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

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ICAR

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CONTENT

PREFACE

IMPORTANCE OF SUSTAINABILITY of Indian agriculture does not require emphasis. However, call of honorable Prime Minister of the country "more food from unit natural resources" further attracted attention to it. The result on long term fertilizer experiments world over proved that sustainability is impossible without external supply of nutrient from fertilizers. But, sometimes indiscriminate use of fertilizer without scientific basis may have adverse effect on soil productivity. Therefore, it is necessary to have a constant watch on soil health. Long-term experiments in India have generated large and valuable informations which are used for sustainability of high input 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 take more time to bounce back to same condition. Long-term experiments provide the best possible platform to study the changes in soil properties and processes, identifying emerging in nutrient imbalances and deficiencies. It is our moral duty to pass on natural resources in better condition to our next generation. 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 summarized would benefit scientific and extension workers, policy makers and personnels 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.

I express may sincere gratitude to Dr. T. Mohapatra, Director General, Indian Council of Agricultural Research (ICAR) and Secretary, Department of Agricultural Research and Education, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi for keen interest and providing financial support for the project. I am honored to express my thanks 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. S.K. Chaudhari, Assistant Director General (Soil and Water Management), ICAR for his generous support and useful suggestions. My thanks are due to Dr. Ashok K. Patra, Director, ICAR- Indian Institute of Soil Science, Bhopal for the facilities extended to coordinating cell in execution of the research programme of the project.

I sincerely thank to Dr. R.H. Wanjari, Sr. Scientist, PC LTFE Unit for his constant support in execution and monitoring programme and help rendered by him in compilation of the report. The help extended by Mr. Sunny Kumar, Jr. Stenographer for his secretarial assistance in not only preparation of manuscript but also day-to-day work of PC Unit is duly acknowledged. Thanks are also due to Mr. A.K. Mishra (Lab Attendant) and Mr Jagannath Gaur (SSS) for assisting me in day-to-day work. The help rendered by Mr. Roopchand Jatav (Research Associate) and Miss Shweta Jamra (Senior Research Fellow) for preparation of this report is duly acknowledged.

ICAR-IISS, Bhopal
14th August, 2017

(Muneshwar Singh)
PROJECT COORDINATOR (LTFE)

Dr SK Chaudhari
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FOREWORD

LONG-TERM EXPERIMENTS started in early 70s with the objective to study the impact of fertilizer on soil productivity but with a wider relevance as platform sites for involving multi-discipline, a resource database for the development and validation of crop/soil simulation models and opportunities to test basic ecological and biogeochemical questions that cannot be answered without long-term experiments. During the last 45 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 to have more relevance in view of changing scenario of climatic change 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 as a result of continuous use of chemical fertilization and manure over a long period. In order to have better 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, Economics, and Meteorology by using their expertise to understand soil processes and Agronomy of long-term fertilization/ manuring experiments. Interaction with other experts like ecologists, meteorologist, modelers and statisticians may add value to work of 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 assessing 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 productivity and the knowledge can be used to develop strategy for mitigating/ harnessing in favour.

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, changing climate impact on crop 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.

(SK Chaudhari)

EXECUTIVE SUMMARY

THE LONG –TERM FERTILIZER EXPERIMENTS conducted across the country clearly brought that it is not possible to sustain productivity without external supply of nutrients

- In Alfisols of Palampur, Ranchi and Bangaluru, the yield data of crops indicated that soil amended with FYM found to be superior to lime as far as soil productivity is concerned. Application of organic manure in addition to moderating soil condition also supply of nutrients whereas lime increases soil pH only.
- Incubation studies on soil with bio-char conducted revealed increase in soil pH, exchangeable K^{+} and Ca^{+2} in soil decline in exchangeable Al^{+3} and Fe^{+3} which are responsible for acidity in soil. Thus, bio-char could be long term solution to maintain soil acidity and enhance productivity.
- Studies on assessment of impact of changing climate on crop productivity indicated decline in productivity of wheat Ludhiana during next 50 -60 but at the same time increase in moisture availability due to increase in rain fall. Increase in fertilizer N with advancement of sowing not only offset the expected decline in yield but also enhanced yield by 15 to 30 percent from base line.
- In contrast at Delhi changing climate does not effect on productivity. However, increase in N dose and advancement in sowing time of wheat may result increase in yield over baseline.
- In Vertisols of Raipur, yield can be sustained on exclusive application of fertilizer nutrients as well as integrated use of nutrient.
- In Vertisols of Akola, results indicated that exclusive application of nutrient from organic manure even after 26 years could not keep the pace with 100% NPK. It is advised to centre further increase the dose of organic manure to obtain more yield to narrow down gap between organic and inorganic nutrient supply.
- The studies on crop response to K in Vertisols conducted at different places indicated response of crop during kharif season invariable whereas in during rabi season response of to applied K is random. Probably due to wetting of soil during kharif season water soluble K which is part of available K is entrapped in between two layers of 2: 1 type minerals and thus available K is reduced below the critical limit
- In Alfisols, results indicated that application of urea alone (i.e. N alone) had deleterious effect on crop productivity of maize and wheat (Palampur) and other places also. This is due to decline soil pH by one unit which reduces the availability of P and K to a large extent.
- It is surprising to note that application of fertilizer resulted in increase of the population of all type of soil microorganisms. Increase in application of nutrient from 50 to 150% NPK also had positive effect on soil microorganism population and their activities.
- Irrespective of soil and crop, incorporation of farm yard manure (FYM) or green manure not only resulted in increase in productivity but also increase microbial count and their enzymatic activities.
- Application of fertilizer increased the enzymatic activity in soil which resulted in evolution of more CO_2. Thus, the observations clearly demonstrated that application of fertilizer is essential not only to sustain the crop productivity but also to maintain or enhance population of soil microorganisms.
- The result revealed that decline in P dose to half in the plots / fields, accumulated P in Ludhiana (Punjab), Bangalore (Karnataka) and Jabalpur (Madhya Pradesh) did not have any adverse effect on crop productivity. Thus, from the results it can be concluded that P accumulated over the years can be reutilized.
- From the yield data of rice at Pantnagar, it was noted that application of S and Zn together had additive effect on yield. Thus, it can be concluded that both the nutrients (S and Zn) should be supplied to crop simultaneously.

- It is surprising that at Akola sorghum responded to applied K but subsequent wheat in same plot did not response to K application. This means total biomass of crop is responsible for K response. The crop like sorghum require more K because of its larger biomass.
- In the field demonstration, incorporation of FYM along with NPK resulted in increase in productivity of rice to the tune of 44.8, 51.6 and 67.8% in Durg, Dhamtari and Janggir district of Chhattisgarh,respectively.
- Field demonstration conducted in Devgarh and Rayagada district in Odisha revealed increase in yield on conjunctive and balance use of nutrient to the extent of 77.8 and 109.2%, respectively.
- The soil carbon predicted by model revealed that soil can't retain carbon beyond a particular limit even if you dump carbon and also soil can't lose its carbon below a certain value. These limits are called as saturation and threshold carbon values of soil, respectively.
- The saturation and threshold carbon limits are dependent on texture (clay), rainfall and temperature and sequestration of carbon is dictated by carbon added through residual biomass. Thus, more is the productivity higher is residual biomass and probability of carbon sequestration is more.
- The increase in productivity on application of fertilizer resulted increase in carbon in soil and microbial population and thus ruled out chemical fertilizer deteriorate soil carbon and kill the soil microorganisms.
- Studies indicated that retention of C and N are dependent on texture (clay +silt) of soil. So soil can't retain beyond its capacity.

सारांश

देश भर में दीर्घकालीन उर्वरक परीक्षणों से एकत्रित ऑकड़ों का विश्लेषण करने के बाद यह तथ्य सामने आया कि बाहर से पोषक तत्वों को प्रदाय किए बिना फसल की स्थाई उत्पादकता प्राप्त करना संभव नहीं है।

- पालमपुर, बैंगलोर, राँची की अम्लीय मृदाओं से प्राप्त उत्पादकता आंकड़ों से ज्ञात हुआ कि गोबर की खाद चूने के मुकाबले में उत्पादकता में अधिक सहायक सिद्ध हुई। गोबर की खाद न केवल मिट्टी को अच्छा बनाती है बल्कि साथ–साथ पोषक तत्वों का भी मिट्टी में समावेश करती है जबकि चूने के उपयोग से केवल मिट्टी का पीएच मान, बढ़ता है। यदि पोषक तत्व न प्रदाय कराए जाएं तो उत्पादकता में बढ़ोत्तरी बहुत कम होती है।
- अम्लीय मृदाओं में बायोचार के साथ मिलाकर एक विशेष तापमान पर रखने पर मिट्टी के पीएच मान विनिमय पोटैशियम तथा कैल्शियम में वृद्धि पायी गई। इसके साथ–साथ विनिमय एल्युमिनियम में कमी पाई गई जोकि मिट्टी के पीएच को बढ़ने के कारक है। इन आंकड़ों से यह निष्कर्ष निकलता है कि यदि अम्लीय मृदाओं में बायोचार का उपयोग किया जाए तो न केवल मिट्टी की उत्पादकता में वृद्धि होगी परंतु एक स्थायी उपाय भी हो सकता है।
- पिछले चार दशकों से वायुमण्डल में कार्बन डाई आक्साइड की सान्द्रता बढ़ने से वायुमण्डल के तापमान में वृद्धि हो रही है। जिसका असर फसलों पर पड़ रहा है। वायुमण्डल का असर पौधें पर अध्ययन करने से पता चला कि यदि कोई ठोस कदम नही उठाया गया तो अगले कुछ वर्षों में गेहूँ की पैदावार में काफी कमी आ सकती है। लुधियाना में बदलते वायुमण्डल के प्रभाव को कम करने के लिए यदि हम फसलों में नाइट्रोजन की मात्रा बढ़ा दे तथा बुवाई के समय 10 दिन परिवर्तन कर दे तो न केवल वायुमण्डल का फसलों पर दुष्प्रभाव कम होगा बल्कि 15 से 20 प्रतिशत उपज में वृद्धि भी हो सकती है।
- दिल्ली में गेहूँ की फसल पर वायुमण्डल के प्रभाव का अध्ययन करने से यह पता चलता है कि विगत अगले कुछ वर्षों तक बदलते वायुमण्डल का गेहूँ की उपज पर कोई प्रभाव नहीं पड़ेगा। यदि हम बुवाई के समय में बुवाई 10 दिन पहले कर दे तथा एक सिंचाई अधिक कर दे तो गेहूँ के उपज में वृद्धि हो सकती है। काली मिट्टीयों में धान की पैदावार केवल रासायनिक खाद के प्रयोग करने से ऊँचे स्तर पर की जा सकती है। यदि हरी खाद तथा गोबर की खाद का प्रयोग करे तो यह उपज और भी अधिक बढ़ायी जा सकती है।
- ज्वार तथा गेहूँ की उपज के आंकड़ों को देखने से यह पाया गया है कि केवल कार्बनिक खाद (Organic manure) के द्वारा पोषक तत्वों को प्रदाय करने पर दोनों फसलों की उत्पादकता, रासायनिक खाद द्वारा प्राप्त उत्पादकता से कम होती है।
- ऐसा माना जाता है कि काली मिट्टी में पोटैशियम की मात्रा काफी अधिक होती है किंतु फिर भी फसलों में पोटैशियम के देने से उत्पादकता में वृद्धि होती है। इसके लिए काली मिट्टीयों पर विभिन्न फसलों में पोटैशियम की उपयोगिता का अध्ययन किया जा रहा है। ऐसा लगता है कि काली मिट्टी गीली होने पर सुलभ पोटैशियम की मात्रा कम हो जाती है। जिससे फसलों में बाहर से पोटैशियम देने की जरूरत पड़ती है।
- लगातार अम्लीय मृदाओं में यदि यूरिया का प्रयोग किया जाए तो फसलों की उत्पादकता बहुत कम हो जाती है। यदि बहुत ज्यादा समय तक यूरिया का उपयोग किया जाए तो उत्पादकता शून्य के बराबर भी हो सकती है। इसका कारण मिट्टी के पीएच मान में कमी आना है।

- मिट्टी के अध्ययन से यह आश्चर्यजनक बात सामने आयी कि रासायनिक खादों के प्रयोग करने से मिट्टी में सूक्ष्म जीवाणुओं की मात्रा में वृद्धि हुई तथा उनसे प्राप्त पोषक तत्वों से यह पता चलता है कि जीवाणु अधिक सक्रिय हैं।
- सभी प्रकार की मिट्टीयों तथा फसलों में गोबर की खाद तथा हरी खाद का प्रयोग करने पर न केवल फसल की उत्पादकता में वृद्धि होती है बल्कि जमीन में पाये जाने वाले सूक्ष्म जीवाणुओं की संख्या में भी वृद्धि पायी गई।
- रासायनिक खाद को देने से मिट्टी से अधिक मात्रा में कार्बन डाई आक्साइड का निकलना यह दर्शाता है कि मिट्टीयों में सूक्ष्म जीवाणुओं की सक्रियता में वृद्धि हुई है जिससे यह सिद्ध होता है कि रासायनिक खाद न केवल पौधों के लिए आवश्यक है वरन सूक्ष्म जीवाणुओं को भी आवश्यकता होती है।
- फसलों में लगातार फास्फोरस के प्रयोग करने से फास्फोरस के स्तर में वृद्धि हुई तथा फास्फोरस की मात्रा आधी करने पर फास्फोरस की मात्रा में वृद्धि को न केवल रोका जा सकता है बल्कि देश पर अत्यधिक आर्थिक बोझ से बचा जा सकता है।
- पंतनगर केंद्र पर धान के उपज आंकड़ों से ज्ञात होता है कि यहां उपज लेने के लिए सल्फर तथा जिंक का प्रयोग आवश्यक है।
- अकोला में पोटैशियम को मिट्टी में डालने पर ज्वार के पैदावार में वृद्धि होती है परंतु उसी क्षेत्र में गेहूँ के पैदावार में वृद्धि नही पाई गई जिसका कारण गेहूँ की कम उपज है।
- छत्तीसगढ़ के दुर्ग, धमतरी, झंझागीर जिलों में कराए गए परीक्षणों से ज्ञात हुआ कि धान में यदि रासायनिक खाद के साथ गोबर की खाद का प्रयोग करें तो धान की पैदावार में लगभग 45, 52 तथा 67 प्रतिशत की वृद्धि होती है।
- उडीसा के रायगढ़ तथा देवगढ़ जिलों में अनुसूचित जनजाति के किसानों के यहां कराए गए परीक्षणों से ज्ञात हुआ यदि वहां पर संतुलित मात्रा में पोषक तत्वों का प्रयोग किया जाए तो धान की उपज में 77 तथा 109.2 प्रतिशत की वृद्धि हो सकती है।
- विगत वर्षों में विकसित किए गए मॉडल से यह तथ्य सामने आया है कि मिट्टी में कार्बन की मात्रा एक सीमा तक ही बढ़ाई जा सकती है तथा मिट्टी में एक सीमा के नीचे कार्बन की मात्रा को घटाया भी नहीं जा सकता। इनको हम क्रमशः संतृप्त (Saturation) तथा थ्रेशोल्ड (Threshold) कार्बन की मात्रा के नाम से जानते हैं।
- मिट्टी में दोनों कार्बन की थ्रेशोल्ड सीमाएं मिट्टी में पाये जाने वाले क्ले (Clay) की मात्रा, वर्षा तथा तापमान पर निर्भर करती है। मिट्टी में कितना कार्बन प्रति वर्ष जमा होता है यह इस बात पर निर्भर करता है कि हम मिट्टी में कितना कार्बन डालते हैं।
- रासायनिक खादों के प्रयोग से न केवल फसलों की उपज में वृद्धि होती है बल्कि मिट्टी में कार्बन की मात्रा तथा सूक्ष्म जीवाणुओं की संख्या में भी वृद्धि होती है। इससे यह निष्कर्ष निकलता है कि रासायनिक खाद न तो कार्बन की मात्रा को कम करते है और न ही मिट्टी में सूक्ष्म जीवाणुओं को मारते हैं। इसलिए रासायनिक खादों के बारे में जो भी गलत धारणाएं हैं वह उचित नहीं है।

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 continuously 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 gave a call for a long term studies at fixed sites for monitoring the nutrient dynamics in soil 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 under 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: **T_1** 50% optimal NPK dose; **T_2**100% optimal NPK dose; **T_3**150% optimal NPK dose; **T_4**100% optimal NPK dose + hand weeding; **T_5** 100% optimal NPK dose + Zinc or lime; **T_6**100% optimal NP; **T_7**100% optimal N; **T_8**100% optimal NPK + FYM; **T_9**100% optimal NPK (Sulphur free/sulphur source); **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 (A.P.)	Inceptisols	2000	Typic Tropaquept	Rice-rice [Earlier expt. continued till 1996 (at Hyderabad,1971-96)]	7	7.2
8.	OUAT Bhubaneswar (Odisha)	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 (Uttarakhand)	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 (Chhattisgarh)	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
18.	IASRI New Delhi (Voluntary centre)	-	1972	-	-	-	-

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

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

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

2.2 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. In order 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. Similary, to address the issue of organic farming treatment were modified and nutrient were supplied through FYM only .

2.2.1 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
100% NPK	Superimposed treatments since 2002 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

2.2.2 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

2.2.3 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

2.2.4 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})
	Superimposed treatments since Kharif, 2005-06
150% NPK	S_1 150% NPK S_2 150% NPK+ 5 t ha^{-1} FYM S_3 100% NPK + 10 t ha^{-1} FYM

2.2.5 New Delhi

Treatment	Superimposed treatments since 2001-2002
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

2.2.6 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}

2.2.7 Coimbatore

Treatment	Superimposed treatments since 2002-2003
100% NPK	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}

2.2.8 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 reutilizing 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

CROP PRODUCTIVITY depends on several factors like agronomic management practices, crop varieties and weather parameters. It is essential for us to sustain and enhance productivity to feed ever growing population vis-à-vis decline in availability of natural resources such as land and water. In order 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 systems is given here under.

3.1 Inceptisol

3.1.1 Barrackpore (Rice-wheat-jute)

Yield data presented in Table 3.1 revealed that all the three crops responded to applied N but the response of crop to applied P was not observed in rice and wheat but noted in jute. Absence of response of P in crop is due to low yield of both the crops because of growing of three crops in the sequence. Delay in sowing/harvesting of one crop delayed sowing of next two crop. This type of situation was recorded in the past at most of the centres and therefore third crop has been dropped from all the centers due to this reason. Perusal of data further indicated that there is response of rice and jute to applied S but wheat did not show any response to applied S. It is interesting to note response of applied K in rice and jute, probably response may be due to downward movement of soluble K during rainy season. Application of FYM over and above NPK and higher dose of nutrient (150% NPK) resulted increase in yield of all the three crops in cropping system.

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

Treatments	Rice			Wheat			Jute		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean	2014-15	2015-16	Mean
Control	1174	1130	1152	600	468	534	840	873	857
100% N	1963	2260	2112	2035	1213	1624	1358	1161	1260
100% NP	2022	2502	2262	2253	1210	1732	1689	1361	1525
50% NPK	1827	2258	2043	2080	933	1507	1457	1311	1384
100% NPK	2730	2901	2816	2625	1533	2079	2159	1869	2014
150% NPK	3015	3188	3102	2933	1668	2301	2373	2052	2213
100% NPK + Zn	2327	2899	2613	2765	1568	2167	1977	1731	1854
100% NPK-S	2051	2610	2331	2350	1268	1809	1713	1390	1552
100% NPK+ HW	1857	2761	2309	2420	1288	1854	1811	1469	1640
100% NPK+ FYM	2961	3250	3106	2853	1633	2243	2395	2078	2237
LSD ($P \leq 0.05$)	298	256	-	428	417	-	146	242	-

3.1.2 Coimbatore (Finger millet-maize)

Finger millet and maize cropping system is being grown as test crop at Coimbatore (*Vertic ustochrept*). Yield data (Table 3.2) clearly demonstrated the response of both the crops to applied N and P. Response of applied S and Z was not noted in both the crops. However, incorporation of FYM over and above NPK was noted on yield which is due to additional supply of nutrient and improvement in soil physical condition suited to root growth and nutrient mineralization. However, increase in dose of nutrient to 150% NPK resulted increasing yield over 100% NPK but was not significant .

