Bangalore, October 18- 22, 2012. pp. 286-287.

TV Talk

- Muneshwar Singh (2012) Importance of soil testing in enhancing crop productivity Doordarshan, Bhopal.

12.1.2 LTFE Centres

AKOLA

Research Papers

- Katkar RN, BA Sonune and PR Kadu (2011) Long term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum-wheat system in Vertisol. *Indian Journal of Agricultural Sciences* **81**(8):734-739.
- Nandapure, SP, BA Sonune, VV Gabhane, RN Katkar, RT Patil (2011) Long term effects of integrated nutrient management on soil physical properties and crop productivity in sorghum-wheat cropping sequence in a vertisol. *Indian Journal of Agricultural Research* **45**(4):336-340.
- Nandapure, SP, BA Sonune, VV Gabhane, RN Katkar, RT Patil (2011) Influence of long term fertilization on micronutrients availability, their uptake and productivity of sorghum-wheat sequence under semiarid condition on a Vertisol. *Crop Research* **42**(1, 2&3):35-39.
- Jadhao, SD *et al* (2011) Effect of sulphur and zinc on yield, nutrient Uptake and quality of Soybean in swell – shrink soil. *PKV Research Journal* 2011 (In Press).
- Jadhao SD, SS Ingle, VK Kharche, BA Sonune, DV Mali (2011) Soil biological properties as influenced by long term manuring and fertilization under sorghum –wheat sequence in Vertisols. *Indian Journal of Agricultural Sciences* (In Press).
- Katkar RN, BA Sonune, Mohan Rao Puli and VK Kharche (2012) Effect of integrated nutrient management on productivity and soil fertility under soybean – wheat cropping system. *PKV Research Journal* 2012 (In Press).

- Katkar RN, VK Kharche, BA Sonune, RH Wanjari and Muneshwar Singh (2012) Long term effect on nutrient management on soil quality and sustainable productivity under sorghum – wheat crop sequence in Vertisol of Akola, Maharashtra. *Agropedology* **22**(2):103-114.

Folders/Booklets

- Katkar RN, SN Ingle, SS Rewatkar and BA Sonune (2008) Salient findings of LTFE experiment (Folder No. Dr. PDKV/PUB/402/MARCH/08).
- Kharche VK, RN Katkar, RB Ulemale, SD Jadhao and associate (2011) Integrated Nutrient Management for Sustainable Soil Health (PDKV/ 256/ March 2011).
- Kharche VK, RN Katkar, SN Ingle, SD Jadhao and associate (2012) Soil Health and fertility management: Akola district (PDKV/PU/ 655/ March 2012).
- Katkar RN, VK Kharche, SN Ingle, GS Laharia, SD Jadhao and associate (2012) Soil Health and fertility management: Bhandara district (PDKV/PU/ 658/ March 2012)
- Jadhao SD, DV Mali and associate (2012) Nutrient Management for Soil Health and Sustainable yield (PDKV/PU/ 668/ March 2012).

Popular articles (Marathi)

- Jadhao SD and VK Kharche (2010) Integrated nutrient management for chickpea. *Agro-Won* (09/11/2010) (Circulation in Maharashtra).
- Jadhao SD and VK Kharche (2010). Integrated nutrient management in wheat. *Agro-Won* (21/11/2010) (Circulation in Maharashtra).
- Jadhao SD and VK Kharche (2010). Balanced fertilization for sustainable yield. *Agro-Won* (28/10/2011) (Circulation in Maharashtra).
- Jadhao SD and VK Kharche (2012). Use of organic manures for improvement in soil fertility. *Agro-Won* (19/03/2012) (Circulation in Maharashtra).
- Jadhao SD, VK Kharche and SN Ingle (2012) Use of organic manure for soil health. *Krishi Patrika* (May, 2012) (Circulation in Vidarbha).
- Jadhao SD, VK Kharche and SN Ingle (2012) Long term fertilizer experiment: A key to sustainable agriculture *Krishi Patrika* (July, 2012) (Circulation in Vidarbha).