Table 3.2 Grain yield (kg ha^{-1}) of finger millet and maize hybrid

Treatments	Finger millet			Maize		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean
Control	1325	1339	1332	3012	3144	3078
100% N	1638	1664	1651	4256	4418	4337
100% NP	2215	2313	2264	5213	5518	5366
50% NPK	1968	2025	1997	5132	5340	5236
100% NPK	2276	2435	2356	5378	5598	5488
150% NPK	2466	2588	2527	5492	5707	5600
100% NPK + Zn	2306	2438	2372	5432	5823	5628
100% NPK (-S)	2218	2307	2263	5349	5567	5458
100% NPK + HW	2156	2206	2181	5311	5528	5420
100% NPK + FYM	2698	2822	2760	6057	6404	6231
LSD ($P \leq 0.05$)	550	770	660	233	232	233

3.1.3 Ludhiana (Maize-wheat)

There are three centres i.e. Ludhiana, Delhi and Udaipur having maize-wheat as test cropping system. Perusal of yield data (Table 3.3) of maize and wheat recorded at Ludhiana revealed that both the crops responded to applied N and P. Response of applied K was also noted in maize but was not found in wheat. This is due to K content of irrigation water applied in wheat, whereas maize is dependent mostly on rain water. Response of S was not recorded in either of the crops. As usual application of FYM with NPK resulted in increase in yield of both the crops compared to NPK alone. However, 50% NPK + FYM could not sustain the productivity at par with 100% NPK.

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

Treatment	Maize			Wheat		
	2014	2015	Mean	2014-15	2015-16	Mean
Control	2194	1872	2033	1692	1173	1433
100% N	3889	3602	3746	4338	3533	3936
100% NP	4259	4251	4255	4998	4733	4866
100% NPK	4903	5095	4999	5096	4767	4931
150% NPK	5056	5241	5148	5050	4886	4968
100% NPK+Zn	4798	5100	4949	5104	4743	4923
100% NPK(-S)	5044	5115	5080	5067	4750	4909
100% NPK+W	5051	5146	5099	5064	4750	4907
50% NPK+FYM	3366	2988	3177	3866	3667	3766
100% NPK+FYM	6051	5619	5835	5592	5207	5399
LSD ($P \leq 0.05$)						

3.1.4 New Delhi (Maize-wheat)

The data (Table 3.4) indicated that 150% NPK gave highest yield of maize and wheat followed by 100% NPK+FYM. Data indicated that maize responded to applied N and P. This year both maize and wheat responded to applied K due to unexpected higher yield due to good crop management and weather favourable to crop growth but wheat did not show response to applied K. Here also irrigation water supplies good amount of K. Additional application of FYM along with NPK and increase in nutrient dose (150% NPK) have increased the yield significantly compared to 100% NPK. It means there is scope to increase the nutrient dose to get potential yield even though there was marginal response to Zn and S in maize but statistically non-significant.

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

Treatment	Maize			Wheat		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean
Control	1750	1740	1745	2410	2590	2500
100% N	3430	3370	3400	4500	4910	4705
100% NP	4080	4500	4290	5320	5350	5335
50% NPK	3040	3060	3050	4390	4750	4570
100% NPK	4520	4840	4680	5870	5590	5730
150% NPK	5740	5790	5765	6350	6810	6580
100% NPK+Zn	4750	5130	4940	5780	6310	6045
100% NPK+S	4750	4980	4865	5290	5540	5415
100% NPK+HW	4760	4150	4455	5480	5680	5580
100% NPK+FYM	5360	5450	5405	5860	6110	5985
LSD ($P \leq 0.05$)	520	270	395	560	850	705

3.1.5 Udaipur (Maize-wheat)

Yield data of maize and wheat (Table 3.5) revealed that both the crops responded to applied N and P. Increase in yield on application of K was also recorded but is non-significant. Yet crop did not respond to either applied Zn or S. Integration of FYM with NPK, however, has resulted in significant increase in yield. On the contrary, yield remained more or less similar to 100% NPK even after partial (25% N basis) substitution nutrients through FYM. Inoculation of *Azotobacter* along with NPK also did not have additional yield advantage. Application of nutrients through FYM alone could not keep pace with yield obtained on application of NPK.

Table 3.5 Long-term effect of nutrient management on grain yield (kg ha^{-1}) of maize and wheat at Udaipur

Treatments	Maize			Wheat		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
Control	1425	1327	1376	1659	1552	1605
100% N	2312	2169	2241	3012	2915	2963
100% NP	2929	2806	2867	3582	3591	3586
100% NPK	3366	3220	3293	4329	4270	4299
100% NPK + Zn	3508	3382	3445	4512	4495	4503
100% NPK + S	3413	3297	3355	4422	4393	4408
100% NPK + Zn + S	3630	3516	3573	4617	4592	4604
150% NPK	3736	3605	3670	4667	4640	4653
100% NPK + FYM	4023	4033	4028	5007	4939	4973
100% NPK – FYM	3466	3490	3478	4616	4585	4600
FYM @ 20 t ha^{-1}	2374	2435	2404	3083	3077	3080
100% NPK + *Azotobacter*	3494	3402	3448	4438	4401	4420
LSD ($P \leq 0.05$)	461	532	345	674	592	440

3.1.6 Jagtial (Rice-rice)

Data presented in Table 3.6 indicated significant response of rice to applied N and P. So far response of K in both the rice crops was not recorded. However, increase in nutrient dose from 100% to 150% has significantly increased rice yield. It means in order to get the potential yield of rice in this area there is need to increase the amount of nutrients. Probably under high yield situations rice may respond to applied K. Experiment conducted on the farmers' field indicated response of K in rice probably due to higher yield. The yields are more than 6 tons when N is applied @ 180 kg ha^{-1} as obtained from on-farm experiment. Application of nutrient exclusively through FYM could not maintained yield at par with 100% NPK even after 20 years.

Table 3.6 Effect of long term fertilizer application on rice grain yield (kg ha^{-1}) during *kharif* and rabi season

Treatment	Rabi			Kharif		
	2013-14	2014-15	Mean	2014-15	2015-16	Mean
Control	2710	2184	2447	3111	2415	2763
100% N	2460	3175	2818	3490	3906	3698
100% NP	5788	5334	5561	5192	5346	5269
50% NPK	4521	4552	4537	4492	4335	4414
100% NPK	5638	5170	5404	4955	5509	5232
150% NPK	6899	6382	6641	5447	6090	5769
100% NPK + Zn	5899	5480	5690	5094	5761	5428
100% NPK - S	5809	5183	5496	5138	5441	5290
100% NPK + HW	6001	5548	5775	5245	5778	5512
FYM @ 20 t ha^{-1}	3856	3942	3899	4346	4722	4534
100% NPK + FYM	6432	5936	6184	5391	5824	5608
LSD ($P \leq 0.05$)	482	827	655	781	651	716

3.1.7 Bhubaneswar (Rice-rice)

Yield data (Table 3.7) of rice-rice grown in Inceptisols at Bhubaneswar indicated that there is response of both the rice crops to applied two major nutrients i.e. N and P. Amending soil with lime also increased the yield but found to be marginally significant. However, incorporation of FYM resulted increase in productivity of both the rice crops significantly and better than the yield obtained on amending soil with lime. Thus the yield data indicated that amending soil with FYM found superior to lime. It is due to additional supply of nutrients and moderating soil condition by chelating the Al^{+3} and Fe^{+3} responsible for acidity in soil. Amending soil with lime and FYM both together did not have any additional advantages in yield over either lime or FYM. The response of rice to Zn application was also observed in both rice but did not respond to applied S and B.

Table 3.7 Effect on rice yield (kg ha^{-1}) in *kharif* and rabi season at Bhubaneswar

Treatments	Rice (*Kharif*)			Rice (Rabi)		
	2013	2014	Mean	2013-14	2014-15	Mean
Control	953	1939	1446	1213	705	959
100% N	1609	2630	2120	2347	1432	1890
100% NP	2063	3112	2588	2759	3247	3003
50% NPK	1938	2879	2409	2691	2122	2407
100% NPK	2156	3289	2723	2981	3457	3219
150% NPK	2563	4288	3426	3200	3892	3546
100% NPK + Lime	2250	3878	3064	2984	4042	3513
100% NPK + Lime + FYM	2641	4555	3598	3528	4492	4010
100% NPK +Zn	2313	3866	3090	2984	4189	3587
100% NPK + S + Zn	2216	3806	3011	2978	3825	3402
100% NPK + B + Zn	2219	3262	2741	3034	3525	3280
100% NPK +FYM	2828	4809	3819	3684	4335	4010
LSD ($P \leq 0.05$)	198	439	319	163	423	293

3.2 Vertisols

3.2.1 Jabalpur (Soybean-wheat)

Yield data (Table 3.8) revealed that there was increase in yield of soybean on application of N and P but did not show any response to applied K. Data further indicated that there was response to applied S. Even though during both the years yields were low due to delay and early withdrawal of monsoon in 2014 and excess rain had adverse impact on yield of soybean during 2015. There was no response to applied K in soybean probably due to poor yield and treatment could not show potential. Response to applied N and P in wheat was recorded in both the years. Response to S was also noted on wheat yield but may not be significant.

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

Treatments	Soybean			Wheat		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean
Control	513	313	413	1225	1350	1288
100% N	675	325	500	1888	1750	1819
100% NP	925	605	765	3181	3000	3091
50% NPK	925	625	775	3063	3100	3081
100% NPK	1100	900	1000	4013	3463	3738
150% NPK	1225	1150	1188	4563	4188	4375
100% NPK-S	988	750	869	3638	3169	3403
100% NPK+HW	1000	875	938	3756	3475	3616
100% NPK+Zn	1013	855	934	3975	3425	3700
100% NPK+FYM	1300	1200	1250	4713	4344	4528
LSD ($P \leq 0.05$)	173.0	114.5	111.3	525.0	460.0	338.0

3.2.2 Raipur (Rice-wheat)

Yield data of rice and wheat (Table 3.9 and Plate 3.1) indicated that there was clear response of rice to applied N and P. However, the response of K was not recorded till date. There is no response to applied Zn too. Incorporation of FYM over and above NPK resulted in increase in productivity of both rice and wheat as well. It is peculiar to note that addition of BGA in rice crop did not have any effect on yield of rice and wheat as well. It has rather declined rice yield may be because of competition between *Azola* and rice crop for P. Effect of *Azola* was also not seen in wheat crop. Application of 150% NPK and incorporation of

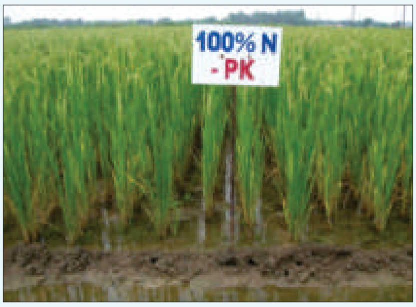
Table 3.9 Yield of rice and wheat (kg ha^{-1}) at IGKV Raipur (AICRP LTFE)

Treatments	Rice			Wheat		
	2014	2015	Mean	2014-15	2015-16	Mean
Control	2500	1810	2154	1050	905	979
100% N	4160	2945	3554	1960	1720	1839
100% NP	5755	4720	5237	3010	2770	2891
50% NPK	5285	4200	4742	2285	2065	2174
50% NPK+BGA	5030	3990	4510	2270	2040	2156
50% NPK+GM	5740	4700	5220	2525	2350	2439
100% NPK	5880	4890	5384	3195	2890	3042
150% NPK	6450	5505	5976	3600	3430	3516
100% NPK+FYM	6445	5495	5970	3540	3395	3469
LSD ($P \leq 0.05$)	899	361	628	513	190	352

BGA=Blue green algae; GM= Green manure

RICE

Control



100% N

100% NP

100% NPK

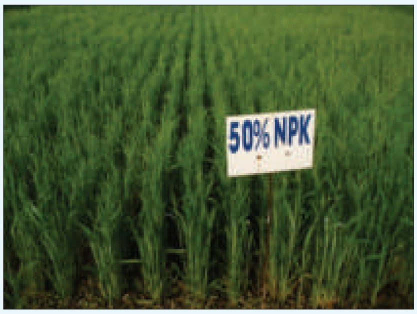
100% NPK+Zn

100% NPK+FYM

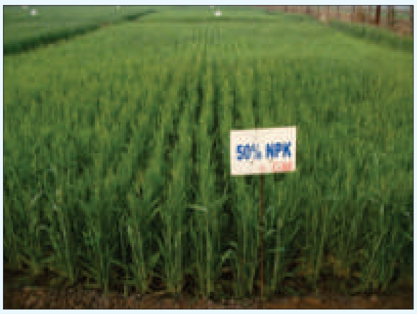
WHEAT

100% N

100% NP

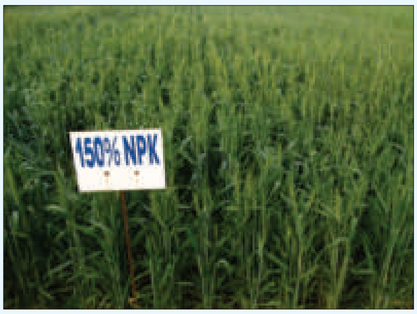


50% NPK



50% NPK+Green Manuring

100% NPK+Zn



150% NPK

Plate 3.1 Effect of long term fertilizer and manure application on growth and development of rice and wheat at Raipur (Chhattisgarh)

FYM over and above NPK (i.e. NPK+FYM) resulted in significant increase in yield of rice and wheat compared to 100% NPK, however, yields of both the treatments were at par. This is due to additional supply of nutrients through FYM. This indicates that yield can be sustained on exclusive application through fertilizer nutrients.

3.2.3 Parbhani (Soybean-safflower)

Data on yield of soybean and safflower recorded at Parbhani did not show any response to applied N (Table 3.10 and Plate 3.2). But application of P has contributed to the yield of both soybean and safflower. There is little response to applied K and S in both the crops. Even application of FYM alone did not have much impact on productivity of both the crops. The yields are low compared to previous years probably because crop could not express the potential of the treatment. However, application of FYM along with NPK out yielded all the nutrient management options in both the crops.

Table 3.10 Effect of manures and fertilizers on grain yield (kg ha^{-1}) of soybean and safflower

Treatments	Soybean			Safflower		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
Control	536	477	506	796	473	635
100% N	509	575	542	707	501	604
100% NP	1875	1312	1594	1744	947	1346
50% NPK	1821	1291	1556	1417	891	1154
100% NPK	1952	1508	1730	1869	1036	1453
150% NPK	2241	1643	1942	2093	1115	1604
100% NPK+HW	1929	1491	1710	1766	1021	1394
100% NPK+Zn	2102	1534	1818	1959	1078	1519
100% NPK – Sulphur	1797	1208	1502	1710	928	1319
Only FYM @ 10 t ha^{-1}	1614	830	1222	1247	847	1047
100% NPK + FYM	2267	1670	1968	2133	1144	1639
LSD ($P \leq 0.05$)	286	179	198	253	49	55

3.2.4 Akola (Sorghum-wheat)

Yield data of sorghum and wheat (Table 3.11) indicated that there was quite good response of both the crops to applied N, P and K as well. Little response of S was also recorded but appears to be non-significant statistically.

Table 3.11 Average yield of sorghum and wheat (kg ha^{-1}) at Akola

Treatments	Sorghum			Wheat		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
Control	321	461	391	61	64	63
100% N	1269	2153	1711	656	670	663
100% NP	2310	3380	2845	1276	1310	1293
50% NPK	2120	3321	2721	1589	1395	1492
100% NPK	2865	4230	3548	2447	2240	2344
150% NPK	3890	4922	4406	2872	2868	2870
100% NPK + Zn @ 2.5 kg ha^{-1}	3062	4537	3800	2607	2470	2539
100% NPK + S @ 37.5 kg ha^{-1}	3278	4622	3950	2753	2510	2632
100% NPK S free	2507	3930	3219	2239	2010	2125
FYM @ 10 t ha^{-1}	2317	2851	2584	972	1098	1035
75% NPK + 25% N through FYM	2890	4067	3479	2205	2105	2155
100% NPK + FYM @ 5 t ha^{-1}	4105	5131	4618	3179	3204	3192
LSD ($P \leq 0.05$)	386	506	446	330	394	362

SOYBEAN

100% NP

100% NPK

100% NPK-S

SAFFLOWER

Control

100% N

100% NP

150% NPK

100% NPK+FYM

100% NPK+HW

100% NPK+Zn

100% NPK-S

FYM @ 10 t ha^{-1}

Plate 3.2 Effect of long term fertilizer and manure application on growth and development of soybean and safflower at Parbhani (Maharashtra)

SORGHUM

Control

100% N

100% NP

WHEAT

100% NPK

150% NPK

100% NPK+FYM

Control

100% N

100% NP

100% NPK

100% NPK+FYM

150% NPK

Plate 3.3 Effect of long term fertilizer and manure application on growth and development of sorghum and wheat at Akola (Maharashtra)

Response of applied Zn was also not recorded. Nutrient supplied through 20 tons FYM (10 tons in each crop) also could not keep the pace even with yield recorded in 50% NPK treatment. Even though nutrient supplied are more or less similar in quantity than 50% NPK. However, 25% substitution of N through organic could keep the pace with 100% NPK as far as yields are concerned. As Akola is not traditionally wheat growing area hence wheat yields are low. Results indicated that there is need to increase the dose of organic manure to obtain more yield and to keep the pace with inorganic nutrient supply.

3.2.5 Junagadh (Groundnut-wheat)

The yields of groundnut are low like other years and there is little effect of treatment on yield (Table 3.12). Data further indicated that there is no response of N probably because of poor P status. A big jump in yield of wheat on P application supports the statement. On the contrary to other hand exclusive incorporation of FYM maintained yield higher than other treatments.

Table 3.12 Mean yield (kg ha^{-1}) of groundnut and wheat at JAU Junagadh

Treatment	Groundnut				Wheat			
	2013	2014	2015	Mean	2013-14	2014-15	2015-16	Mean
Control	712	710	707	710	1808	1679	1826	1771
100% N	610	622	626	619	1612	1563	1612	1596
100% NP	716	736	787	746	2589	2426	2597	2537
50% NPK	744	816	808	789	2176	2093	2296	2188
50% NPK+10 t ha^{-1} FYM *	1014	1147	1203	1121	3454	3407	3853	3571
50% NPK++Rhizobium +PSM $	756	856	868	827	2690	2567	2840	2699
100% NPK	825	942	946	904	2829	2759	3013	2867
150% NPK	935	1013	1028	992	3020	2893	3266	3060
100% NPK+ $ZnSO_4$	840	952	954	915	2812	2695	3183	2897
NPK as per soil test	815	929	989	911	2822	2720	3168	2903
100% NPK (P as SSP)	797	919	881	866	2810	2753	3119	2894
FYM 25 t ha^{-1} to groundnut only	909	1047	1118	1025	3258	3310	3656	3408
LSD ($P \leq 0.05$)	94	133	148	125	409	381	390	393

* 50% NPK+10 t ha^{-1} FYM to groundnut and 100% NPK to wheat
$ 50% NPK$ +Rhizobium +Phosphate solubilizing microorganism (PSM)

3.3 Alfisols

3.3.1 Bangalore (Finger millet-maize)

Unlike the yield trend at Coimbatore, finger millet did not show any response to applied N and P until K was not applied. Thus, balanced use of nutrient is essential in Alfisol of Bangalore. Alfisols are hungry for K and crop did not show any response to N and P without K application. Application of lime and FYM both have resulted increase in yield of finger-millet but magnitude of increase in yield was far larger on amending soil with FYM (Table 3.13). A similar trend was noted in maize also but with larger magnitude. The larger increase in yield on application of FYM compared to lime is due to additional supply of nutrient particularly K and moderation of soil condition conducive to plant growth. Increase in yield on application of 150% NPK supports the statement.

FINGER MILLET


Control


100% NP


150% NPK

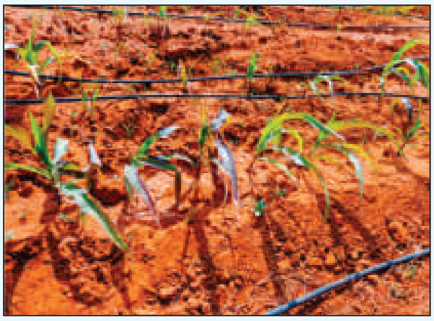

100% NPK +FYM


100% NPK+Lime


100% NPK+FYM+Lime

HYBRID MAIZE


Control


100% N


100% NP


150% NPK


100% NPK+FYM


100% NPK+FYM+Lime

Plate 3.4 Effect of long term fertilizer and manure application on growth and development of hybrid maize and finger millet at Bangalore (Karnataka)

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	Finger millet			Maize		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean
Control	552	805	679	550	1285	918
100% N	827	916	872	539	991	765
100% NP	774	777	776	1554	1463	1509
50% NPK	2547	1756	2152	1707	3458	2583
100% NPK	3299	2385	2842	2059	3868	2964
150% NPK	3842	2845	3344	2371	4880	3626
100% NPK + lime	3380	2479	2930	2225	3736	2981
100% NPK (S-free)	3055	2671	2863	2270	3965	3118
100% NPK + FYM + lime	4112	3235	3674	2584	5062	3823
100% NPK + HW	3536	2508	3022	2090	3833	2962
100% NPK + FYM	4246	3067	3657	2438	5049	3744
LSD ($P \leq 0.05$)	450	470	460	236	667	452

3.3.2 Palampur (Maize-wheat)

Perusal of yield data (Table 3.14) indicated that continuous use of nitrogen (urea) alone not only declined yield but brought down the yield to zero. Decline in yield on application of N alone is due to decline in soil pH. This resulted in reduction in availability of P and K which were already low. Increase in productivity on application of P and K confirm the statement. It is more appropriate instead of applying full dose of nutrients, apply only half (50% NPK) dose will fetch good economic returns. Application of lime and FYM both resulted increase in productivity of maize but the magnitude of increase in productivity (yield) is more in FYM amended plot than lime. It is peculiar to note that application of 150% NPK did not increase the yield of maize compared to 100% NPK. It means application of lime and FYM are acting as correcting measures. Application of lime increases the availability of nutrients by raising the pH whereas FYM not only moderate the soil condition but also supply additional nutrients. Thus, FYM is responsible for more yield of maize over lime application. A similar effect of treatment was noted in wheat also. Thus results indicated that application of urea alone (i.e. N alone) had deleterious effect on crop productivity of both maize and wheat and application of FYM could be an alternative to lime.

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

Treatment	Maize			Wheat		
	2013	2014	Mean	2013-14	2014-15	Mean
Control	831	961	896	442	400	421
100% N	0	0	0	0	0	0
100% NP	1985	2233	2109	1217	1092	1155
50% NPK	3391	3601	3496	1650	1725	1688
100% NPK	3995	4002	3999	2092	2038	2065
150% NPK	3753	3862	3808	1842	1683	1763
100% NPK + Zn	3872	4131	4002	2158	1892	2025
100% NPK (-S)	1703	2457	2080	1292	1067	1180
100% NPK + lime	5295	5511	5403	3242	3035	3139
100% NPK +HW	4206	4401	4304	2300	2200	2250
100% NPK + FYM	5602	5800	5701	3492	3158	3325
LSD ($P \leq 0.05$)	467	313	390	341	309	325

3.3.3 Ranchi (Soybean-wheat)

Yield data of soybean and wheat (Table 3.15) revealed that increase in dose from 50% to 100% of nutrients (NPK) resulted in increase in the yield of soybean and wheat as well. However, further increase in nutrient dose to 150% did not show any effect on yield of either soybean or wheat. It means optimal nutrient dose (i.e. 100% NPK) is sufficient. On critical evaluation of yield data, it was noted that application of N alone resulted decline in productivity of soybean compared to the absolute control. It implies that application of N had adverse effect on productivity of soybean. A similar effect of N was also noted in wheat which is due to decline in soil pH and mining of soil P and K at faster rate during early years of N application. Even though significant increase in yield of both soybean and wheat was recorded on integration of P with N but more increase in yield was recorded on combined application of N, P and K. It means application of N alone without P and K is not advisable to sustain productivity of soil in Alfisols.

Table 3.15 Mean grain yield (kg ha^{-1}) of soybean and wheat in Alfisol of Ranchi

Treatment	Soybean				Wheat			
	2013	2014	2015	Mean	2013	2014	2015	Mean
Control	283	394	420	366	550	465	270	428
100% N	247	371	441	353	867	945	594	802
100% NP	713	1004	1207	975	3300	3373	2170	2948
50% NPK	1103	1618	1785	1502	2185	2330	1370	1962
100% NPK	1458	2050	2123	1877	3210	3385	2390	2995
150% NPK	1290	2154	2176	1873	3087	3417	2613	3039
100% NS(P)K	1437	2121	2342	1967	2940	3335	2444	2906
100% NPK + HW	1315	1954	2096	1788	3385	3395	2265	3015
100% NPK + Lime	1715	2280	2405	2133	3430	3518	2235	3061
100% NPK + FYM	1938	2425	2390	2251	3650	3810	2775	3412
LSD ($P \leq 0.05$)	213	264	253	243	353	410	345	369

3.3.4 Pattambi (Rice-rice)

Pattambi is situated in the Western Ghat region of the country. Perusal of data (Table 3.16) revealed that application of urea alone did not have much effect on rice yields in both the seasons. But application of P along with N resulted increase in productivity of both the rice crops in big way. It means soil is low in P availability. Even though there has been improvement in rice yield on application of K but magnitude was very low in-spite of low K status.

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

Treatments	Kharif			Rabi		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean
Control	2160	3645	2903	2490	3158	2824
100% N	1943	3888	2916	3025	3359	3192
100% NP	2830	4432	3631	3777	4342	4060
50% NPK	2733	4390	3562	3375	3864	3620
100% NPK	3080	4634	3857	3931	4108	4020
150% NPK	3507	5425	4466	4588	4818	4703
100% NPK+ lime	3233	4687	3960	3871	4418	4145
100% NPK +Cu	3173	4921	4047	3917	4384	4151
50% NPK+ in situ GM	3640	4680	4160	4246	4215	4231
100% NPK+ in situ GM	3743	5083	4413	4821	4561	4691
50 % NPK+ FYM	3676	4888	4282	4473	4324	4399
100% NPK+ FYM	3900	5467	4684	4715	4884	4800
LSD ($P \leq 0.05$)	185	136	161	194	174	184

These soils are low in available K even then response of rice is not conspicuous. Absence of response of K in rice may be due to addition of K through irrigation water. During monsoon season water moves from upper reaches to the valley along with the K and silt which fulfill the K requirement of the crop. Whereas rain water stored during rainy season is used for irrigation purpose in rabi season. The higher productivity during rabi is due to more sunshine hours because of clear sky. *In situ* green manuring and FYM with 50% NPK sustained the yield at par with 100% NPK and surpassed productivity of rice and attaining towards 150% NPK. Thus, 50% NPK can be saved without any loss in yield.

3.4 Mollisols

3.4.1 Pantnagar

Yield data of rice (Table 3.17) clearly indicated the response to applied N, P and Zn and to some extent to S. Yield data of wheat also indicated the response to N, P, Zn and S also (Table 3.17). Application of FYM over and above NPK has always edge over 100% NPK even without Zn. Thus, results indicated that application of Zn is essential along with N and P in order to sustain the productivity of rice and wheat at Pantnagar. So far response to applied K was not noted in both rice and wheat. Growing of rice with biofertilizer (*Azola*) did not show any additional benefit on yield and maintained yield at par with control. Incorporation of FYM over NPK sustained yield of both the crops better than any other treatment .

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

Treatments	Rice			Wheat		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
Control	1363	1203	1283	1235	1173	1204
100% N +Zn	3320	3025	3173	3228	3015	3122
100% NP +Zn	4175	3898	4037	3538	3348	3443
50% NPK+ Zn	3445	3255	3350	2790	2853	2822
100% NPK	3667	3690	3679	3293	3303	3298
150% NPK	3503	3557	3530	3253	3280	3267
100% NPK + Zn	4453	4078	4266	4188	4013	4101
100% NPK-S + Zn	3910	3760	3835	3703	3603	3653
Bio-fertilizer	1345	1283	1314	1260	1210	1235
100% NPK+ HW + Zn	3963	3863	3913	3730	3661	3696
100% NPK + FYM	5228	5113	5171	4613	4863	4738
LSD ($P \leq 0.05$)	245	221	233	244	302	273

3.3.3 Ranchi (Soybean-wheat)

Yield data of soybean and wheat (Table 3.15) revealed that increase in dose from 50% to 100% of nutrients (NPK) resulted in increase in the yield of soybean and wheat as well. However, further increase in nutrient dose to 150% did not show any effect on yield of either soybean or wheat. It means optimal nutrient dose (i.e. 100% NPK) is sufficient. On critical evaluation of yield data, it was noted that application of N alone resulted decline in productivity of soybean compared to the absolute control. It implies that application of N had adverse effect on productivity of soybean. A similar effect of N was also noted in wheat which is due to decline in soil pH and mining of soil P and K at faster rate during early years of N application. Even though significant increase in yield of both soybean and wheat was recorded on integration of P with N but more increase in yield was recorded on combined application of N, P and K. It means application of N alone without P and K is not advisable to sustain productivity of soil in Alfisols.

Table 3.15 Mean grain yield (kg ha^{-1}) of soybean and wheat in Alfisol of Ranchi

Treatment	Soybean				Wheat			
	2013	2014	2015	Mean	2013	2014	2015	Mean
Control	283	394	420	366	550	465	270	428
100% N	247	371	441	353	867	945	594	802
100% NP	713	1004	1207	975	3300	3373	2170	2948
50% NPK	1103	1618	1785	1502	2185	2330	1370	1962
100% NPK	1458	2050	2123	1877	3210	3385	2390	2995
150% NPK	1290	2154	2176	1873	3087	3417	2613	3039
100% NS(P)K	1437	2121	2342	1967	2940	3335	2444	2906
100% NPK + HW	1315	1954	2096	1788	3385	3395	2265	3015
100% NPK + Lime	1715	2280	2405	2133	3430	3518	2235	3061
100% NPK + FYM	1938	2425	2390	2251	3650	3810	2775	3412
LSD ($P \leq 0.05$)	213	264	253	243	353	410	345	369

3.3.4 Pattambi (Rice-rice)

Pattambi is situated in the Western Ghat region of the country. Perusal of data (Table 3.16) revealed that application of urea alone did not have much effect on rice yields in both the seasons. But application of P along with N resulted increase in productivity of both the rice crops in big way. It means soil is low in P availability. Even though there has been improvement in rice yield on application of K but magnitude was very low in-spite of low K status.

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

Treatments	Kharif			Rabi		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean
Control	2160	3645	2903	2490	3158	2824
100% N	1943	3888	2916	3025	3359	3192
100% NP	2830	4432	3631	3777	4342	4060
50% NPK	2733	4390	3562	3375	3864	3620
100% NPK	3080	4634	3857	3931	4108	4020
150% NPK	3507	5425	4466	4588	4818	4703
100% NPK+ lime	3233	4687	3960	3871	4418	4145
100% NPK +Cu	3173	4921	4047	3917	4384	4151
50% NPK+ in situ GM	3640	4680	4160	4246	4215	4231
100% NPK+ in situ GM	3743	5083	4413	4821	4561	4691
50 % NPK+ FYM	3676	4888	4282	4473	4324	4399
100% NPK+ FYM	3900	5467	4684	4715	4884	4800
LSD ($P \leq 0.05$)	185	136	161	194	174	184

These soils are low in available K even then response of rice is not conspicuous. Absence of response of K in rice may be due to addition of K through irrigation water. During monsoon season water moves from upper reaches to the valley along with the K and silt which fulfill the K requirement of the crop. Whereas rain water stored during rainy season is used for irrigation purpose in rabi season. The higher productivity during rabi is due to more sunshine hours because of clear sky. *In situ* green manuring and FYM with 50% NPK sustained the yield at par with 100% NPK and surpassed productivity of rice and attaining towards 150% NPK. Thus, 50% NPK can be saved without any loss in yield.

3.4 Mollisols

3.4.1 Pantnagar

Yield data of rice (Table 3.17) clearly indicated the response to applied N, P and Zn and to some extent to S. Yield data of wheat also indicated the response to N, P, Zn and S also (Table 3.17). Application of FYM over and above NPK has always edge over 100% NPK even without Zn. Thus, results indicated that application of Zn is essential along with N and P in order to sustain the productivity of rice and wheat at Pantnagar. So far response to applied K was not noted in both rice and wheat. Growing of rice with biofertilizer (*Azola*) did not show any additional benefit on yield and maintained yield at par with control. Incorporation of FYM over NPK sustained yield of both the crops better than any other treatment .

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

Treatments	Rice			Wheat		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean
Control	1363	1203	1283	1235	1173	1204
100% N +Zn	3320	3025	3173	3228	3015	3122
100% NP +Zn	4175	3898	4037	3538	3348	3443
50% NPK+ Zn	3445	3255	3350	2790	2853	2822
100% NPK	3667	3690	3679	3293	3303	3298
150% NPK	3503	3557	3530	3253	3280	3267
100% NPK + Zn	4453	4078	4266	4188	4013	4101
100% NPK-S + Zn	3910	3760	3835	3703	3603	3653
Bio-fertilizer	1345	1283	1314	1260	1210	1235
100% NPK+ HW + Zn	3963	3863	3913	3730	3661	3696
100% NPK + FYM	5228	5113	5171	4613	4863	4738
LSD ($P \leq 0.05$)	245	221	233	244	302	273

4. SOIL HEALTH

SOIL HEALTH is essential to improve and to sustain the soil productivity over a long period. In this chapter effect of nutrient management on changes in soil properties with reference to initial values is given.

4.1 Soil Chemical Properties

4.1.1 Soil pH

Soil pH is an intrinsic property which normally does not change by adoption of cultural practices or if change occurs then with a very slow pace. Perusal of data (Table 4.1) revealed that continuous use of fertilizer did not have any effect on soil pH except in Alfisols. Application of fertilizer in Alfisols (Red soil) resulted decline in soil pH and the effect is more pronounced with an application of urea alone (100% N). Data further indicated that application of organic manure (FYM) resisted to decline soil pH. At Ludhiana, decline in pH was also recorded which is yet to be confirmed by doing in replicated study. The decline in soil pH of acid soil is due to production of H^+ on mineralization of urea and hydrolysis of Al^{+3} and Fe^+ but incorporation of FYM chelated Al^{+3} in acid soils, which reduces the release of H^+ ions.

Table 4.1 Effect of nutrient management on soil pH at AICRP LTFE centres (2015)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Akola	8.1	8.1	7.9	8.0	8.0	7.9	8.0		8.1
Bangalore	6.2	6.4	4.3	4.7	5.4	4.8	-	5.9	5.8
Barrackpore	7.1	-	7.2	7.3	7.3	7.3	7.3	-	7.5
Bhubaneswar	5.8	5.4	5.5	5.5	5.4	5.4	5.4	6.3	6.0
Coimbatore	8.2	8.9	8.8	8.8	8.8	8.8	8.7	-	8.8
Jabalpur	7.6	7.5	7.5	7.6	7.6	7.6	7.6	-	7.5
Jagtial	8.2	8.1	8.1	8.1	8.2	8.0	8.1	-	7.9
Junagadh	8.2	8.1	8.0	8.1	8.1	8.1	8.1	-	-
Ludhiana	8.2	7.7	7.2	7.4	7.5	7.4	7.4	-	7.3
Palampur	5.8	5.7	4.5	5.1	5.2	4.9	5.2	6.3	5.4
Pantnagar	7.3	8.2	8.2	8.2	8.3	8.3	8.2	-	8.3
Parbhani	8.1	8.1	8.1	8.1	8.1	8.1	8.1	-	8.0
Pattambi	5.5	5.0	5.1	4.7	4.7	4.5	-	5.6	5.2
Raipur	7.7	7.3	7.2	7.3	7.4	7.3	7.1	-	7.3
Ranchi	5.3	5.2	4.2	4.7	5.1	4.5	-	6.2	4.9

4.1.2 Electrical conductivity

Electrical conductivity (EC) of soil gives an idea of soluble salt present in the soil. Data presented in Table 4.2 indicated little increase in electrical conductivity, possibly due to application of phosphatic and potassic fertilizer over the years. However, the change noted is very meager and far less than the prescribed yardstick of EC to be considered as saline. Time of sampling also gives variation in EC. If soil samples are drawn during summer then higher EC is expected because of upward movement of soluble salt through evaporation of water.

Table 4.2 Effect of nutrient management on EC (dS m^{-1}) (2015)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Akola	0.30	0.25	0.29	0.32	0.37	0.38	0.36	-	0.39
Bangalore	0.06	0.14	0.09	0.13	0.11	0.13	-	0.15	0.18
Bhubaneswar	0.12	0.36	0.44	0.53	0.64	0.50	0.54	0.48	0.35
Coimbatore	0.20	0.60	0.60	0.62	0.63	0.66	0.64	-	0.65
Jabalpur	0.18	0.15	0.14	0.18	0.17	0.19	0.17	-	0.18
Jagtial	0.47	0.42	0.40	0.49	0.40	0.41	0.39	-	0.47
Junagadh	0.37	0.36	0.39	0.38	0.38	0.43	0.39	-	-
Ludhiana	0.20	0.16	0.16	0.14	0.18	0.18	0.18	-	0.18
Palampur	-	0.43	0.45	0.51	0.62	0.68	0.59	0.67	0.62
Pantnagar	0.35	0.80	0.84	0.85	0.82	0.86	0.84	-	0.87
Parbhani	0.22	0.24	0.25	0.25	0.25	0.27	0.26	-	0.24
Pattambi	-	0.08	0.10	0.08	0.09	0.09	-	0.09	0.10
Raipur	0.20	0.22	0.22	0.24	0.22	0.21	0.22	-	0.24
Ranchi	-	0.04	0.06	0.07	0.06	0.06	-	0.07	0.09

4.1.3 Soil organic carbon

Organic carbon (SOC) is key constituent of soil which dictate the soil physical condition and to a large extent nutrient status also. As most of the soil processes like chemical, physical and biological are dependent on soil organic carbon. It is well documented that if there is more carbon in soil better will be the soil condition. Data presented in Table 4.3 revealed that imbalanced or no use of fertilizer nutrients resulted decline in soil carbon at almost all the places.

Table 4.3 Effect of nutrient management on SOC (g kg^{-1}) at AICRP-LTFE (2015)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK + Zn	NPK+ Lime	NPK+ FYM
Akola	4.6	3.1	4.3	4.9	5.4	6.8	6.6		7.9
Bangalore	4.6	4.8	5.1	5.2	5.5	5.8	-	6.0	5.8
Barrackpore	7.1	-	6.8	7.2	7.2	7.4	7.2	-	9.0
Bhubaneswar	4.3	3.1	4.2	4.4	4.7	5.0	4.9	5.8	6.3
Coimbatore	3.0	4.2	4.6	5.7	5.7	5.8	5.2	-	6.8
Jabalpur	5.7	4.2	5.2	6.8	7.6	8.7	7.6	-	8.9
Jagtial	7.9	7.6	7.4	7.9	8.0	8.6	7.9	-	10.3
Junagadh	8.9	6.6	6.4	7.6	7.7	8.1	7.8	-	-
Ludhiana	2.2	2.8	3.9	3.9	4.2	4.2	4.1	-	5.3
New Delhi	4.4	3.4	4.3	4.6	4.6	4.8	4.7	-	5.2
Palampur	7.9	7.9	8.8	9.3	10.2	10.2	9.7	10.6	13.7
Pantnagar	14.8	6.1	9.1	9.9	9.8	8.8	10.0	-	15.6
Parbhani	5.5	5.7	5.4	5.9	6.2	6.4	6.3	-	6.8
Pattambi	9.3	13.2	15.9	16.5	15.3	17.5	-	16.1	19.7
Raipur	6.2	6.0	4.4	5.3	6.3	6.4	5.6		6.4
Ranchi	4.5	3.5	4.2	4.2	4.0	3.9	-	3.7	4.9

On the contrary, balanced use of fertilizer nutrient resulted in increase in carbon status of soil. Decline in soil carbon is due to addition of carbon less in quantity than lost from the system on annual basis. Imbalanced use of nutrient (N, NP) led to poor crop productivity which in turn adds less amount of carbon through residual biomass (stubble and roots), whereas balanced use of nutrient resulted in increase in crop productivity which in turn adds more carbon through residual biomass. However, Pantnagar is an exception where except NPK + FYM none of the treatments could maintain initial carbon. Decline in carbon at Pantnagar is due to change in land use pattern from forest to agriculture which accelerated oxidization of native carbon from soil. Only NPK+ FYM could maintained the C status because of additional supply of carbon through 15 t ha^{-1} FYM annually.

4.2 Nutrient Status

4.2.1 Available N

Available N content is dependent of soil carbon content. Data (Table 4.4) indicated increase in available N status on balanced use of nutrients and followed the pattern similar to soil carbon. Most of the places there was increase in soil N compared to initial status. This is due to addition of carbon through residual biomass, which also contain N. Thus, from the results it is concluded that balanced use of nutrient irrespective of soil resulted not only increase in crop productivity but also increased carbon and available N status of soil. This could be one of the reasons for continuous increase in soil productivity at most of the sites of LTFE.