PALAMPUR

Research Papers/Abstract

- Verma G, Sharma, RP Sharma, SP Subehia, SK and Shambhavi S (2012) Changes in soil fertility status of maize-wheat system due to long-term use of chemical fertilizers and amendments in an Alfisol. *Plant and Soil Environment* **58**(12): 529-533.
- Dutta Jintu, Sankhyan NK, Sharma SP and Sharma GD. 2012. Sulphur sorption under maize-wheat cropping system as influenced by long-term effect of chemical fertilizers and amendments in an acid Alfisol of Western Himalaya. *Communications in Soil Science and Plant Analysis* (Accepted).
- Dutta, Jintu, Sankhyan, Narender K, Sharma SP, Sharma GD and Sharma Sanjay K 2012. Sulphur fractions in acid soil continuously fertilized with chemical fertilizers and amendments under maize-wheat system. *Journal of the Indian Society of Soil Science* (Accepted).
- Sharma Raj Pal, Sharma Surya Prakash and Verma Gayatri (2013). Crop productivity and soil fertility as influenced by long-term use of chemical fertilizers and amendments in maize-wheat system in western Himalayas. *In* Proceedings of National Seminar on Indian Agriculture : Present Situation, Challenges, Remedies and Roadmap, at CSK HPKV, Palampur, August 4-5, 2012. pp 52-55.

Pamphlets (Hindi)

- Sharma RP, Sankhyan N, Singh Muneshwar and Dixit SP (2013). Gandhak apnao upaj badhao. Department of Soil Science, CSKHPKV, Palampur, HP.
- Sharma RP, Verma Gayatri, Katoch, KK and Sharma, SP (2012). Potassium ka makki-gehoon phasal chakra mein mahatva. Department of Soil Science, CSK HPKV, Palampur, HP.

Extension Articles

- Verma Gayatri, Sharma Raj Paul and Shweta Shambhavi (2010) Santulit khaden evam mrida swasthya ._Parvatiya Khetibari. pp 5-6
- Sharma RP and Verma, Gayatri. Potash ke uchit proyag se krishi mein labh. *Kheti*. 66: 29-29.

TV / Radio Talk

- Raj Paul Sharma: TV Talk on 'Balanced Fertilization for enhancing productivity of rabi crops' at Doordarshan Kendra, Shimla (8.10.2012).
- Narender Kumar Sankhyan: TV Talk on 'Soil Testing' (5.9.2012) 'Method of Collection of Soil sample' (4.10.2012) and 'Deficiency symptoms of different nutrients' (12.12.2012) at Doordarshan Kendra, Shimla.
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PANTNAGAR

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NEW DELHI

Research Papers

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- Meena MC (2011) Bagwani phasalo ke leye mrada prabandhan (Hindi). (Eds RP Gupta, RK Yadav, Ritu Singh and Rakesh Kumar), KVK Ujwa (Delhi) & National Horticultural Research and Development Foundation, Nashik (MS).

Seminar/Symposia Papers

- Abir Dey, Dwivedi BS, Datta SP, Meena MC, Aggarwal BK, and Polara KB (2011) Fractions of soil boron and their relationship with boron uptake by wheat in different soils as influenced by long-term fertilization and manuring. 76th Annual Convention of ISSS, 16-18 November 2011, UAS, Dharwad.
- Meena MC, Dwivedi BS, Krishan Kumar and Rana DS (2010) Soil fertility and productivity of maize-wheat cropping system as influenced by long-term fertilization and manuring on a Typic Haplustept. The 75th Annual Convention of ISSS, November 14-17, 2010, IISS, Bhopal.

Theses

- Dynamics of boron in soils under long-term fertilization and manuring, M.Sc. Thesis.
- Sulphur dynamics in a Typic Haplustept as influenced by long-term fertilizer and manure application in a maize-wheat cropping system, Ph.D. Thesis.

Training Programme Participation

- MC Meena: Training Course on “Predicting Soil Carbon Sequestration in view of Global Warming and Climate Change” at NBSS&LUP, Nagpur (February 24 - March 08, 2012).
- MC Meena: Training Programme on “Data Analysis of Natural Resource Management Research using SAS” of the NAIP Consortium at IASRI, New Delhi (June 20-25, 2011).