Table 4.4 Available soil N (kg ha^{-1}) under different nutrient management options at AICRP LTFE (2015)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Akola	120	129	232	245	264	311	264	-	320
Bangalore	257	173	239	242	198	292	-	194	194
Barrackpore	223	-	240	245	255	272	246	-	277
Bhubaneswar	187	154	205	215	220	257	235	217	291
Coimbatore	178	134	178	180	177	206	182	-	210
Jabalpur	193	178	204	259	285	323	282	-	342
Jagtial	108	150	156	181	166	191	172	-	191
Junagadh	161	163	183	194	198	226	202	-	-
Ludhiana	87	87	112	117	120	130	123	-	137
New Delhi	-	180	256	238	261	266	260	-	291
Palampur	736	258	324	339	344	361	355	352	380
Pantnagar	392	173	226	233	232	302	232	-	313
Parbhani	216	189	199	200	211	226	212	-	235
Raipur	236	163	213	204	226	251	204	-	254
Ranchi	295	224	225	214	211	235	-	204	228

4.2.2 Available P

After nitrogen, P contributed significantly to crop productivity. Perusal of data (Table 4.5) on crop productivity indicated that crop responded to applied P at majority of sites. Continuous absence of P in nutrient schedule resulted in decline of available P status in soil. Whereas inclusion of P in fertilizer schedule increased P status in soil. Increase in available P status was more in alluvial and acid soil compared to Vertisols. This is due to very high P fixation capacity of Vertisols. Increase in soil P status is quite obvious, because of uptake of P by crop is less than the quantity applied. The unused amount of P is reflected in different forms of P occurs in soil.

Table 4.5 Available soil P (kg ha^{-1}) under different nutrient management options at AICPR-LTFE (2015)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Akola	8.40	4.26	8.10	14.46	14.66	19.03	15.55	-	20.96
Bangalore	34.30	38.89	42.48	79.07	83.06	109.15	-	82.23	88.81
Barrackpore	41.50	-	3.90	47.90	48.20	62.50	28.00	-	68.90
Bhubaneswar	19.40	5.76	8.54	10.55	10.63	12.79	10.30	11.37	41.65
Coimbatore	11.00	6.53	10.12	19.25	21.91	25.56	21.09	-	26.91
Jabalpur	7.60	8.80	10.30	31.50	36.40	39.40	34.70	-	37.70
Jagtial	19.30	22.20	23.30	24.60	22.90	32.20	22.70	-	32.20

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Junagadh	9.48	14.70	14.98	23.42	24.31	28.07	23.42	-	-
Ludhiana	9.00	17.30	17.60	56.90	58.80	85.50	57.90	-	97.70
New Delhi	16.00	20.40	31.90	34.50	39.40	43.80	34.50	-	47.50
Palampur	12.10	14.96	15.68	95.20	72.80	164.26	80.26	78.40	136.26
Pantnagar	18.00	7.83	9.93	18.60	18.80	32.53	18.93	-	29.00
Parbhani	16.00	10.40	10.26	16.44	16.35	18.40	16.93	-	18.80
Pattambi	15.57	10.49	8.79	16.81	14.57	19.62	-	14.52	22.41
Raipur	16.00	8.11	8.38	26.32	27.84	28.99	26.61	-	28.72
Ranchi	12.60	17.40	23.40	165.20	178.10	361.00	-	137.40	363.50

4.2.3 Available K

Potassium is the third major nutrient and required by plant in large quantity. Available status of K presented in Table 4.6 indicated different scenario in different soil. In Alfisol there has been decline in available K status in most of the treatment except 150% NPK and NPK+ FYM. But at Bhubaneswar increase in available K status was recorded in the plots which were even deprived off supply of K. This is due to supply of K through irrigation water. In Vertisols decline in available K was noted in most of the treatments except in NPK + FYM. In this particular treatment supply of K through organic manure is more than the crop removal. On the contrary to Vertisols, increase in available K status was recorded in alluvial soils of Punjab, Delhi and Pantnagar irrespective of absence and presence of K in fertilizer schedule. Increase in available K status is due to two reasons. First addition of K through irrigation water, flood water and upward movement of soluble K through evaporation and K removed by roots from lower layer and plant return back extra K to soil at maturity, which is accumulated in root zone. More K status and absence of response even after 45 years support the hypothesis.

Table 4.6 Effect of nutrient management options on available soil K status (kg ha^{-1}) at AICRP-LTFE locations (2015)

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ Zn	NPK+ Lime	NPK+ FYM
Akola	358	169	204	230	381	468	375	-	490
Bangalore	123	73	55	57	156	214	-	146	170
Barrackpore	143	-	130	123	179	198	179	-	197
Bhubaneswar	43	61	72	68	111	122	120	123	133
Coimbatore	810	474	493	475	559	588	544	-	614
Jabalpur	370	238	243	250	292	313	282	-	329
Jagtial	364	357	306	301	321	296	311	-	322
Junagadh	184	174	155	160	207	238	229	-	-
Ludhiana	88	81	89	106	134	136	140	-	155
New Delhi	155	187	252	259	315	351	285	-	302
Palampur	194	111	128	121	156	184	154	168	194
Pantnagar	125	93	89	91	129	142	123	-	145
Parbhani	766	666	664	671	739	760	750	-	786
Pattambi	173	41	49	41	59	65	-	57	69
Raipur	474	380	386	374	481	494	450		493
Ranchi	157	124	140	113	109	139	-	108	131

4.2.4 Available S

Sulphur is secondary nutrient and it helps in amino acid synthesis in plant (Table 4.7). Like P, application of S resulted in increase in S status of soil whereas absence of S in fertilizer schedule resulted decline in S status. At some of the places S deficiency was recorded particularly during Kharif season when S is reduced to sulphide form and not available to plant.

Table 4.7 Effect of nutrient management options on available soil sulphur status (kg ha^{-1}) at AICRP-LTFE locations (2015)

Location	Initial	Control	N	NP	NPK (-S)	NPK	150% NPK	NPK+ Lime / Zn	NPK+ FYM
Bangalore	20.3	65.0	62.7	62.7	63.5	62.1	61.8	64.4	64.5
Bhubaneswar	22.2	19.1	33.4	35.3	-	38.3	41.3	41.0	44.7
Jabalpur	17.5	10.9	11.7	30.2	11.1	32.1	36.1	30.7	38.0
Jagtial	14.0	11.1	10.9	16.1	11.0	17.6	21.3	17.3	17.8
Junagadh	17.4	21.2	23.7	24.7	-	23.9	29.7	27.1	-
New Delhi	23.5	14.9	23.8	32.2	-	27.7	28.8	22.6	21.5
Palampur	13.4	13.7	18.1	24.7	29.9	37.5	25.7	27.6	31.3
Pantnagar	-	7.2	27.6	14.0	9.6	26.1	29.2	25.5	17.9
Parbhani	30.5	21.5	21.4	30.1	20.0	30.5	33.3	30.6	34.8
Pattambi	-	7.4	5.5	13.8	-	12.1	7.6	9.3	20.4
Raipur	-	10.6	8.6	9.8	-	16.1	20.2	18.1	22.1
Ranchi	-	20.8	20.5	20.3	21.1	20.4	-	20.0	23.9

4.2.5 Available micronutrient cation

After green revolution deficiency of micronutrient emerged out at several locations in the country which had adverse effect on soil productivity. Even though in AICRP LTFE except Zn and other micronutrients are added at a regular interval or whenever, status of micronutrients goes down. Samples were analyzed at a regular interval to monitor the status of micronutrients. In this section status of different micronutrients (DTPA extractable micronutrients) are given.

4.2.5.1 Available Zn

The wide spread deficiency of Zn has been reported, however, in the recent past, area under deficiency of Zn has reduced due to application of Zn. Perusal of data presented in table 4.8 revealed that in red soils of Bangalore, Bhubaneswar, Palampur, Ranchi Zn availability is not a problem. At the same time there are places where Zn status

Table 4.8 Effect of cropping and fertilizers on available Zn (mg kg^{-1}) in soil at different centres of AICRP LTFE

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ HW	NPK+ Lime/Zn	NPK+ FYM
Bangalore	2.34	2.33	2.45	2.96	3.30	3.59	2.69	3.38	4.18
Bhubaneswar	1.61	0.87	0.74	1.32	0.88	0.88	-	1.78	2.07
Coimbatore	2.58	0.64	0.76	0.82	0.83	0.87	0.83	2.04	0.99
Jabalpur	0.33	0.24	0.34	0.50	0.54	0.56	0.53	1.07	0.63
Ludhiana	-	1.62	1.51	1.51	2.50	3.80	2.95	5.34	3.57
New Delhi	1.10	0.63	0.70	0.71	0.83	0.82	0.75	1.23	0.78
Palampur	1.90	1.10	1.70	1.39	1.34	1.46	1.35	5.10	2.27
Pantnagar	2.70	0.60	1.22	1.20	0.60	0.53	1.25	1.22	1.06
Parbhani	0.98	0.68	0.72	0.74	0.89	0.85	0.92	1.84	1.09
Raipur	1.20	0.71	0.83	0.87	0.93	0.98	-	1.42	1.31
Ranchi	1.10	5.13	2.98	3.95	6.45	5.39	4.90	5.78	6.30

in quite high. Among Vertisols Zn status at Jabalpur is below the critical limits in some of the treatments. Which are not supplied with fertilizer nutrient in balanced form otherwise decomposition of roots mobilize Zn from soil. Increase in Zn availability in spite of greater mining in 100% NPK and 150% NPK support the statement.

4.2.5.2 Available Fe

Data presented in Table 4.9 indicated that there is no problem as far as available Fe status is concerned at all the places except at Coimbatore. At Coimbatore, Fe deficiency in maize is noted in some of the years during early crop growth stages which disappears after first irrigation due to conversion of ferric to ferrous.

Table 4.9 Effect of cropping and fertilizers on available Fe (mg kg^{-1}) in soil at different centres of AICRP LTFE

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ HW	NPK+ Lime/Zn	NPK+ FYM
Bangalore	5.22	19.59	26.07	25.39	22.12	34.21	24.15	24.32	38.87
Bhubaneswar	29.46	24.95	20.41	38.16	34.46	41.33	0.00	62.55	53.24
Coimbatore	2.74	1.77	1.83	2.14	2.10	2.23	2.14	2.05	2.31
Ludhiana	-	6.17	7.24	12.15	10.61	17.58	11.06	11.20	17.48
Palampur	26.00	20.02	32.88	29.45	29.63	34.48	30.51	27.77	42.74
Pantnagar	29.40	22.56	28.10	36.30	36.10	38.56	35.30	38.10	45.13
Raipur	-	10.24	11.72	12.38	14.03	15.13	-	13.11	16.43
Ranchi	47.00	22.18	28.48	25.85	37.63	47.64	25.75	15.93	37.33

4.2.5.3 Available Mn

Data presented in Table 4.10 revealed that at all the sites the available status of Mn in soil is in higher range and the crop did not suffer for Mn.

Table 4.10 Effect of cropping and fertilizers on available Mn (mg kg^{-1}) in soil at different centers of AICRP LTFE

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ HW	NPK+ Lime/Zn	NPK+ FYM
Bangalore	108.40	50.81	53.06	51.52	53.74	56.32	52.12	56.70	62.07
Bhubaneswar	6.72	7.23	7.84	42.17	20.25	7.22	0.00	20.20	27.38
Coimbatore	2.740	5.68	5.84	5.98	6.12	6.21	6.05	6.07	6.34
Ludhiana	-	11.95	12.91	9.81	11.67	15.39	11.71	12.82	13.67
Palampur	24.30	18.30	31.21	33.29	27.72	31.35	29.55	33.68	36.62
Pantnagar	26.80	13.33	15.10	20.00	20.11	24.23	20.00	20.26	26.10
Raipur	-	6.89	7.22	7.24	7.90	8.03	-	7.88	8.49
Ranchi	57.00	83.98	33.93	68.03	57.80	61.10	60.00	34.43	66.98

4.2.5.4 Available Cu

Data on available status of Cu (Table 4.11) revealed that soils of Coimbatore and Ludhiana are marginally above the critical status of Cu and crop may response to applied Cu. Decline in Cu status in soils of Ranchi was noted and the status has reached below the critical limit of Cu. It means crops may respond to applied Cu and due care will be taken to apply Cu as per soil status.

Table 4.11 Effect of fertilizers on available Cu (mg kg^{-1}) in soil at different centers of AICRP LTFE

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ HW	NPK+ Lime/Zn	NPK+ FYM
Bangalore	2.30	2.17	2.30	2.38	2.25	2.46	2.35	2.24	2.14
Bhubaneswar	2.81	1.45	1.38	1.70	1.30	1.65	0.00	1.55	1.88
Coimbatore	0.42	0.76	0.84	0.89	0.89	0.91	0.87	0.90	0.99
Ludhiana	-	0.74	0.76	0.76	0.72	0.80	0.97	0.79	0.97
Palampur	0.40	1.62	1.87	1.71	1.80	1.91	1.79	1.75	2.36
Pantnagar	2.90	3.04	3.75	3.82	3.83	3.63	4.10	3.80	4.80
Raipur	-	0.82	0.92	0.95	0.95	0.99	-	1.02	1.35
Ranchi	2.00	0.63	0.60	0.39	0.58	0.55	0.47	0.39	1.09

4.2.5.5 Available B

Estimates of available boron in soils of Bhubaneswar and Ranchi are quite low and crop may suffer for B (Table 4.12). However, other places, Bangalore and Pattambi available B status is more than the critical value (0.6 mg kg^{-1}).

Table 4.12 Effect of cropping and fertilizers on available B (mg kg^{-1}) in soil at different centers of AICRP LTFE

Location	Initial	Control	N	NP	NPK	150% NPK	NPK+ HW	NPK+ Lime/Zn	NPK+ FYM
Bangalore	-	0.83	0.77	0.92	0.91	0.97	0.91	0.98	1.01
Bhubaneswar	0.41	0.25	-	-	0.31	0.38	-	0.38	0.44
Pattambi	-	1.86	0.60	0.72	1.16	1.13	-	0.67	0.63
Raipur	-	0.03	0.04	0.05	0.06	0.06	-	0.05	0.05
Ranchi	-	0.15	0.32	0.27	0.23	0.28	0.18	0.18	0.28

4.2.5.6 Pantnagar

All the four micronutrient cations are above the prescribed sufficiency range. One thing is clear that from the yield data that Zn application is essential to maintain higher productivity (Table 4.13). In all the treatments except 100% NP and 100% NPK and NPK+FYM, NPK+Zn is applied regularly.

Table 4.13 DTPA extractable micronutrients (mg kg^{-1}) at Pantnagar

Micronutrient	Initial	Control	100% N +Zn	100% NP +Zn	100% NPK	150% NPK	100% NPK+ HW+Zn	100% NPK +Zn	100% NPK +FYM
Zn	2.70	0.60	1.22	1.20	0.60	0.53	1.25	1.22	1.06
Cu	2.97	3.04	3.75	3.82	3.83	3.63	4.10	3.80	4.80
Fe	29.50	22.56	28.10	36.30	36.10	38.56	35.30	38.10	45.13
Mn	26.08	13.33	15.10	20.00	20.11	24.23	20.00	20.26	26.10

4.2.5.7 Ludhiana

Perusal of data (Table 4.14) revealed that balanced nutrient management led to increase micronutrient status in soil. It is probably due to mobilization from native source during decomposition of fresh residual biomass added in larger quantity by crops. All the four micronutrient cations are above the critical level.

Table 4.14 DTPA extractable micronutrients (mg kg^{-1}) at Ludhiana

Treatment	Fe	Zn	Cu	Mn
Control	6.17	1.62	0.74	11.95
100% N	7.24	1.51	0.76	12.91
100% NP	12.15	1.51	0.76	9.81
50% NPK	10.47	2.21	0.82	11.17
100% NPK	10.61	2.50	0.72	11.67
150% NPK	17.58	3.80	0.80	15.39
100% NPK+W	11.06	2.95	0.97	11.71
100% NPK+Zn	11.20	5.34	0.79	12.82
100% NPK-S	12.99	1.82	0.83	13.29
100% NPK+FYM	17.48	3.57	0.97	13.67

4.2.5.8 Ranchi

Data (Table 4.15) clearly indicated that all the four micronutrient cations are present in sufficient quantity except Cu. Copper could be a yield limiting nutrient in Alfisols of Ranchi.

Table 4.15 DTPA extractable micronutrients (mg kg^{-1}) at Ranchi

Treatment	DTPA –Fe (mg kg^{-1})	DTPA- Cu (mg kg^{-1})	DTPA-Mn (mg kg^{-1})	DTPA –Zn (mg kg^{-1})
Control	22.18	0.63	83.98	5.13
100% N	28.48	0.60	33.93	2.98
100% NP	25.85	0.39	68.03	3.95
50% NPK	37.73	0.57	60.10	2.70
100% NPK	37.63	0.58	57.80	6.45
150% NPK	47.64	0.55	61.10	5.39
100% NPK + HW	25.75	0.47	60.00	4.90
100% NPK + Lime	15.93	0.39	34.43	5.78
100% N(S)PK	28.93	0.81	28.01	6.45
100% NPK + FYM	37.33	1.09	66.98	6.30
LSD ($P \leq 0.05$)	6.29	0.08	22.52	0.84

4.3 Heavy Metal Contamination

4.3.1 Ranchi

Even though there is no definite effect of treatment or trend as far as heavy metal status is concerned (Table 4.16).

Table 4.16 Heavy metal status (mg kg^{-1}) at Ranchi

Treatment	Ni (mg kg^{-1})	Co (mg kg^{-1})	Cd (mg kg^{-1})	Pb (mg kg^{-1})
Control	0.55	0.67	0.07	1.20
100% N	0.38	0.57	0.04	1.62
100% NP	0.46	0.93	0.19	1.61
50% NPK	0.50	1.15	0.06	1.70
100% NPK	0.51	0.50	0.06	1.84
150% NPK	0.43	0.51	0.10	1.60
100% NPK + HW	0.30	0.35	0.05	1.65
100% NPK + Lime	0.35	0.28	0.07	1.16
100% N (S) PK	0.22	0.56	0.04	1.71
100% NPK + FYM	0.29	0.64	0.14	1.4
LSD ($P \leq 0.05$)	0.08	0.21	0.02	0.5

However, data indicated little increase in concentration of Pb in soil which seems to be due to application of P fertilizer (diammonium phosphate, DAP). The DAP contains Pb in variable ranges due to rock phosphate one of the ingredients used for synthesis of DAP.

4.4 Soil Physical Properties

Physical condition of soil is very important as far as soil health is concerned, as most of the soil processes are governed by physical condition of soil.

4.4.1 Parbhani

Data on bulk density (BD) presented in Table 4.17 indicated that application of fertilizer resulted decline in BD compared to fallow and control but statistically found to be non-significant. However, decline in bulk density on application of FYM is statistically significant due to addition of more biomass through larger yield and resulted increase in porosity. Data on infiltration rate followed pattern similar to porosity but reverse to bulk density, it means decline in bulk density led to increase in porosity and water infiltration rate

Table 4.17 Effect of organic manures and inorganic fertilizers on physical properties of after harvest of experimentation at Parbhani (2014-15)

Treatments	Bulk density (Mg m^{-3})	Porosity (%)	Infiltration rate (cm hr^{-1})
Control	1.31	51.80	1.63
100% N	1.30	50.00	1.70
100% NP	1.28	56.50	1.68
50% NPK	1.29	56.50	1.68
100% NPK	1.28	56.75	1.73
150% NPK	1.27	60.25	1.89
100% NPK-Sulphur	1.27	57.00	1.78
Only FYM @ 10 t ha^{-1}	1.24	60.75	1.88
100% NPK+HW	1.28	56.50	1.72
100% NPK+Zn	1.27	55.00	1.67
100% NPK+FYM @ 5 t ha^{-1}	1.21	62.00	1.96
Fallow	1.32	50.10	1.61
LSD ($P \leq 0.05$)	0.03	1.64	0.094
Initial	1.31	51.00	1.68

4.4.2 Akola

Data generated on bulk density and hydraulic conductivity (Table 4.18) indicated that application of nutrients in balanced and integrated manner resulted decline in bulk density. But the reverse was noted in respect of hydraulic conductivity. Decline in bulk density on application of nutrient is due to increase in pore space as a result of better aggregation, this is due to addition of larger residual biomass to soil. Increase in hydraulic conductivity on application of nutrient support the hypothesis.