Training Programme Organized for Extension Functionaries/Farmers

- Impact of long-term fertilization and manuring on crop productivity and soil health in different training programmes organised by IARI, New Delhi for extension workers and farmers.

Extension Activities

- Field days (04), Farmers Fairs (PUSA Krishi Vigyan Mela) (05), Radio talks (06), TV programmes (03)

PATTAMBI

Research Papers

- Moossa PP and Thulasi V (2012) Effect of integrated nutrient management and *in situ* green manuring on productivity of rice-rice sequence under long term fertilizer experiment. Plant Soil Interactions at Low pH. October 2012, UAS Bangalore.
- Thulasi V, Moossa PP and Johnkutty I (2012) Integrated nutrient management in rice rice cropping system on organic carbon and nutrient balance sheet in acid lateritic soil under long term fertilizer experiment. Plant Soil Interactions at Low pH. October 2012, UAS Bangalore.
- Moossa PP, Thulasi V and Jhonkutty I (2012) Long term effects of organic manures and inorganic fertilizers on soil organic carbon. *In* Proceedings of the International Symposium on 100 years of Rice Science and Looking Beyond. *9-12 Jan 2012*, Vol **II** page 628.
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Abstract

- Thulasi V, Poornima Yadav, Abdul Kareem, Moossa PP, Ameena M (2010) Suitability evaluation of indigenous upland rice varieties in coconut based homesteads for food security. *In* National Seminar on 'Health, Food and Agro-biodiversity Changing Paradigms' at Calicut, February 12-14, 2010,
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- Thulasi V, Deo Pal, Rajesh P and Moossa PP (2012) Biomass yield and carbon partitioning under elevated atmospheric co_2 in rice and wheat in a *Typic haplustept*. *In* International Symposium on 100 Years of Rice Science and Looking Beyond' January 9-12, 2012
- Thulasi Viswanath, Deo Pal, TJ Purakayastha Elevated CO2 reduces rate of decomposition of rice and wheat residues in soil. *Agriculture, Ecosystems and Environment* **139**: 557–564
- ThulasiV, Deo Pal, T J Purakayastha and Rajesh P (2012) Dynamics of soil carbon under elevated atmospheric CO_2 in rice and wheat in a *Typic haplustept* International Symposium on 100 years of rice science and looking beyond 9-12 january 2012
- Thulasi V, Deo pal, Rajesh P, Purakayastha TJ and Chitra P Impact of elevation of atmospheric CO_2 on biomass production, yield, terrestrial carbon and nitrogen dynamics and residue quality and decomposition in rice and wheat and modification of mineralization subroutine of CERES-N *Kerala Environemnt congress 16-18 August 2012*

Books

- Mannujalasamrakshanam- Soil and water conservation- Malayalam (2010). (Thulasi V, Moossa PP, Purnima and A Kareem) (2010)
- Karshika yanthravathkaranam- Mechanisation in Agriculture- Malayalam (2010)
- Evaluation of shade tolerance of upland rice varieties suitable for intercropping in coconut – English (2010)

Radio talks- All India Radio, Calicut

- Dr Moossa PP : (i) Know your soil and add nutrients (ii) Integrated Nutrient management (iii) Soil conditions for precision farming

UDAIPUR

Research Paper

- Joshi Ekta, V Nepalia, Arvind Verma, Dilip Singh and SK Sharma (2013). Performance and sulphur and zinc utilization by maize (Zea mays L.) as influenced by integrated nutrient management. *Annals of Agriculture Research*.34 (1):77-80.
- Choudhary Mukesh, Arvind Verma, and Hanuman Singh (2012) Productivity and economics of maize (Zea mays L.) as influenced by phosphorus management in Southern Rajasthan. *Annals of Agriculture Research*.33(1&2):88-90.
- Balai M L , Arvind Verma, V Nepalia and PC Kanthaliya (2011) Productivity and quality of maize (*Zea mays*) as influenced by integrated nutrient management under continuous cropping and fertilization. *Indian Journal of Agricultural Sciences* 81(4): 65-67.
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- Kanthaliya PC and Verma, Arvind (2009) Use of soil nutrient indices to make fertilizer recommendation in sub humid southern plain of Rajasthan. Advances in Experimental Agriculture 1: 123-131.
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Book

- Gulati IJ, Arvind Verma, KC Laddha and LL Somani (2010) Hand Book of Green Manuring Agrotech Publishing Academy, Udaipur Pp 304.