Table 4.18 Soil physical properties after harvest of wheat (2015-16)

Treatments	Bulk density (g cm^{-3})	Hydraulic conductivity (cm hr^{-1})
Control	1.55	0.29
100% N	1.54	0.32
100% NP	1.48	0.38
50% NPK	1.48	0.37
100% NPK	1.41	0.46

Treatments	Bulk density (g cm^{-3})	Hydraulic conductivity (cm hr^{-1})
150% NPK	1.34	0.60
100% NPK S free	1.44	0.43
FYM @ 10 t ha^{-1}	1.32	0.65
75% NPK + 25% N through FYM	1.38	0.61
100% NPK + Zn @ 2.5 kg ha^{-1}	1.36	0.58
100% NPK + FYM @ 5 t ha^{-1}	1.30	0.73
100% NPK + 37.5 kg S ha^{-1}	1.36	0.58
LSD ($P \leq 0.05$)	0.097	0.084

4.4.3 Bhubaneswar

Perusal of data on physical attributes of soil as influenced by nutrient management presented in Table 4.19 indicated that application of nutrient resulted increase in proportion of larger size aggregate, hydraulic conductivity and water holding capacity. But the reverse was noted in case of bulk density. Increase in bigger size aggregate is due to incorporation of residual biomass in larger quantity every year which resulted in binding of small aggregates together to form bigger aggregate. The bigger size aggregate led to increase in pore space and water holding capacity and on the contrary, reduced the bulk density. Thus, application of nutrients improved the physical condition of soil.

Table 4.19 Effect of nine years of long term manuring on physical properties of surface soil (0-15 cm) (Rabi 2014-15)

Treatments	Water stable aggregates (%)		Bulk density (Mg m^{-3})	Hydraulic conductivity (cm hr^{-1})	Water holding capacity (%)
	(<53 µm)	(> 253 µm)			
Control	1.45	4.95	1.41	1.44	34.87
100% NPK	1.68	4.97	1.35	1.55	40.67
150% NPK	1.36	5.69	1.34	1.57	42.65
100% NPK + Zn	1.61	5.14	1.37	1.55	39.72
100% NPK + FYM	1.81	5.67	1.28	1.69	52.38
100% NPK + B + Zn	1.53	5.22	1.35	1.58	40.66
100% NPK + S + Zn	1.46	5.10	1.38	1.53	40.12
LSD ($P \leq 0.05$)	0.34	0.53	0.03	0.10	3.52
Initial			1.55	1.52	42.2

4.4.4 Pantnagar

Data generated on different soil physical properties and presented in Table 4.20 revealed that addition of chemical fertilizer resulted decline in bulk density and further reduced on application of fertilizer in larger amount. Incorporation of FYM further reduced the BD of soil. Data on mean weight diameter (MWD), penetration resistance, hydraulic conductivity and water stable aggregate followed the trend reverse to bulk density. All the physical properties are dependent on each other. Increase in soil aggregates on fertilizer application increases the proportion of large pore size which increase the pore spaces and flow of water. Increase in mean weight diameter (MWD) and air spaces are responsible for reduction in bulk density.

Table 4.20 Effect of inorganic fertilizer and manure on physical properties of soil (2014-15)

Treatments	Bulk density ($Mg\ m^{-3}$)	MWD (mm)	Penetration resistance ($kg\ cm^{-2}$)	Hydraulic conductivity ($cm\ hr^{-1}$)	Water stable aggregates(%) (> 0.25 mm)	Water holding capacity (%)
Control	1.49	0.55	3.54	0.63	20.84	21.84
100% N+Zn	1.38	0.68	3.39	0.70	44.52	40.52
100% NP+Zn	1.29	0.74	3.23	0.78	50.81	43.81
50% NPK+Zn	1.38	0.66	3.36	0.70	41.80	40.01
100% NPK	1.36	0.70	3.32	0.78	52.10	45.10
150% NPK	1.32	0.71	3.36	0.75	50.40	46.40
100% NPK+HW	1.30	0.77	3.20	0.82	53.01	48.01
100% NPK+Zn	1.31	0.78	3.16	0.86	54.10	50.10
100% NPK+FYM	1.29	1.07	2.42	0.95	59.24	56.20
100% NPK-S+Zn	1.32	0.72	3.28	0.75	49.55	45.55
LSD ($P \leq 0.05$)	0.035	0.042	0.073	0.09	4.53	4.53
Fallow	1.08	1.14	2.15	1.02	45	54.00

4.4.5 Pattambi

Perusal of data presented in Table 4.21 revealed that application of FYM and fertilizer both reduced the bulk density (BD) of soil but magnitude of reduction was more in FYM. Data further indicated increase in porosity and water holding capacity on increase in dose of fertilizer from control to 150% NPK. Incorporation of FYM and green manuring both have additional effect on both the properties.

Table 4.21 Soil physical properties at Pattambi

Treatments	Bulk density ($g\ cm^{-3}$)	Water holding capacity (%)	Porosity (%)
Control	1.35	34.75	41.42
100% N	1.26	35.73	42.75
100% NP	1.26	34.76	43.55
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
50% NPK+ in situ GM	1.26	34.97	43.17
100% NPK+ GM	1.20	36.97	45.63
50% NPK+ FYM	1.21	38.77	47.39
100% NPK+ FYM	1.17	40.89	49.25

4.4.6 Jagtial

Perusal of data (Table 4.22) indicated that on application of fertilizer nutrients there has been increase in available water content, infiltration rate and hydraulic conductivity, gravimetric soil moisture content compared to control. Addition of organic manure (FYM) over and above NPK resulted in further improvement of these properties. Decline in bulk density on application of fertilizer nutrients supports the above findings.

Table 4.22 Effect of long term fertilizer and manure application on physical properties of post–harvest soils of rice (Rabi 2015-16)

Treatments	BD (Mg m^{-3})	Porosity (%)	Available water content	Infiltration rate (mm hr^{-1})	Hydraullic conductivity (cm hr^{-1})	Water holding capacity	Gravimetric moisture content (%)
Control	1.49	44.19	15.87	5.60	0.244	36.74	18.14
100% N	1.46	44.31	17.43	6.15	0.256	38.05	20.57
100% NP	1.45	45.38	19.42	6.70	0.269	37.13	20.19
50% NPK	1.46	45.00	17.89	5.21	0.253	37.00	19.93
100% NPK	1.44	45.64	19.80	6.65	0.277	37.67	20.80
150% NPK	1.42	46.20	19.93	7.35	0.286	38.57	20.56
100% NPK + HW	1.46	44.63	19.07	7.10	0.267	37.40	22.56
100% NPK + Zn	1.44	45.58	19.70	6.50	0.285	37.91	21.52
100% NPK - S	1.45	45.27	19.34	6.50	0.265	37.22	20.59
100% NPK + FYM	1.39	46.65	21.22	9.10	0.316	42.41	23.99
FYM	1.37	47.50	21.84	9.86	0.309	44.64	24.69
Fallow	1.45	44.75	16.96	6.10	0.307	39.04	17.45
LSD ($P \leq 0.05$)	0.06	NS	3.31	0.67	0.027	1.76	3.87
Initial	1.47	-	-	6.0	-	-	-

The results on aggregates analysis (Table 4.23) clearly demonstrated that application of fertilizer nutrient resulted increase in proportion of all size of water stable aggregates compared to control. Proportion of aggregate increased with increase in nutrient dose from 50 to 150% NPK. The values on different aggregate size further increased on addition of FYM. This means application of fertilizer nutrient has binding effect on soil particles together and made more stable aggregates. Increase in aggregate size is due to addition of more carbon through residual biomass which acts as a binding agent. Significant increase in mean weight diameter (MWD) of the aggregate on fertilizer application supports the results.

Table 4.23 Effect of long term fertilizer and manure application on percentage water stable aggregates of post-harvest soils of rice (Rabi 2015-16) at Jagtial

Treatment	> 2000 µm	2000 -1000 µm	1000-500 µm	500-250 µm	Total	250-100 µm	WSA	MWD
Control	8.4	48.9	6.7	4.7	68.75	4.43	73.18	1.34
100% N	12.5	58.8	4.0	3.4	78.59	2.42	81.01	1.45
100% NP	19.1	46.2	5.3	3.6	74.11	5.60	79.71	1.43
50% NPK	11.2	44.7	6.7	4.9	67.50	6.82	74.31	1.35
100% NPK	18.0	39.2	8.8	7.0	72.94	4.02	76.96	1.36
150% NPK	24.4	40.9	8.6	6.9	80.89	3.97	84.86	1.41
100% NPK + FYM	38.6	30.0	12.2	6.4	87.12	2.97	90.09	1.49
FYM	41.3	25.3	12.6	7.8	87.04	2.49	89.53	1.49
Fallow	24.4	43.1	4.9	2.7	75.09	5.27	80.35	1.48
LSD ($P \leq 0.05$)	3.27	3.51	1.17	0.61	5.93	0.80	6.00	0.09

WSA= Water stable aggregates

4.4.7 Raipur

Data (Table 4.24) revealed that application of fertilizer resulted increase in hydraulic conductivity, infiltration rate and reduced crack volume. Addition of FYM and BGA further made improvement in these properties. Application of nutrients resulted in increase in proportion of bigger size aggregates. However, incorporation of FYM and blue green algae (BGA) had more conspicuous effect on soil aggregates. It means application of nutrients resulted in improvement of soil physical condition. Significant increase in mean weight diameter (MWD) on application of nutrient, support the overall aggregate analysis. Increase in porosity and decline in bulk density further supports the observation recorded.

Table 4.24 Long- term impact of integrated nutrient management on hydraulic properties and cracking pattern of soil (after kharif 2013)

Treatments	Hydraulic conductivity (cm hr^{-1})	Infiltrationrate (mm hr^{-1})	Cumulative infiltration (mm)	Crack volume (cm^3 m^{-2})
Control	0.73	3	443	1407.36
100% N	0.78	5	416	1298.57
100% NP	0.91	5	443	1156.54
50% NPK	0.85	4	484	841.26
100% NPK	0.93	5	536	847.80
150% NPK	0.95	6	543	918.19
100% NPK + Zn	0.97	4	522	831.74
50% NPK + BGA	1.00	5	625	806.80
50% NPK + GM	1.06	7	578	747.53
100% NPK + FYM	1.11	8	694	625.73
LSD ($P \leq 0.05$)	0.12	0.68	54.0	150.0

Data (Table 4.25) indicated that increase in proportion of bigger size aggregate and MWD on increase in fertilizer nutrient from 50 to 150% NPK. On the other hand, decline in smaller size aggregates was recorded on fertilizer application which means smaller size aggregate combined together made bigger size aggregate. It means there is positive effect of fertilizer nutrient on physical properties of soil which is conductive for plant growth, moisture retention and plant available water (Table 4.26).

Table 4.25 Percent water stable aggregates and mean weight diameter under different treatments after harvest of rice (2013)

Treatments	>2 mm	2-1 mm	1-0.5 mm	0.5-0.25 mm	<0.25 mm	MWD (mm)
Control	4.70	63.06	19.97	7.68	4.55	1.302
100% N	12.78	68.92	9.75	6.09	2.42	1.559
100% NP	19.24	56.19	12.37	10.45	1.54	1.636
50% NPK	15.23	57.87	14.51	7.11	5.14	1.532
100% NPK	22.03	44.63	22.51	8.57	2.22	1.626
150% NPK	32.10	46.48	11.48	7.51	2.24	1.924
100% NPK + Zn	16.17	52.19	9.01	15.43	7.16	1.468
50% NPK+BGA	31.54	51.51	8.71	7.38	0.82	1.963
50% NPK+GM	37.11	49.84	5.33	4.45	3.22	2.093
100% NPK+FYM	48.56	16.05	6.76	16.77	11.77	2.051
LSD ($P \leq 0.05$)	5.72	7.76	4.59	4.86	3.53	0.15

Increasing rate of fertilizer nutrient from 50% to 150% led to increase in porosity, hydraulic conductivity and water holding capacity (Table 4.26). However, reverse was noted with bulk density of soil. Increase in proportion of large size aggregate support the findings (Table 4.25).

Table 4.26 Effect of long term fertilizer and manure application on physical properties of soil

Treatments	BD ($Mg\ m^{3}$)	Total porosity (%)	HC ($cm\ hr^{-1}$)	Moisture content (%)	WHC (%)
Control	1.45	46.63	0.79	21.51	37.86
100% N	1.42	46.8	0.8	20.11	40.29
100% NP	1.41	46.84	0.8	22.47	43.36
50% NPK	1.41	48.93	0.91	23.93	45.06
100% NPK	1.4	47.37	0.91	23.49	46.25
150% NPK	1.41	47.47	0.93	25.62	46.66
100% NPK + Zn	1.41	47.29	0.87	25.58	44.63
50% NPK + BGA	1.37	49.11	0.88	23.19	45.93
50% NPK + GM	1.35	49.72	0.94	26.11	48.10
100% NPK+ FYM	1.36	49.67	0.96	30.17	50.59
LSD ($P \le 0.05$)	0.03	1.28	0.051	3.709	3.939

4.5 Soil Biological Properties

Though biological properties of soil are good indicator of soil health but due to lengthy procedure of estimation and poor reproducibility always restrict to include in soil testing programme followed for assessment of soil health. In this chapter effect of nutrient management on soil biological properties is discussed.

4.5.1 Barrackpore

Data generated (Table 4.27) on microbial biomass carbon (MBC) and enzymatic activities in soil revealed that application of nutrient resulted increase in MBC, dehydrogenase activities (DHA), fluorescein diacetate (FDA) and phosphatase enzymes in soil. Data further indicated that increase in dose of nutrient from 50 to 150% NPK resulted in concomitant increase in biological properties. It means use of chemical fertilizer had positive effect on microbial activity in soil. Regular use of FYM had additional effect on these properties.

Table 4.27 Long-term effect of manure and fertilizer use on microbial biomass carbon, microbial quotient and enzymatic activities

Treatments	MBC ($mg\ kg^{-1}$)	MBC/ SOC Ratio	DHA (μg TPF g^{-1} 24 h^{-1})	FDA (μg fluorescein g^{-1} hr^{-1})	Acid phosphatase (μg $PNPg^{-1}$ hr^{-1})	Alkaline phosphatase (μg $PNPg^{-1}$ h^{-1})
Control	221	3.95	2.8	10.9	139	479
100% N	287	4.16	4.0	11.3	146	519
100% NP	298	4.20	4.4	11.6	147	532
50% NPK	273	4.01	4.9	12.3	151	557
100% NPK	328	4.62	6.0	13.9	170	579
150% NPK	331	4.53	5.7	16.1	186	603
100% NPK+HW	345	4.66	6.4	14.1	172	581
100% NPK +Zn	360	4.74	6.1	15.2	180	588
100% NPK - S	305	4.30	4.6	14.9	176	575
100% NPK + FYM	435	4.89	7.1	19.0	275	616

4.5.2 Palampur

Data (Table 4.28) generated on microbial biomass C, N, P and S clearly indicated that application of nutrients and increased doses had resulted increase in microbial biomass C, N, P and S. Incorporation of FYM over and above

NPK further increased these parameters. Application of lime also had positive effect on microbial activities in soil. It means application of fertilizer nutrient had favoured microbial activities in soil. It is interesting to note that absence nutrient application or imbalanced use of nutrients both had adverse effect on activities of microorganisms in soil.

Table 4.28 Effect of long-term use of chemical fertilizers and amendments on microbial biomass (mg kg^{-1})

Treatment	Microbial biomass C		Microbial biomass N		Microbial biomass P		Microbial biomass S	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Control	279	239	10.5	9.56	1.87	1.42	4.41	3.93
100% N	182	143	12.3	11.3	0.81	0.78	5.80	4.68
100% NP	295	256	13.9	12.2	1.89	1.64	6.62	5.43
50% NPK	309	268	14.3	11.6	2.89	2.35	6.77	5.28
100% NPK	464	422	18.4	14.9	3.09	2.47	7.29	6.25
150% NPK	441	399	21.3	16.2	3.37	2.82	7.66	6.54
100% NPK +HW	564	525	19.1	15.7	3.19	2.77	8.33	7.51
100% NPK (-S)	408	364	14.9	13.7	3.07	2.45	5.85	5.04
100% NPK + Zn	420	380	17.8	14.1	3.05	2.54	6.99	6.13
100% NPK + lime	620	578	22.0	16.8	3.44	2.72	10.93	7.95
100% NPK + FYM	676	636	23.4	17.8	3.49	2.86	11.67	8.03
LSD ($P \leq 0.05$)	11.9	12.8	3.07	1.78	0.19	0.23	0.89	1.19

4.5.3 Bangalore

Data generated on different fractions of carbon (Table 4.29) revealed that application fertilizer nutrient, resulted increase in all the fractions of carbon *viz*., Available carbon, particulate soil organic carbon (PSOC), soil microbial biomass carbon (SMBC), water soluble organic carbon (WSOC), soil carbohydrate carbon (SCC) and soil mineralizable carbon (SMC). Data further indicated that increasing amount of fertilizer as well as addition of FYM and lime further made improvement in these fractions of carbon. It means that with the application of fertilizer nutrient there was increase of available carbon along with its fractions present in soil. Increase in carbon and its fractions is due to addition of more carbon through residual biomass of root as a result of higher biomass yield on application of fertilizer.

Table 4.29 Effect of long term manure and fertilizers application on fractions of carbon in soil under finger millet–maize cropping system (mg kg^{-1}) (2013)

Treatments	TOC (mg kg^{-1})	PSOC (mg kg^{-1})	SMBC (mg kg^{-1})	WSOC (mg kg^{-1})	SCC (mg kg^{-1})	SMC (mg kg^{-1})
Control	4792.0	325.0	180.0	14.5	244.8	288.0
100% N	4896.0	344.0	198.0	18.6	265.6	311.0
100% NP	5123.0	373.0	204.0	20.0	286.8	319.0
50% NPK	5990.0	463.0	214.0	25.2	314.5	323.0
100% NPK	6243.0	551.0	229.0	26.7	350.5	339.0
150% NPK	6632.0	679.0	239.0	28.8	398.6	364.0
100% NPK (S-free)	6010.0	420.0	220.0	25.8	325.9	331.0
100% NPK + HW	6203.0	525.0	230.0	26.5	338.5	334.0
100% NPK + lime	6423.0	657.0	235.0	27.4	377.6	350.0
100% NPK + FYM	7418.0	839.0	293.0	32.1	439.2	424.0
100% NPK + FYM + lime	7600.0	863.0	304.0	33.5	449.8	430.0
LSD ($P \leq 0.05$)	335.5	32.8	17.7	2.3	23.3	35.1
Virgin soil	4685.0	316.0	185.0	12.9	238.0	276.0

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

Data presented in Table 4.30 revealed that application of fertilizer resulted increase in estimates of humic acid (HA) and fulvic acid (FA) and their ratio which indicates sequestration of carbon in soil into resistant pool of carbon. From the data it can be concluded that to sequester carbon in soil application of nutrients is essential. Addition of FYM over and above 100% NPK resulted in improvement in C sequestration compared to NPK alone. However, application of lime did not have any additional effect on estimates of HA and FA as application of lime have added more carbon in terms of residual biomass compared to NPK alone. Probably application of lime favoured microbial growth which oxidizes soil carbon.

Table 4.30 Effect of long term manure and fertilizers application on fractions of carbon in soil under finger millet–maize cropping system (mg kg^{-1}) (2013)

Treatments	HA (g kg^{-1})	FA (g kg^{-1})	E_4/E_6 ratio of HA	E_4/E_6 ratio of FA
Control	1.1	1.1	1.1	3.77
100% N	1.12	1.13	1.72	4.12
100% NP	1.13	1.14	1.59	4.12
50% NPK	1.18	1.19	1.95	4.58
100% NPK	1.26	1.22	2.12	5.1
150% NPK	1.33	1.28	2.24	5.42
100% NPK (S-free)	1.2	1.18	2.02	4.81
100% NPK + HW	1.26	1.23	2.07	5.07
100% NPK + lime	1.28	1.26	2.19	5.37
100% NPK + FYM	1.42	1.39	2.38	6.2
100% NPK + FYM + lime	1.45	1.4	2.6	6.27
LSD ($P \leq 0.05$)	0.1	0.09	0.194	0.46
Virgin soil (Fallow)	0.093	0.092	0.09	3.68

HA= humic acid; FA= fulvic acid

Increase in glomalin content on application of increasing dose of fertilizer nutrient confirms the above findings (Table 4.31). However, incorporation of FYM had more pronounced effect on synthesis of glomalin. It means application of nutrient is essential to sequester more carbon into soil.