Book chapters

- Yadav BK and Arvind Verma (2012) Phosphate Solubilization and Mobilization in Soil Through Microorganisms Under Arid Ecosystems: *The Functioning of Ecosystem* (Mahamane Ali Ed.), pp 93-108. In Tech,- Open Access Company
- Bhandari SC and Arvind Verma (2010) Jev Prodhoki dwara vermicompost tiyar karna. In : *Carbonic Kheti Ke Sidhant* (RC Tiwari, VN Joshi and SK Khandelwal Eds.), pp77-86. Himanshu Publications, New Delhi.India.
- Arvind Verma, and Kanthaliya, PC (2010) Jevik Khadon Ka Mahatv evanm Prabhandan. In : *Carbonic Kheti Ke Sidhant* (RC Tiwari, VN Joshi and SK Khandelwal Eds.), pp-280-298. Himanshu Publications, New Delhi,India.
- Kanthaliya PC, Arvind Verma and MS Chahar (2010) Long Term Effect of Continuous application of Chemical Fertilizers and Organic Manure on Organic Carbon Content and Nitrogen Fractions in Typic Haplustepts. In :*Organic Farming for Sustainable Agriculture* (RC Tiwari, GS Sharma and SK Khandelwal Eds.), pp-304. Himanshu Publications, New Delhi, India.

Abstracts/ Extended Summaries

- Verma Arvind and SK Sharma (2012) Effect of continuous application of nutrients through inorganic fertilizers, organic manure and their combinations on yield and soil properties in maize – wheat cropping system, 3rd International Agronomy Congress, Indian Society of Agronomy, ICAR, New Delhi, pp-589-590.

- Sharma SK and Verma A (2011). Influence of long term fertilization on yield, nutrient uptake and economics of maize-wheat cropping system. 76th Annual Convention and National Seminar on Development in Soil Science of ISSS, 16-19.
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- Sharma SK and Urmila (2010). Effect of organic treatments on yield, yield attributes and nutrient uptake of maize-kabulli gram cropping system. Symposium on Natural Resource Management Agriculture, 10-11.

Research Bulletin

- Sharma Sunil, Verma Arvind, Kanthaliya PC, Singh Muneshwar and Wanjari R.H.(2012) Research Bulletin on " Impact Of Long Term Fertilizer Application On Soil Quality, Crop Productivity ,Sustainability And Grain Quality Of Maize-Wheat Grown On Loamy Soils of Southern Rajasthan" AICRP-LTFE, IISS (ICAR), Nabi bagh, Bhopal Pp.1-76.

Extension Activities

- Extension activities undertaken Field days (2), Agric. Exhibition (3), Farmer Fairs (2), Radio (3) and TV talk (2), Training lectures (7), Training Materials (5)

13. STAFF POSITION

The Headquarter of the ***AICRP*** on ***LTFE*** was shifted from IARI New Delhi to Indian Institute of Soil Science, Bhopal during 1997 and started functioning w.e.f. 06.03.1997. The current staff position of PC LTFE Unit and Cooperating Centres is listed below:

Name	Designation	Date of joining
PC Unit, IISS, Bhopal		
DR. MUNESHWAR SINGH	Project Coordinator	18.08.2005
DR RH WANJARI	Sr. Scientist	07.01.1999
MR AK MISHRA	Lab Attendant	10.06.1999
IARI New Delhi		
DR BS DWIVEDI	Pr. Scientist	2003
DR MC MEENA	SCIENTIST	
DR DS RANA	Research Associate	1993
CRIJAF Barrackpore		
DR AR SAHA	Pr. Scientist	2000
DR JALADHI CHAUDHARY	Senior Scientist	1999
MR JALADHAR MISRA	Field Technician	1999
MRS DIPALI GHOSH	Lab Attendant	1979
CSKHPKV Palampur		
DR RP SHARMA	Soil Scientist	22.02.2007
DR GAYTRI VERMA	Research Associate	10.07.2009
MR SATISH KUMAR	Beldar	22.12.1995
GKVK Bangalore		
DR RC GOWDA	Pr. Scientist	
DR HANUMANTHAPA	Sr. Scientist	13.03.2006
MRS. GAYATHRI	Research Associate	19.11.2012
BAU Ranchi		
DR BK AGARWAL	Sr. Scientist	01.01.2007
DR PRABHAKAR MAHAPATRA	Sr. Scientist	21.07.2004
MR RAJEEV KUMAR	Research Associate	23.11.2005
MR SAMAUDDIN ANSARI	Lab. Attendant	01.07.1976
PAU Ludhiana		
DR BS BRAR	Sr. Soil Scientist	13.11.1998
MR JAGDEEP SINGH	Research Fellow	16.01.2004
MR MOHINDER SINGH	Lab. Attendant	19.02.2002
ARS ANGRAU Hyderabad (Jagtial)		
DR S HARISH K SHARMA	Sr. Scientist	07.02.2003
DR M SRILATHA	Scientist	01.03.2007
MR M SHANKARAIAH	Research Associate	01.05.2006
MR M GANGARAM	Lab. Assistant	01.04.2004
GBPUA&T Pantnagar		
DR SHRI RAM	Assistant Professor	16.06.1998
DR PRADEEP KUMAR	Research Associate	01.05.2006
MR MUKHTAR ALI	Lab. Attendant	01.09.1989
TNAU Coimbatore		
DR. K. ARULMOZHISELVAN	PROFESSOR	
DR M ELAYARAJAN	Associate Professor	05.05.2008
DR J BALAMURUGAN	Research Associate	01.06.2006
MR M VISWANATHAN	Lab Assistant	04.08.2003

OUAT Bhubaneswar

DR MR PATNAIK	Senior Scientist	01.08.2007
DR AK DASH	Scientist	01.10.2005
MR S SAHOO	Lab Attendant	28.08.2007

JNKVV Jabalpur

DR B. S. DWIVEDI	Principal Scientist	
DR SD SAWARKAR	Sr. Scientist	28.02.2008
DR RK THAKUR	Res. Associate	17.06.2008
MR PL PATEL	Lab Attendant	01.03.1974

IGKV Raipur

DR RK BAJPAI	Senior Scientist	19.09.2003
DR SUKUL SINGH PORTE	Senior Scientist	21.03.2005
MR PYARELAL NIAHAD	Lab Attendant	01.08.1996

MPAU&T Udaipur

MR ARVIND VERMA	Assistant Professor	19.05.1997
MR JET SINGH	Lab Attendant	14.09.2000

RRS KAU Pattambi

DR PP MOOSA	Assistant Professor	29.07.2008
DR V THULASI	Asst. Professor	28.06.2010
MR CK DILEEP	Lab Attendant	05.09.2009

MAU Parbhani (Maharashtra)

DR DS KIDE	Associate Professor	01.07.2010
MR ST SHIRALE	Assistant Professor	01.03.2009
MD MUMTAZ NAWAJ	Lab Attendant (Ret.)	01.04.2006

PDKV Akola (Maharashtra)

DR SD JADHAV	Associate Professor	01.03.2008
DR DV MALI	Asst Professor	
MR RP NERKAR	Lab Attendant	19.09.2005

JAU Junagarh (Gujarat)

DR M. SOLANKI	Associate Professor	01.07.2010
MR HK SHOBHANA	Assistant Professor	01.07.1998
MS GITA H SARDHARA	Lab Attendant	01.07.1999

IASRI, New Delhi

MR KISHAN LAL	Senior Scientist	01.12.2009

Mr. D. K. Sehgal, Dr. N. K. Khamparia, Dr. M.R. Patnaik have been retired recently after rendering their services in AICRP LTFE at their respective centres. The Project Coordinator (LTFE) acknowledges their valuable services contributed to this project.