Table 4.31 Effect of long term manure and fertilizers application on glomalin content in soil under finger millet–maize cropping system

Treatments	Glomalin content (mg kg^{-1})		
	2013	2014	Mean
Control	1.49	1.49	1.49
100% N	1.56	1.60	1.58
100% NP	1.78	1.81	1.79
50% NPK	1.97	2.05	2.01
100% NPK	2.20	2.29	2.24
150% NPK	2.95	3.09	3.02
100% NPK (S-free)	2.12	2.18	2.15
100% NPK + HW	2.24	2.30	2.27
100% NPK + lime	2.65	2.73	2.69
100% NPK + FYM	4.16	4.30	4.23
100% NPK + FYM + lime	4.28	4.42	4.35
LSD ($P \leq 0.05$)	0.34	0.37	0.35
Virgin soil (Fallow)	1.31	1.31	1.31

4.5.4 Pantnagar

Data on microbial population count of bacteria, fungi, actinomycetes and *Azotobacter* presented in table 4.32 indicated that there is increase in microbial count of all the four types of organisms exists in the soil on application of fertilize nutrient. Incorporation of FYM further increased their number in soil. Increase in number of cells of all these organisms is due to more availability of fresh residual biomass compared to control and 100% N. More increase in organism population on application of FYM support the hypothesis. In fact, fresh residual biomass (root, stubble, leaves) act as a food for soil organisms and nutrients are required for synthesis of body of microorganisms.

Table 4.32 Long term effect of fertilizer and manure on microbial population in soil (After 44th crop cycles at Pantnagar)

Treatment	Fungi ($x 10^4$)		Bacteria ($x 10^6$)		Actinomycetes ($x10^5$)		Azotobacter ($x10^3$ cfu g^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Control	0.60	0.45	0.55	0.40	0.78	0.40	152	146
100% N+Zn	1.27	1.06	1.46	1.55	1.89	1.71	410	346
100% NP+Zn	1.66	1.29	1.68	1.53	1.00	1.52	476	338
50% NPK+Zn	1.06	0.85	1.60	1.51	1.59	1.31	236	218
100% NPK	1.48	1.18	1.80	1.75	1.71	1.67	286	208
150% NPK	1.48	1.27	1.87	1.77	1.76	1.70	256	204
100% NPK+Zn	1.91	1.29	2.19	1.92	1.84	1.55	336	216
100% NPK+HW+Zn	1.84	1.42	1.99	1.88	1.85	1.70	379	254
100% NPK-S+Zn	1.40	1.31	1.79	1.63	1.81	1.75	422	380
100% NPK+FYM	1.99	1.48	2.32	1.99	2.16	1.82	630	601
LSD ($P \leq 0.05$)	0.11	0.14	0.17	0.26	0.31	0.27	43.8	38.4

Data with respect to carbon pools and DHA presented in Table 4.33 followed similar trend to that of soil microbial population count and support the above data. Increase in activity of DHA on fertilizer application further confirms that application of fertilizer favoured the growth of microorganism in soil.

Table 4.33 Long term effect of fertilizer and manure on carbon pools and dehydrogenase activity (Pantnagar)

Treatment	SMBC (mg kg^{-1})	SMBN (mg kg^{-1})	SMBP (mg kg^{-1})	WSC (mg kg^{-1})	WSCH (mg kg^{-1})	DHA (mg TPF kg^{1} Soil / 24 hr)
Control	7.850	6.94	0.24	2.96	2.30	0.24
100% N+Zn	245.2	34.2	3.7	60.8	41.3	5.78
100% NP+Zn	199.2	36.2	4.1	59.6	40.6	5.45
50% NPK+Zn	168.0	23.2	3.0	42.7	25.8	4.12
100% NPK	177.2	29.0	3.2	51.8	31.1	4.27
150% NPK	186.7	27.5	4.2	53.7	33.2	5.40
100% NPK+Zn	230.5	33.2	3.6	59.7	40.8	5.45
100% NPK+HW+Zn	208.5	34.2	5.3	57.1	39.3	5.36
100% NPK-S+Zn	289.2	41.2	4.9	78.5	43.0	6.61
100% NPK+FYM	260.0	35.2	6.2	74.7	42.5	6.82
LSD ($P \leq 0.05$)	2.731	2.411	0.08	1.031	0.74	0.08

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

4.5.5 Ranchi

Data (Table 4.34) indicate increase in water soluble carbohydrate and water soluble carbon, microbial biomass carbon and nitrogen and CO_2 evolution was observed with application of fertilizer, which means more activities of soil microorganisms took place. Thus, results indicated that application of fertilizer had positive effect on microbial activities in soil. Increase in amount of water soluble carbon and carbohydrate on application of fertilizer is due to larger root activity as a result of better growth. Thus, results clearly demonstrated that application of fertilizer had positive effect on growth and activities of soil organisms and root activities.

Table 4.34 Long term effect of continuous cropping, fertilization, manuring and liming on active and slow pool of SOC under soybean-wheat cropping system

Treatment	Water soluble C (mg kg^{-1})	Water soluble carbohydrates (mg kg^{-1})	CO_2 evolution (mg /100 g soil / day)	SMBC (mg kg^{-1})	SMBN (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
150% NPK	40.5	312.5	50.0	217.0	22.8	39.2
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
LSD ($P \leq 0.05$)	7.3	26.3	6.5	8.8	1.4	NS

Data on humic acid fraction (Table 4.35) indicated that the imbalanced application of chemical fertilizer resulted decline in carbon content in all the fractions of humic acid including soil organic carbon (SOC) which means there is net loss of carbon from soil and from resistant pool of carbon as well. However, balanced application of nutrient (100% NPK, 150% NPK, 100% NPK+FYM) resulted in increase of all the carbon fractions. It is interesting to note that in-spite of larger yield with application of lime, decline in carbon content in all fraction was noted. It means lime may increase the crop productivity but at the same time increases the carbon loss from soil . This could be reason lime treated plat could not maintain initial carbon of soil.

Table 4.35 Long term effect of continuous cropping, fertilization, manuring and liming on different fractions of soil humus.

Treatment	Total organic C (%)	Humic C (%)	Fulvic C (%)	Humic + Fulvic C (%)	Humin C (%)
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
150% NPK	0.42	0.074	0.098	0.172	0.248
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
LSD ($P \leq 0.05$)	0.08	0.01	0.02	0.025	0.04

4.5.6 Coimbatore

Effect of application of nutrient alone and in combination with other nutrient and FYM on population of soil microorganisms and enzyme activities in soil is given in Table 4.36 and 4.37, respectively. The results indicated that application of nutrients resulted increase in population of all the three types of organisms in soil compared to control. The higher activities (Table 4.37) of soil enzymes on application of fertilizer support the data on population of soil organisms. Data further indicated that increasing dose of nutrient also did not have any adverse effect on population of bacteria, fungi and actinomycetes.

Table 4.36 Effect of long term fertilization on microbial population in post harvest soil of maize hybrid (2012)

Treatments	Bacteria ($x10^6$ CFU / g of dry soil)	Fungi ($x10^3$ CFU / g of dry soil)	Actinomycetes ($x10^4$ CFU / g of dry soil)
Control	45	11	7
100% N	72	12	8
100% NP	72	12	8
50% NPK	81	13	9
100% NPK	90	14	10
150% NPK	83	13	9
100% NPK + HW	90	14	10
100% NPK (- S)	87	13	9
100% NPK + $ZnSO_4$	87	13	9
100% NPK + FYM	131	16	12

Table 4.37 Effect of long term fertilization on soil enzyme activity in post harvest soil of maize hybrid (2012)

Treatments	Ac-PA (µg p -nitro phenol released g^{-1} soil hr^{-1})	Al-PA (µg p -nitro phenol released g^{-1} soil hr^{-1})	Aryl-SA (µg p -nitro phenol released g^{-1} soil hr^{-1})	UA (µg NH_4^+ released g^{-1} soil hr^{-1})	DA (µg TPF (tri phenyl formazan) released g^{-1} soil day^{-1})
Control	35.2	104.3	7.4	37.6	1.1
100% N	34.1	109.1	8.2	58.8	1.5
100% NP	27.1	103.6	9.6	60.4	1.5
50% NPK	34.2	100.8	9.8	37.8	1.2
100% NPK	31.9	103.8	9.5	63.4	1.4
150% NPK	24.3	99.3	8.7	63.7	1.4
100% NPK + HW	29.4	96.2	9.7	76.3	1.1
100% NPK (- S)	25.0	111.7	8.0	53.1	1.7
100% NPK + $ZnSO_4$	26.3	99.9	9.8	46.0	1.3
100% NPK + FYM	37.9	115.1	11.4	83.9	2.2

APA=Acid phosphatase activity, APA=Alkaline phosphatase activity, ASA=Aryl sulphatase activity, UA=Urease activity, DA=Dehydrogenase activity

Effect of growth stages on activities of acid and alkaline phosphates, urease and dehydrogenase given in (Table 4.38) revealed that activities of acid and alkaline phosphate increases with the advancement of crop growth (Table 4.39 and 4.40). Whereas reverse was noted in respect of urease and dehydrogenase activities (Table 4.41). Activity of urease and dehydrogenase is highest in the early growth states of maize and declined with time till maturity, may be because of less availability of carbohydrate in the form of rhizodeposition as a result of higher demand of crop for seed formation.

Table 4.38 Effect of long term fertilization on soil acid phosphatase activity (µg p-nitro phenol released g^{-1} soil hr^{-1}) (2014)

Treatments	Monsoon fallow period			Cropping period (maize)			
	Before Rainfall	After rainfall	End of fallow period	Knee high	Tasseling	Milky	Harvest
Control	35.0	25.2	28.5	32.6	35.8	36.0	34.9
100% N	33.4	24.6	27.2	29.6	31.1	32.8	31.5
100% NP	26.6	18.2	19.8	24.5	27.9	29.5	28.9
50% NPK	29.1	20.7	23.5	27.0	30.1	32.1	31.0
100% NPK	26.9	18.6	19.5	25.5	28.0	30.0	28.8
150% NPK	24.6	17.0	17.9	23.4	24.6	27.0	25.9
100% NPK (-S)	28.0	19.4	21.7	25.1	28.1	30.1	28.6
100% NPK + HW	26.5	19.0	19.9	25.8	27.9	29.6	28.9
100% NPK + Zn	25.0	17.7	18.6	24.1	26.2	27.5	27.1
100% NPK + FYM	42.3	35.1	37.3	40.6	46.1	47.0	45.5
LSD ($P \leq 0.05$)	2.05	1.09	1.04	1.03	1.16	1.11	0.95

Table 4.39 Effect of long term fertilization on soil alkaline phosphatase activity (µg p-nitro phenol released g^{-1} soil hr^{-1}) (2014)

Treatments	Monsoon fallow period			Cropping period (maize)			
	Before Rainfall	After rainfall	End of fallow period	Knee high	Tasseling	Milky	Harvest
Control	74.9	58.7	61.6	69.3	54.8	67.1	81.1
100% N	87.8	63.5	64.5	71.8	60.7	78.6	90.2
100% NP	88.2	67.3	69.1	74.0	63.9	80.8	92.7
50% NPK	79.1	61.9	62.8	70.4	60.0	84.3	95.8
100% NPK	88.6	68.7	69.8	75.0	66.7	89.8	98.3
150% NPK	86.7	64.8	65.7	65.8	63.2	87.0	96.4
100% NPK + HW	85.3	67.6	69.3	74.4	64.7	88.7	97.8
100% NPK (-S)	87.6	67.2	70.2	74.1	65.8	89.3	97.5
100% NPK + Zn	84.4	69.1	71.4	75.6	63.5	86.9	96.1
100% NPK + FYM	93.4	71.4	76.8	90.0	85.1	106.3	134.5
LSD ($P \leq 0.05$)	3.27	2.82	2.99	3.24	2.89	3.51	3.90

Table 4.40 Effect of long term fertilization on soil urease activity (µg NH_4^+ released g^{-1} soil hr^{-1}) (2014)

Treatments	Monsoon fallow period			Cropping period (maize)			
	Before Rainfall	After rainfall	End of fallow period	Knee high	Tasse ling	Milky	Harvest
Control	69	177	146	196	168	94	67
100% N	163	267	213	271	255	178	109
100% NP	160	280	218	289	262	183	115
50% NPK	200	275	229	323	266	165	106
100% NPK	167	306	254	351	279	190	125
150% NPK	122	262	201	338	238	148	92
100% NPK + HW	169	298	250	341	276	194	126
100% NPK (-S)	164	305	257	341	277	187	127
100% NPK + Zn	170	301	254	347	276	191	128
100% NPK + FYM	223	327	283	378	341	220	155
LSD ($P \leq 0.05$)	7.81	10.81	8.21	15.89	12.95	8.34	5.88

Table 4.41 Effect of long term fertilization on soil dehydrogenase activity (µg TPF, tri phenyl formazan released g^{-1} soil day^{-1}) (2014)

Treatments	Monsoon fallow period			Cropping period (maize)			
	Before Rainfall	After rainfall	End of fallow period	Knee high	Tasseling	Milky	Harvest
Control	3.5	3.7	3.6	3.3	3.0	3.4	2.7
100% N	4.4	5.6	5.2	4.8	4.4	4.6	3.9
100% NP	4.1	5.6	5.4	5.0	4.7	4.9	4.1
50% NPK	4.8	5.5	5.3	4.8	4.0	4.3	3.8
100% NPK	4.6	5.7	5.4	4.7	4.5	4.5	3.7
150% NPK	5.1	6.0	5.7	5.2	4.8	5.1	4.1
100% NPK + HW	4.6	5.3	5.1	4.7	4.4	4.6	3.8
100% NPK (-S)	3.8	4.2	3.9	3.7	3.5	3.9	3.6
100% NPK + Zn	4.0	5.1	4.9	4.3	4.0	4.2	4.0
100% NPK + FYM	6.7	8.1	7.2	7.0	6.6	6.9	6.3
LSD ($P \leq 0.05$)	0.74	0.41	0.45	0.44	0.52	0.44	0.39

4.5.7 Pattambi

Earthworms, may also be considered as good indicator of soil health. Activities of earthworms manipulate soil carbon. Data presented in Table 4.42 revealed that application of fertilizer resulted decline in number of earth worms in a unit area but incorporation of FYM and green manure (GM) both along with fertilizer increased the number of earth worms. On the contrary, increase in number of arthropods was recorded on application of fertilizer compared to control. Incorporation of FYM and GM both have additive effect as far as number of arthropods are concerned. Arthropods cut the plant into small pieces and helps in decomposition of plant parts / crop residue.

Table 4.42 Impact of different nutrient management options on soil macro fauna

Treatments	**Earth worm count (m^{-2})**	**Arthopods count (kg^{-1} soil)**
Control	7.00	40.50
100% N	4.75	46.75
100% NP	7.75	49.50
50% NPK	3.75	55.00
100% NPK	5.75	34.25
150% NPK	5.75	47.50
100% NPK*	5.00	44.00
50% NPK+ GM	11.75	43.50
100% NPK+ GM	11.25	63.75
50% NPK+ FYM	12.00	49.00
100% NPK+ FYM	16.25	78.00
100% NPK+ lime	6.00	32.50
LSD ($P \leq 0.05$)	4.03	21.05

*Application of $CuSO_4$ was done till Rabi 2000 at Pattambi

Data generated (Table 4.43) on microbial population count (MPC) indicated that there was increase in number of bacteria, fungi, *Azospirillum*, *Actinomycetes*, *Azotobacter* and P solubilizer on application increasing dose of fertilizer from 50% NPK to 150% NPK and always larger than control which means chemical fertilizer had positive effect on growth of soil microorganisms. Through incorporation of green manure (GM) and FYM maintained number larger than chemical fertilizer alone.

Table 4.43 Effect of treatments on soil micro flora

Treatments	Bacteria (10^6cfu g^{-1} soil)	Actinomycetes (10^3cfu g^{-1} soil)	Fungi (10^4cfu g^{-1} soil)	Azospirillum (10^4cfu g^{-1} soil)	Azotobacter (10^3cfu g^{-1} soil)	P solubilizers (10^4cfu g^{-1} soil)
Control	24.00	7.75	15.25	15.50	9.50	0.25
100% N	29.50	9.75	18.50	17.25	10.75	0.50
100% NP	32.00	11.50	21.25	20.25	12.25	3.00
50% NPK	33.00	13.75	23.75	22.50	15.75	2.00
100% NPK	39.75	16.50	26.00	25.75	17.50	3.75
150% NPK	40.75	17.25	26.75	28.75	18.25	4.75
100% NPK+ lime	37.50	14.75	24.50	23.75	16.75	4.00
100% NPK*	39.25	16.00	25.75	25.00	19.75	2.75
50% NPK+ GM	43.75	18.75	34.50	29.75	20.25	1.25
100% NPK+ GM	52.25	27.25	36.75	34.75	24.75	2.00
50% NPK+ FYM	48.50	21.25	41.50	31.25	20.75	2.00
100% NPK+ FYM	61.50	33.00	48.50	42.25	28.25	4.25
LSD ($P \leq 0.05$)	9.652	9.762	9.175	9.884	7.653	1.535

*Application of $CuSO_4$ was done till Rabi 2000 at Pattambi

Increase in activities of soil enzymes like urease, phosphate, dehydrogenase and soil respirations on application of fertilizer as well as increase in amount of fertilizer from 50 to 150% NPK (Table 4.44). Increase in mineralizable carbon and nitrogen on application of fertilizer compliments each other (Table 4.45).

Table 4.44 Effect of treatments on soil enzymes and soil respiration

Treatments	Urease (ppm urea g^{-1} soil hr^{-1})	Phosphatase (µg pnitrophenol g^{-1} soil hr^{-1})	Dehydrogenase (µg TPF g^{-1} soil 24 hr^{-1})	Soil respiration (mg CO_2 100 g^{-1}soil d^{-1})
Control	141.50	17.63	188.28	3.63
100% N	214.25	19.68	164.79	5.86
100% NP	180.75	27.96	121.23	6.05
50% NPK	165.75	18.08	160.73	5.99
100% NPK	192.50	19.11	106.82	5.91
150% NPK	202.75	19.22	106.93	5.74
100% NPK+ lime	180.25	21.49	207.35	6.07
100% NPK	163.00	20.40	150.98	6.17
50% NPK+ GM	205.00	27.89	257.39	6.67
100% NPK+ GM	223.50	29.90	368.25	6.62
50% NPK+ FYM	216.50	28.13	313.67	6.85
100% NPK+ FYM	239.00	38.54	394.41	7.03
LSD ($P \leq 0.05$)	9.090	2.866	7.379	0.624

Table 4.45 Effect of treatment on MBC, C mineralization potential, N mineralization potential and hot water extractable soil carbohydrates (HWC)

Treatments	MBC (µg g^{-1} soil)	C- Mineralization (%)	N-Mineralization (kg ha^{-1})	HWC (kg ha^{-1})
Control	205.45	1.32	177.27	2132.43
100% N	244.06	1.51	208.74	3081.21
100% NP	338.58	1.66	201.20	3644.80

Treatments	MBC ($\mu g\ g^{-1}$ soil)	C- Mineralization (%)	N-Mineralization (kg ha^{-1})	HWC (kg ha^{-1})
50% NPK	242.61	1.58	192.73	2860.25
100 % NPK	332.40	1.70	205.71	3051.75
150% NPK	223.36	1.79	214.21	3877.01
100% NPK+ lime	353.23	1.69	216.71	3071.67
100% NPK	317.73	1.69	199.66	3714.53
50% NPK+GM	420.45	1.74	234.71	4888.59
100% NPK+ GM	468.65	1.89	250.21	5014.13
50% NPK+ FYM	515.43	1.83	222.25	5583.59
100% NPK+ FYM	552.75	1.90	228.83	5917.08
LSD ($P \leq 0.05$)	33.307	0.048	12.213	315.042

4.5.8 Jagtial

Activity of dehydrogenase (DHA) with time (Table 4.46) revealed that there was increase in activity from 30 to 60 days after transplanting (DAT) and declined at 90 days. Data further revealed that activity of DHA is always greater in Rabi season compared to kharif. Probably larger yield of rice during rabi provided more soluble carbohydrate through root exudates. Increase in activity at 60 DAT is due to increase in crop growth and thereafter decline is due to translocation of photosynthates to grain which may reduce the transport of photosynthates to root.

Table 4.46 Effect of long term fertilizer and manure application on soil dehydrogenase activity (mg TPF produced g^{-1} soil d^{-1}) at various growth stages of rice (2014-15)

Treatments	30 DAT		60 DAT		90 DAT	
	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif
Control	1.885	1.38	3.513	2.738	3.220	2.035
100% N	2.098	1.60	5.390	3.293	2.773	2.220
100% NP	2.115	1.70	5.505	3.450	5.083	2.720
50% NPK	2.565	1.73	5.333	3.513	3.455	2.648
100% NPK	2.670	2.12	6.165	4.065	4.030	3.065
150% NPK	2.898	2.10	6.538	4.183	5.138	3.330
100% NPK + HW	2.519	1.89	5.580	3.810	4.503	2.993
100% NPK – S	2.198	1.81	5.173	3.663	4.423	2.985
100% NPK + Zn	2.203	1.91	5.903	3.718	4.605	3.105
100% NPK + FYM	3.232	2.34	7.523	4.610	5.703	3.625
FYM	2.992	1.79	5.503	3.668	4.665	3.088
Fallow	2.590	1.90	5.533	3.568	3.345	3.310
LSD ($P \leq 0.05$)	0.350	0.187	0.501	0.358	0.387	0.266

Similar effect of fertilizer nutrient was also recorded on activity of phosphatase (Table 4.47). It means increase in activity of phosphatase was noted with increase in amount of fertilizer nutrient. However, addition of organic manure further increased the phosphatase activity. Increase in phosphate activities is probably due to availability of more substrates.