The Statement of Centre-wise and Head-wise Financial Outlay for XII Plan for 2012-2017 in respect of AICRP on LTFE

Sr. No.	Name of the Centre	Grant in aid salary (estb & wages)			Grant in aid General	Grant in aid capital	NEH	TSP	TOTAL	ICAR	STATE	ICAR	NRC	NRC	NRC
		Estt.	TA	RC	HRD (Domestic/International)	(Works/ Equipments/ Repair)				**share**	**share**	TOTAL	Equipments	Works	Total
1	UAS, Bangalore	199.67	2.10	29.75	0.00	6.00	0.00	3.00	240.52	181.14	59.38	228.200	5.00	1.00	6.00
2	OUAT, Bhubaneswar	142.70	2.10	30.35	0.00	6.00	0.00	27.00	208.15	162.86	45.29	207.000	5.00	1.00	6.00
3	TNAU, Coimbatore	187.94	2.10	30.35	0.00	6.00	0.00	0.00	226.39	169.79	56.60	225.740	5.00	1.00	6.00
4	APAU, Hyderabad	96.03	2.10	30.35	0.00	6.00	0.00	0.00	134.48	100.86	33.62	125.300	5.00	1.00	6.00
5	JNKVV, Jabalpur	177.10	2.10	29.25	0.00	6.00	0.00	33.00	247.45	193.84	53.61	225.400	5.00	1.00	6.00
6	PAU, Ludhiana	191.46	2.10	30.35	0.00	6.00	0.00	0.00	229.91	172.43	57.48	228.460	5.00	1.00	6.00
7	HPKV, Palampur	180.45	2.10	30.35	0.00	6.00	0.00	32.00	250.90	196.18	54.73	231.800	5.00	1.00	6.00
8	BAU, Ranchi	103.83	2.10	30.35	0.00	6.00	0.00	34.00	176.28	140.71	35.57	140.630	5.00	1.00	6.00
9	GBPUAT, Pantnagar	141.00	2.10	30.35	0.00	6.00	0.00	0.00	179.45	134.59	44.86	194.700	5.00	1.00	6.00
10	KAU, Vellanikkara	104.30	2.10	30.35	0.00	6.00	0.00	1.00	143.75	108.06	35.69	137.800	5.00	1.00	6.00
11	GAU, Junagarh	146.60	2.10	30.35	0.00	6.00	0.00	0.00	185.05	138.79	46.26	183.800	5.00	1.00	6.00
12	RAU, Udaipur	176.85	2.10	30.35	0.00	6.00	0.00	28.00	243.30	189.48	53.83	226.000	5.00	1.00	6.00
13	MAU, Parbhani	151.60	2.10	30.35	0.00	6.00	0.00	0.00	190.05	142.54	47.51	182.200	5.00	1.00	6.00
14	PDKV, Akola	158.33	2.10	29.25	0.00	6.00	0.00	4.00	199.68	150.76	48.92	189.200	5.00	1.00	6.00
15	IGKVV, Raipur	131.10	2.10	29.25	0.00	6.00	0.00	38.00	206.45	164.34	42.11	201.400	5.00	1.00	6.00
16	IARI, New Delhi	36.20	2.10	26.05	0.00	6.00	0.00	0.00	70.35	70.35	0.00	66.700	5.00	1.00	6.00
17	CRIJAF, Barrackpore	35.08	2.10	25.05	0.00	6.00	0.00	0.00	68.23	68.23	0.00	64.300	5.00	1.00	6.00
18	IASRI, New Delhi	0.00	1.50	3.00	0.00	0.80	0.00	0.00	5.30	5.30	0.00	8.000	0.80	0.00	0.80
19	P.C.Unit, IISS, Bhopal	0.00	21.25	37.93	0.00	12.45	0.00	0.00	71.63	71.63	0.00	110.270	12.45	0.00	12.45
	Total	2360.24	58.45	543.38	0.00	115.25	0.00	200.00	3277.32	2561.87	715.45	3176.900	98.25	17.00	115.25
	ICAR Share	**1788.00**	**50.58**	**430.54**	**0.00**	**92.75**	**0.00**	**200.00**	**2561.87**			2494.993	**79.50**	**13.25**	**92.75**
	State Share	572.24	7.87	112.84	0.00	22.50	0.00	0.00	715.45			681.908	18.75	3.75	22.50