Table 4.47 Effect of long term fertilizer and manure application on soil acid phosphatase activity (µg p-nitrophenol released g^{-1} soil hr^{-1}) at various growth stages of rice (2014 -15 and 2015-16)

Treatments	30 DAT		60 DAT		90 DAT	
	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif
Control	83.13	74.93	182.88	90.68	94.55	80.90
100% N	72.30	65.20	168.48	80.93	86.50	70.45
100% NP	81.80	68.93	177.75	85.75	95.88	78.48
50% NPK	89.45	76.88	185.33	94.45	107.50	91.15
100% NPK	102.75	83.78	192.13	108.95	120.78	102.35
150% NPK	123.73	96.58	204.20	128.63	139.38	110.23
100% NPK + HW	101.55	84.93	190.78	108.00	126.53	98.33
100% NPK – S	101.03	84.55	191.35	107.43	129.55	95.50
100% NPK + Zn	103.13	85.23	192.80	104.43	127.53	96.65
100% NPK + FYM	110.45	90.25	198.25	114.53	153.83	105.90
FYM	106.70	91.70	196.05	101.08	142.63	98.30
Fallow	102.78	88.55	191.60	100.45	139.93	99.90
LSD ($P \leq 0.05$)	10.38	8.96	17.98	12.65	15.40	12.13

4.5.9 Parbhani

Data on microbial population of bacteria, fungi and *Actinomycetes* (Table 4.48) revealed that integration of nutrients and increasing dose of fertilizer both resulted increase in number of cells of bacteria, fungi and *Actinomycetes* and incorporation of FYM over and above NPK maintained largest number of all these species of soil microorganisms.

Table 4.48 Effect of organic manures and fertilizers on microbial population (cfu/g Soil) in soil after harvest of safflower in soybean–safflower crop sequence (2014-15)

Treatment	Bacteria ($x10^7$)	Fungi ($x10^4$)	Actinomycetes ($x10^6$)
Control	31.00	15.00	26.00
100% N	36.00	19.50	28.50
100% NP	34.00	21.00	31.00
50% NPK	32.0	19.00	31.00
100% NPK	34.0	20.00	32.00
150% NPK	37.0	22.00	40.00
100% NPK+HW	33.25	21.00	34.00
100% NPK+Zn	37.00	20.00	37.00
100% NPK - Sulphur	35.00	20.00	31.25
100% NPK + FYM	53.00	23.00	46.00
Only FYM @ 10 t/ha.	50.25	25.00	47.00
Fallow	32.50	17.00	27.00
LSD ($P \leq 0.05$)	2.67	1.57	3.02

Increase in activities of soil enzymes (acid and alkaline phosphate dehydrogenase) on application of fertilizer confirms the finding (Table 4.49). Increase in activities of soil enzymes are due to availability of more substrate through residual biomass as a result of better crop growth on application of fertilizer.

Table 4.49 Effect of organic manures and fertilizers on soil enzymatic activities in soil after harvest of safflower in soybean–safflower crop sequence (2014-15)

Treatment	Acid phosphatase (ug p-NP g^{-1} soil hr^{-1})	Soil DHA (ug TPF/g 24 hr.)	Alkaline phosphatase (ug p-NP g^{-1} soil hr^{-1})
Control	56.89	34.09	132.63
100% N	57.91	36.25	133.31
100% NP	64.69	40.15	142.15
50% NPK	62.27	38.48	139.01
100% NPK	64.97	40.02	140.77
150% NPK	72.39	46.74	151.13
100% NPK+HW	66.71	41.33	144.59
100% NPK – Sulphur	63.90	40.01	139.70
100% NPK+Zn	68.27	43.11	145.94
100% NPK + FYM	76.75	51.65	161.78
Only FYM @ 10 t/ha	70.31	45.06	155.75
Fallow	57.54	36.05	133.54
LSD ($P \leq 0.05$)	2.43	2.48	2.84

4.5.10 Akola

Increase in CO_2 evolution with increasing dose of fertilizer indicate more activities of soil organisms. Increase in activity of DHA and urease on application of nutrients conformed the higher activity of soil organisms (Table 4.50).

Table 4.50 Soil biological properties after harvest of wheat (2015-16)

Treatments	Evolution of CO_2 (mg 100 g^{-1})	DHA (µg TPF g^{-1} 24 hr^{-1})	Soil urease activity (ug g^{-1} 24 hr^{-1})
Control	20.08	36.34	38.88
100% N	24.75	41.02	50.50
100% NP	28.05	44.89	51.77
50% NPK	27.23	43.67	47.59
100% NPK	31.63	45.89	55.40
150% NPK	38.23	51.02	61.02
100% NPK (S free)	29.98	46.65	52.13
100% NPK + Zn @ 2.5 kg ha^{-1}	32.73	47.05	57.75
100% NPK + FYM @ 5 t ha^{-1}	41.80	57.92	65.19
100% NPK + 37.5 kg S ha^{-1}	35.48	50.11	58.12
75% NPK + 25% N through FYM	39.05	52.47	60.66
FYM @ 10 t ha^{-1}	40.15	52.71	62.84
LSD ($P \leq 0.05$)	4.18	6.09	8.47

4.5.11 Bhubaneswar

Perusal of data (Table 4.51 and 4.52) on microbial population and enzyme activity indicated that application of fertilizer nutrients either alone or in combination and also with organic manure increased the population of organisms in soil also their activities. A similar effect of fertilizer was also recorded on microbial carbon and nitrogen. Many times, number of microorganisms may be more but effective count is less. Increase in respiration (CO_2evolution) confirms the findings (Table 4.52).

Table 4.51 Effect of long term treatments on microbial population (cfu g^{-1}) (2013-14)

Treatment	Bacteria (x 10^7)	Fungi (x 10^5)	Actinomycetes (x 10^5)
Control	3.18	4.03	0.48
100% N	3.95	6.20	1.48
50% NPK	5.13	7.08	1.75
100% NPK	6.13	7.53	1.50
100% NPK +Lime	8.13	5.08	0.53
100% NPK +FYM	9.03	9.05	3.10
100% NPK + FYM + Lime	11.08	6.10	2.82
LSD ($P \leq 0.05$)	2.74	3.88	1.02

Table 4.52 Effect of nine years of long term manuring on microbial properties of surface soil (0-15 cm) (2014-15)

Treatments	MBC (mg kg^{-1})	MBN (mg kg^{-1})	Microbial quotient x 100	Soil Respiration (mg CO_2 g^{-1} soil per day)	Respiration quotient
Control	151	26.76	4.52	0.049	0.329
100% NPK	251	61.07	5.39	0.06	0.238
150% NPK	338	76.97	6.5	0.063	0.189
100% NPK + Zn	313	71.69	6.31	0.062	0.197
100% NPK + FYM	420	143.07	6.72	0.072	0.171
100% NPK + B + Zn	292	73.08	5.88	0.059	0.203
100% NPK + S + Zn	321	83.56	6.26	0.063	0.198
LSD ($P \leq 0.05$)	50.76	14.66	1.46	0.007	0.027

4.5.12 Raipur

Increase in soil respiration (CO_2 evolution) and microbial biomass N, on application of fertilizer indirectly indicate increase in activity of organism (Table 4.53). Increase in activity of DHA and urease supports the better activities of soil organisms on application of fertilizer. Though incorporation of FYM as well with green manuring always favoured the growth of soil organisms.

Table 4.53 Effect of inorganic fertilization and integrated nutrient management practices on enzyme activity and microbial biomass

Treatments	CO_2 evolution (mg 100 g^{-1} soil)	SMBC (µg g^{-1} soil)	SMBN (mg 100 g^{-1} soil)	Potential mineralizable N (µg)	Urease activity (µg NH_4-N g^{-1} 24 hr^{-1})	Dehydrogenase activity (µg TPF g^{-1} 24 hr^{-1})	Metabolic Quotient
Control	37.13	158.05	62.91	175.00	18.35	21.69	0.24
100% N	37.73	187.30	74.56	182.00	18.04	30.14	0.20
100% NP	39.83	208.85	75.16	196.00	22.56	29.79	0.19
50% NPK	42.00	218.60	73.75	217.00	27.19	32.29	0.19
100% NPK	43.13	223.34	82.48	238.00	31.77	37.28	0.19
150% NPK	45.75	250.59	92.50	252.00	34.82	44.67	0.18
50% NPK + BGA	40.20	225.10	77.09	196.00	28.52	31.04	0.18
50% NPK + GM	45.08	247.58	82.91	245.00	30.42	43.32	0.18
100% NPK + Zn	42.38	232.14	75.27	245.00	26.75	36.87	0.18
100% NPK+ FYM	46.65	253.22	96.85	273.00	36.41	46.62	0.18
LSD ($P \leq 0.05$)	4.75	17.06	8.70	62.73	4.58	5.16	0.03

4.6 Special Studies

4.6.1 Identification of best nutrient management practices for SOC in Vertisols

(a) Long-term manure management

The effects of fertilizer and manure management practices on soil organic C status of Vertisols of Jabalpur was studied. After 43 cropping cycles under soybean-wheat cropping system it was observe that soil organic C has increased significantly in balanced fertilization (100% NPK) and integrated nutrient management system (NPK + 10 t FYM ha^{-1}) over the control treatment where no nutrient was added to the crop. There was also significant increase in SOC in 150% NPK applied plot (Fig. 4.1). Walkley and Black soil organic carbon was the highest in application of 100% NPK + FYM (T_8), followed by application of 150% NPK (T_3) and T_4 (application of 100% NPK + hand weeding), respectively, and lowest found in case of control.

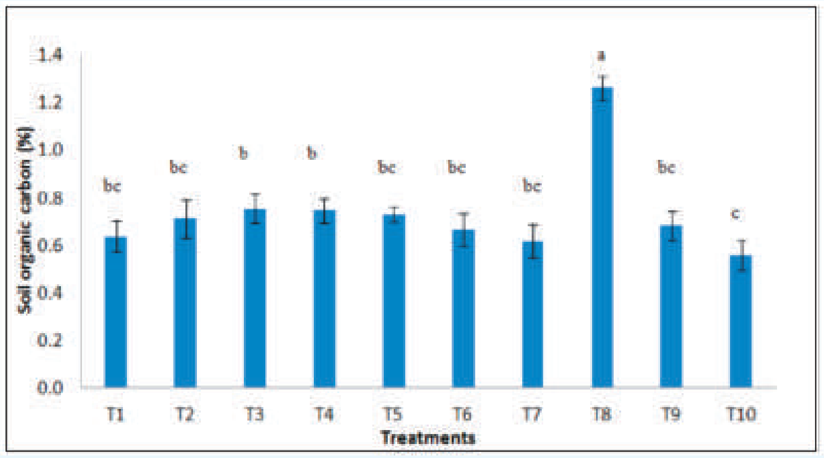


Figure 4.1 Effect of long term fertilization and manure on soil organic carbon (SOC)

Overall soil organic carbon was found the highest in macroaggregates followed by micro aggregates and lowest in case of silt + clay which revealed that macro-aggregates (>0.25 mm) contain higher concentrations of SOC than micro-aggregates (< 0.25–0.05 mm) because micro-aggregates are bound together by organic matter to form macro-aggregates (Fig. 4.2.).

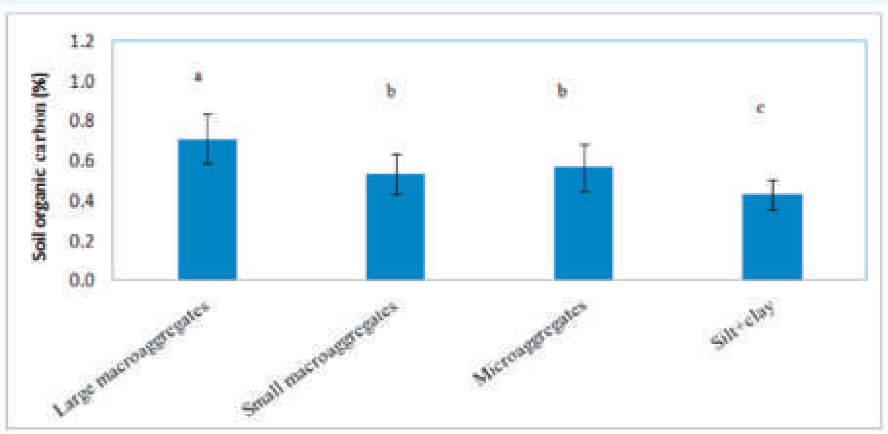


Figure 4.2 Effect of long term fertilization and manure on different size fraction associated carbon

The study revealed that application of FYM with chemical fertilizer (NPK+FYM) enhanced soil organic carbon in Vertisols. The best management practices to improve SOC in Vertisols are the balanced fertilization and integrated nutrient management with FYM.

(b) Effect of climate change on SOC and crop productivity changes under balanced fertilization in central Indian Vertisols

The climate change effects on soil organic carbon in 106 grids (0.5 degree x 0.5 degree) of central Indian Vertisols under balanced fertilization was studied in soybean-wheat cropping systems. Four climate change scenarios (Representative concentration pathways i.e. RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) and two time slices (2050 and 2080) were considered for the study (Table 4.54). The simulation study was carried out using well calibrated and validated APSIM model for grain yield and soil organic C (Fig. 4.3). The study revealed that under balanced fertlization in soybean and wheat, the change in soil organic C in the soil depth of 0-15 cm and 15-30 cm was non-significant in all the RCPs and time slices under study. This results agreed well with the change in grain yield of soybean and wheat crops. In the year 2050, the soybean yield will increase by 12, 17, 15 and 22% in RCPs 2.6, 4.5, 6.0 and 8.5, respectively (Fig. 4.4). Similar trend in results of soybean grain yield was also observed in the year 2080 in all RCPs under investigation. The yield of soybean was increased by 14, 19, 25 and 37% over base in RCPs 2.6, 4.5, 6.0 and 8.5, respectively. This result showed that soybean yield will increase more in year 2080 than the year 2050. The increased temperature effects in all RCPs and time slices are masked by increase CO_2 concentration, the positive effects of which are reflected in increase soybean yield and miner change in wheat yield. However, the wheat yield increased 2 to 4% over base in the year 2050 whereas it would be 1 to 6% increase in the year 2080. However, the model will be tested for organic, integrated and farmers' practices to estimate the climate change impacts on soil organic C and grain yield.

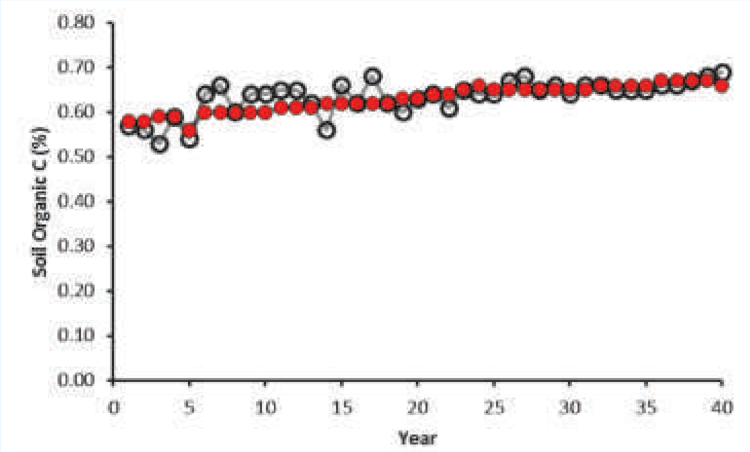
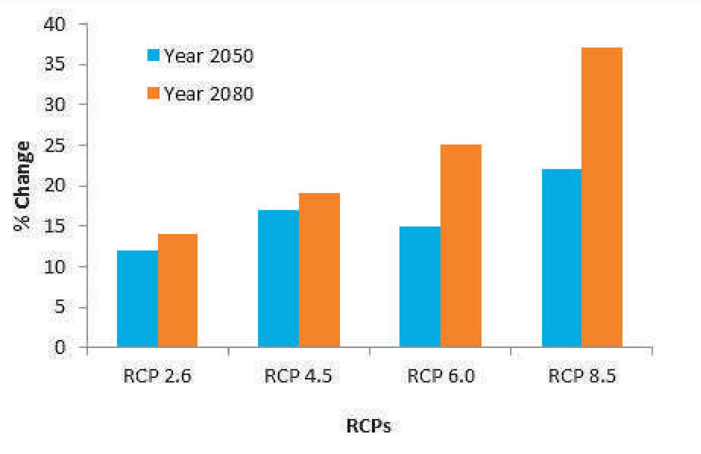


Figure 4.3 Validation of APSIM model for SOC concentration at 0-15 cm soil layer in balanced fertilization treatment from the long-term fertilizer experiments in Vertisols from Jabalpur. Empty circle represents observed data and filled circles represent predicted values from the model.

Table 4.54 Features of representative concentration pathways (RCPs) used in the study

RCPs	Base	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Time slice			2050		
CO_2 concentration (ppm)	354	441	495	494	572
Change in temperature (ºC)		1.4	1.9	1.7	2.6
Change in precipitation (%)		8.2	5.8	3.7	8.8
Time slice			2080		
CO_2 concentration (ppm)	354	429	532	612	799
Change in temperature (ºC)		1.5	2.5	2.7	4.4
Change in precipitation (%)		4.7	9.1	12.3	16.0



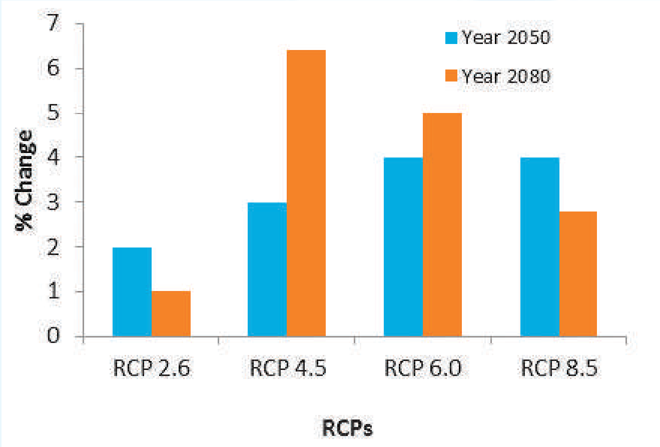


Figure 4.4 Change in yield (%) under the RCPs scenarios of the soybean and wheat in central Indian Vertisols (a: soybean and b: wheat).

5. NUTRIENT UPTAKE

INPUT OUTPUT BALANCE OF NUTRIENT gives an idea about extent of mining of nutrients from soil or difference between nutrient removed by crop and added through fertilizer. It indirectly indicates the change in soil fertility over a time period. In this section details of nutrients mined or added to soil are given.

5.1 New Delhi (Maize-wheat)

Perusal of data (Table 5.1) revealed that uptake of nutrients (N, P, K and S) is proportional to yield. As the yield increases uptake of nutrient also increases which is quite obvious. Uptake of N in both maize and wheat is more or less similar to the amount of N applied. Uptake of P is far less than the amount P applied through fertilizer. On the contrary to N and P, removal of K by crops is far larger than supplied through fertilizer in all the treatments except NPK+FYM. In this particular treatment good amount of K is supplied through FYM which helped in balancing of K. The uptake of S is more or less equal to amount of S applied through fertilizer. Amongst the micronutrients, Zn is the most important because of its wide spread deficiency. Data (Table 5.2) revealed that increase in uptake of Zn was recorded on integration of the nutrients. There is increase in uptake with application $ZnSO_4$ and FYM and simultaneously increase the total assimilation of Zn by crops. It implies that some fortification took place as there was no increase in yield on application of Zn (Table 5.2).

Table 5.1 Nutrient uptake (kg ha^{-1}) by crops at IARI New Delhi (2014-15)

Treatment	N		P		K		S	
	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat
Control	68.8	82.6	9.6	13.8	38.4	99.5	4.1	9.2
100% N	110.5	109.5	14.8	18.3	56.1	103.5	9.8	17.1
100% NP	133.0	113.5	16.0	22.5	58.1	111.5	11.3	19.4
50% NPK	91.5	97.9	13.7	17.4	49.6	112.5	8.5	14.8
100% NPK	132.0	122.0	16.0	22.1	63.2	125.0	14.1	21.3
150% NPK	169.5	145.0	21.2	26.1	89.4	141.5	20.3	23.4
100% NPK+HW	127.5	127.5	16.3	23.4	64.6	119.5	12.4	20.3
100% NPK+S	139.0	123.0	17.2	20.1	66.0	121.0	23.3	23.9
100% NPK+Zn	143.0	135.0	17.6	24.1	64.4	126.0	13.2	21.5
100% NPK+FYM	162.0	139.5	21.3	24.6	82.9	130.5	19.4	21.5
LSD ($P \leq 0.05$)	18.2	18.0	3.8	4.5	15.3	21.3	1.7	2.8

Table 5.2 Total Zn uptake (g ha^{-1}) by crops at IARI New Delhi (2014-15)

Treatment	Maize	Wheat
Control	162.5	116.5
100% N	321.5	227.5
100% NP	364.5	264.0
50% NPK	275.0	206.5
100% NPK	432.0	278.0
150% NPK	586.0	306.5
100% NPK+HW	478.5	263.0
100% NPK+S	456.5	280.0
100% NPK+Zn	654.0	326.5
100% NPK+FYM	607.5	313.5
LSD ($P \leq 0.05$)	68.1	22.9

5.2 Ranchi (Soybean-wheat)

Data on nutrient uptake (Table 5.3) revealed that uptake of N by soybean is far larger than applied which is due to biological N fixation by soybean. In general, increase in uptake of N results in increase in uptake of other nutrients also. This is due to increase in productivity of crop, which mined more nutrients from soil to fulfill its requirement. The uptake of P is far less than applied whereas reverse is true with K uptake. Due to this trend of uptake accumulation of P in soil and decline in soil K status was noted. In case of Alfisols, K is most crucial element as soils are already hungry for K and removal of K more than applied may aggravate the situation further.

Table 5.3 Nutrient uptake (kg ha^{-1}) at BAU, Ranchi (2014-15)

Treatments	N		P		K	
	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat
Control	45.9	16.9	2.1	1.5	14.9	8.7
100% N	24.4	15.9	1.4	1.3	7.8	8.5
100% NP	72.9	76.9	4.5	7.0	20.0	29.8
50% NPK	106.7	60.3	5.7	5.3	34.9	28.6
100% NPK	137.0	86.9	7.8	8.6	44.4	43.2
150% NPK	141.0	100.8	8.2	9.8	45.9	54.7
100% NPK+HW	136.7	93.8	7.7	8.9	46.0	48.9
100% N (S) PK	58.5	57.8	3.6	4.9	19.6	29.2
100% NPK + Lime	165.9	110.8	9.9	11.0	55.1	55.5
100% NPK + FYM	180.5	115.7	11.0	12.8	65.1	63.0

5.3 Akola (Sorghum-wheat)

Integration of nutrient with each other resulted increase in nutrient uptake by crops. Data (Table 5.4) further indicated that P uptake is quite larger than expected but may vary from years . Application of P is larger than uptake which led to accumulation of P in soil. Whereas reverse is noted with K. This is the reason that K status of soil over the years declined and crop showed a good response to applied after few years.

Table 5.4 Nutrient uptake (kg ha^{-1}) at PDKV, Akola (2013-14)

Treatment	Sorghum			Wheat		
	N	P	K	N	P	K
Control	8.7	1.7	7.5	1.5	0.4	1.5
100% N	45.6	8.3	41.9	16.5	3.6	15.9
100% NP	74.9	18.0	71.4	32.3	7.6	30.2
50% NPK	69.8	16.9	72.4	38.4	8.9	37.6
100% NPK	98.4	24.8	107.5	59.8	13.8	54.1
150% NPK	130.4	36.9	150.5	79.1	20.2	76.9
100% NPK S free	86.7	21.1	100.3	53.7	13.0	50.4
100% NPK + Zn @ 2.5 kg ha^{-1}	107.4	29.1	122.2	67.3	16.9	63.6
100% NPK + FYM @ 5 t ha^{-1}	147.4	44.3	161.6	90.7	24.5	87.5
100% NPK + S @ 37.5 kg ha^{-1}	115.2	31.9	132.3	69.7	17.1	66.1
FYM only 10 t ha^{-1}	66.8	16.0	71.5	25.8	6.0	24.9
75% NPK + 25% N through FYM	95.6	24.9	106.4	55.8	14.1	53.4
LSD ($P \leq 0.05$)	5.7	1.4	5.7	3.3	1.0	3.4

5.4 Barrackpore (Rice-wheat- jute)

Increase in nutrients uptake with the integration of N with P (100% NP) and NP with K (100% NPK) and NPK with FYM (100% NPK+FYM) recorded, is due to increase in productivity (Table 5.5). At Barrackpore, uptake of nutrients (NPK) in all the three crops is relatively less compared to other places, is due to less yield. But total removal of nutrients from soil by all three crops jointly in this cropping system as a whole is larger. Due to this, system would be more vulnerable to sustainability due to nutrients stress.

Table 5.5 Nutrient uptake (kg ha^{-1}) at CRIJAF, Barrackpore (2015-16)

Treatment	Jute			Rice			Wheat		
	N	P	K	N	P	K	N	P	K
Control	50.3	19.3	57.1	34.8	6.9	44.9	18.9	3.3	26.0
100% N	65.5	18.2	68.2	66.2	9.5	60.3	56.3	6.5	77.1
100% NP	69.8	27.8	80.7	71.4	13.0	63.2	56.2	8.3	78.5
50% NPK	70.0	22.7	76.6	59.9	10.1	55.1	39.6	6.1	60.7
100% NPK	88.2	28.0	109.7	71.2	13.1	62.0	64.3	9.6	87.2
150% NPK	94.3	30.4	111.1	80.8	15.0	64.0	73.1	10.7	91.6
100% NPK - S	68.9	23.8	88.6	74.2	13.0	63.9	55.3	9.7	81.6
100% NPK+HW	81.7	28.2	92.2	78.3	13.6	67.9	57.1	8.3	85.3
100% NPK +Zn	89.7	27.0	94.0	71.9	12.3	56.4	57.7	10.1	82.1
100% NPK + FYM	96.9	31.1	120.0	83.9	15.6	69.5	74.4	11.4	98.1
LSD ($P \le 0.05$)	8.5	3.1	10.5	8.7	2.3	6.1	9.5	2.7	11.5

5.5 Pattambi (Rice-rice)

Data (Table 5.6) indicated that examination of balanced and integrated use of nutrients resulted increase of uptake of all the three nutrients. Increase in nutrient uptake is due to increase in productivity. Critical examination of uptake data further indicated that nutrient removal by rabi rice is larger than *kharif* rice which is again due to larger productivity of rabi rice compared to *Kharif* rice. Uptake of N and P is less than the amount of applied through fertilizer and due to this accumulation of only P is taking place in soil. While N content in soil is maintained probably due to high rainfall and losses of N from the system. It is interesting to note that at Pattambi in-spite of K uptake

Table 5.6 Nutrient uptake (kg ha^{-1}) in rice at KAU Pattambi (2014-15)

Treatment	N		P		K	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Control	32.20	33.22	5.58	5.73	38.27	43.94
100% N	28.27	33.58	5.84	6.97	35.68	48.89
100% NP	41.69	49.02	6.97	8.21	46.43	60.58
50% NPK	34.47	38.15	7.57	8.02	53.26	67.52
100% NPK	37.51	42.77	7.48	8.36	52.37	70.35
100% NPK	35.58	39.25	6.98	7.71	53.61	67.21
150% NPK	41.25	46.47	9.24	10.26	60.33	76.64
100% NPK+ lime	40.46	45.23	8.17	9.15	47.54	60.33
100% NPK+ FYM	53.91	59.21	11.58	12.45	68.78	86.57
50% NPK+ FYM	44.93	49.70	8.94	9.96	64.87	77.40
100% NPK+ GM	44.93	49.70	8.94	9.96	64.87	77.40
50% NPK+ GM	39.70	42.86	8.33	8.91	57.50	68.24

larger than applied there is no decline in soil K content. This is due to application of irrigation water which is stored during *Kharif* season contained soluble K on decomposition of forest litter .

5.6 Jagtial (Rice-rice)

Data on nutrient uptake (Table 5.7) indicated that N removed by crop is more or less similar to applied through fertilizer and P removed by rice-rice is less than the applied which resulting in accumulation of P in soil, whereas in case of K the situation is different. Potassium uptake by rice in both seasons is larger than applied and this situation could be alarming in future. Due to very high yield and decline in native K, crops have already started showing response to applied K. However, sulphur application did not have much effect on S uptake.

Table 5.7 Nutrient uptake (kg ha^{-1}) by rice at ANGRAU Jagtial (Mean for 2014-15 to 2015-16)

Treatment	N		P		K		S	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Control	54.4	56.2	13.3	12.0	51.6	47.0	5.2	5.5
100% N	82.2	53.8	18.7	15.2	70.1	52.3	6.3	6.2
100% NP	102.9	96.2	24.7	23.1	105.6	110.0	10.4	11.6
50% NPK	80.4	77.0	19.6	20.1	83.9	84.1	9.2	9.7
100% NPK	103.0	95.3	24.2	23.0	106.9	108.0	12.0	12.5
150% NPK	116.6	111.1	27.4	27.6	113.5	123.6	13.2	14.7
100% NPK + HW	108.0	99.5	24.7	23.7	111.0	110.1	11.2	12.2
100% NPK - S	102.7	93.1	24.2	21.3	104.7	108.0	10.8	11.9
100% NPK + Zn	108.0	98.6	24.4	23.3	108.0	109.1	10.8	12.0
100% NPK + FYM	107.4	107.5	26.0	25.5	104.1	119.0	12.2	13.8
FYM	86.2	71.8	19.7	16.2	78.6	73.6	8.4	8.0
LSD ($P \leq 0.05$)	12.4	12.6	2.8	2.8	9.6	12.0	1.6	1.1

5.7 Ludhiana (Maize-wheat)

5.7.1 Macronutrient

Like other places nutrient uptake increased with increase in productivity of crops (Table 5.8). The N uptake is more or less similar to applied nitrogen. Removal of P is far less than applied which resulted in accumulation of P in soils of Punjab. However, contrary to P, removal of K is far greater than K applied but decline in soil K status was not observed on research farm and at farmer's field. On the contrary, increase

Table 5.8 Nutrient uptake (kg ha^{-1}) at Ludhiana (Mean for 2015 to 2016)

Treatment	Maize			Wheat		
	N	P	K	N	P	K
Control	37.3	5.9	21.9	19.4	3.9	13.4
100% N	82.3	12.1	44.7	64.2	12.7	43.9
100% NP	99.0	16.3	55.9	84.6	15.8	57.6
50% NPK	71.8	11.9	43.1	64.6	12.8	48.0
100% NPK+W	113.2	19.6	68.0	90.3	17.7	66.5
150% NPK	124.4	23.0	75.4	97.7	21.7	71.8
100% NPK	114.5	21.2	67.3	90.1	19.0	64.6
100% NPK-S	118.3	19.7	64.7	89.9	18.4	67.5
100% NPK+Zn	114.4	20.0	68.1	92.7	17.1	67.4
100% NPK+FYM	140.3	27.0	91.9	111.0	23.2	80.7

in soil K status was noted which is due to addition of K through canal irrigation water which contains K and many times add silt to soil during early and late *Kharif* season because of turbid water.

5.7.2 Micronutrient

Perusal of micronutrients uptake data (Table 5.9) revealed that there was maximum uptake of Fe followed by Zn, Mn and Cu. Here also uptake increased with increase in yield due to balanced application of nutrients (NPK). Which means balanced application increased use efficiency of micronutrient.

Table 5.9 Nutrient uptake (g ha^{-1}) at Ludhiana (Mean for 2015 to 2016)

Treatments	Maize				Wheat			
	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn
Control	160.0	25.0	278.0	209.0	36.8	8.0	563.0	42.3
100% N	349.0	49.0	547.0	417.0	127.7	26.1	1674.0	159.4
100% NP	343.0	59.0	686.0	513.0	163.8	32.4	2240.0	211.7
50% NPK	293.0	40.0	575.0	359.0	122.9	24.4	1610.0	160.2
100% NPK+W	438.0	68.0	842.0	534.0	182.1	34.8	2479.0	234.6
150% NPK	455.0	68.0	899.0	609.0	210.9	37.7	2650.0	273.2
100% NPK	447.0	65.0	834.0	554.0	175.0	34.4	2383.0	228.9
100% NPK-S	431.0	64.0	848.0	563.0	177.8	34.0	2392.0	225.4
100% NPK+Zn	487.0	65.0	926.0	580.0	190.3	34.6	2475.0	230.5
100% NPK+FYM	548.0	81.0	1122.0	734.0	234.2	44.3	3013.0	341.5

5.8 Jabalpur (Soybean-wheat)

Uptake of N in soybean is far more than applied is obviously due to biological N fixation by soybean (Table 5.10). Removal of P is less than applied P which resulted in increase in P status in soil but removal of K by the cropping system is far larger than applied which declined K status in soil to the extent that crop started showing response to applied K at Jabalpur. So there is need to be vigilant to monitor K status in the soils.

Data on S and Zn uptake given in Table 5.11 indicated that S uptake is lower than applied and very poor in control and 100% N because of continuous absence of S in these treatments. At Jabalpur many a times S deficiency symptoms are seen in soybean but disappear after some time. At Jabalpur Zn is not a problem as soils are high in

Table 5.10 Nutrient uptake (kg ha^{-1}) by at JNKVV Jabalpur (2014-15)

Treatments	N		P		K	
	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat
Control	32.55	30.82	1.18	14.49	23.79	22.76
100% N	43.11	63.32	1.85	13.78	27.79	39.56
100% NP	76.55	117.30	5.32	21.59	47.21	72.32
50% NPK	72.17	108.28	4.85	13.03	54.69	82.66
100% NPK	105.14	158.53	7.84	21.11	82.77	121.84
150% NPK	129.46	189.56	9.41	33.00	97.94	161.99
100% NPK+HW	91.08	144.67	6.71	32.73	70.92	107.84
100% NPK-S	87.21	133.92	6.37	34.13	66.62	95.84
100% NPK+Zn	95.32	153.81	7.15	24.48	74.82	113.16
100% NPK+FYM	139.20	197.37	10.22	23.55	112.62	181.64
LSD ($P \le 0.05$)	17.59	22.03	1.01	4.29	13.52	19.00

Zn status and continue to maintain. Increase in Zn uptake with integration of nutrient is due to increase in yield of both the crops.

Table 5.11 Nutrient uptake (kg ha^{-1}) at JNKVV Jabalpur (2014-15)

Treatments	S		Zn	
	Soybean	Wheat	Soybean	Wheat
Control	0.99	2.49	22.05	42.75
100% N	1.46	5.21	30.83	81.53
100% NP	4.43	11.48	66.16	172.30
50% NPK	4.36	11.42	59.43	150.35
100% NPK	7.11	20.74	97.15	258.02
150% NPK	8.63	26.29	114.69	364.42
100% NPK+HW	5.79	17.93	86.29	228.00
100% NPK-S	3.39	8.98	73.39	183.05
100% NPK+Zn	6.16	18.91	115.86	352.65
100% NPK+FYM	10.60	28.81	137.16	401.86
LSD ($P \leq 0.05$)	0.93	3.01	14.13	43.47

5.9 Bhubanesawar (Rice-rice)

Nutrient uptake data presented in Table 5.12 revealed increase in nutrient uptake on application N, NP, NPK and increase in dose of NPK as well. Application of lime and FYM also increased the nutrient uptake, is due to increase in rice productivity. In general uptake of all the four nutrients is larger in rabi crop than Kharif rice, probably due to better yield during rabi season, because of more sunshine hours. Little increase in uptake these nutrients was noted on application of Zn. However, application either S or B did not have any effects on uptake of N, P, K and S.

Table 5.12 Nutrient uptake (kg ha^{-1}) at OUAT Bhubaneswar (Mean for 2013-14)

Treatments	Kharif Rice				Rabi Rice			
	N	P	K	S	N	P	K	S
Control	21.71	3.87	16.83	1.87	17.55	2.76	17.78	2.78
100% N	37.83	6.06	28.27	3.46	41.51	5.65	34.62	5.65
100% NP	44.28	8.77	31.79	4.49	47.52	10.36	45.50	8.30
50% NPK	36.95	8.29	34.78	3.38	38.55	7.72	38.17	5.65
100% NPK	46.75	10.33	40.74	4.22	48.09	11.15	50.47	7.07
150% NPK	63.47	13.87	54.65	6.11	57.04	13.72	66.07	9.25
100% NPK + Lime	53.93	12.27	44.65	6.53	54.99	13.14	59.94	11.20
100% NPK + Lime + FYM	69.46	14.85	61.10	8.49	72.98	15.64	74.89	13.41
100% NPK + Zn	52.60	10.75	45.02	5.83	51.12	11.87	56.53	9.53
100% NPK + S + Zn	50.98	10.75	41.32	7.57	50.10	11.63	54.87	12.35
100% NPK + B + Zn	40.81	9.44	37.77	5.15	51.02	10.92	54.43	8.88
100% NPK + FYM	70.55	15.19	59.36	8.97	73.33	14.84	73.22	13.22

5.10 Pantnagar (Rice-wheat)

Increase in nutrient uptake with increase in nutrient dose from 50 to 150 percent and integration of P resulted increase in nutrient uptake (Table 5.13). Application of K did not have any effect on nutrient uptake, is due to absence of response of crop to applied K. Application of Zn especially in rice increased the uptake of N, P, K. Which is due to increase in productivity.

Table 5.13 Nutrient uptake (kg ha^{-1}) at Pantnagar (Mean for 2012-15)

Treatments	Rice			Wheat		
	N	P	K	N	P	K
Control	61.0	17.1	67.3	54.8	11.7	41.6
100% NPK	75.1	19.0	77.7	69.7	15.4	56.8
150% NPK	80.2	22.7	84.9	75.9	17.9	64.4
50% NPK+Zn	82.2	23.8	90.2	79.0	17.8	61.1
100% N+Zn	91.0	26.9	96.2	85.8	20.6	66.8
100% NP+Zn	80.8	22.7	69.1	69.8	15.2	43.8
100% NPK -Zn	65.4	14.9	59.9	62.8	13.2	42.0
100% NPK+HW+Zn	111.8	37.9	110.9	106.5	25.1	87.5
100% NPK-S+Zn	76.7	24.2	82.3	71.3	13.7	53.6
Bio-fertilizer	23.1	6.2	31.8	21.4	3.7	16.8
100% NPK+FYM	21.8	5.3	29.6	19.3	3.7	16.2
LSD ($P \leq 0.05$)	9.4	3.4	9.7	4.7	2.5	16.0

5.11 Coimbatore (Finger millet-maize)

As usual increase in uptake of N, P and K was recorded with increase in nutrient dose from 50% to 150% and integration of nutrient (Table 5.14). Application of FYM further increased the uptake of nutrient. Increase in nutrient uptake is due to increase in productivity of the crop. Absence of S registered slight decline in nutrient uptake. Which is due to decline in overall productivity of crops.

Table 5.14 Nutrient uptake (kg ha^{-1}) at TNAU Coimbatore (2014-15)

Treatment	Maize			Finger millet		
	N	P	K	N	P	K
control	70.8	9.7	91.0	34.2	3.3	36.3
100% N	97.0	12.3	112.4	49.3	5.0	53.3
100% NP	107.9	14.3	127.5	67.9	6.6	81.6
50% NPK	92.6	13.0	124.9	59.4	5.9	65.1
100% NPK	113.2	14.7	141.1	71.8	7.2	83.9
150% NPK	126.3	15.4	149.0	84.7	8.5	95.5
100% NPK + HW	108.7	14.5	137.8	68.7	6.6	82.5
100% NPK + Zn	115.0	15.0	140.2	76.7	7.6	90.7
100% NPK + FYM	133.5	17.0	160.8	99.6	10.5	109.4
100% NPK (-S)	107.5	14.0	139.0	68.9	6.8	78.6
LSD ($P \leq 0.05$)	3.4	0.6	5.3	2.7	0.3	3.5

5.12 Junagadh (Groundnut-wheat)

Integration of nutrient and increase in dose of nutrient from 50 to 150% resulted increase in uptake of nutrients (Table 5.15). Incorporation of *rhizobium* and PSM did not contribute to nutrient uptake. Nutrient supply through soil test and general recommended dose also did not have effect as far as nutrient uptake is concerned. Similar trend to NPK was also noted on uptake of micronutrients. In both the crops uptake of Fe was far more than other micronutrients cations (Table 5.16).

Table 5.15 Nutrient uptake (kg ha^{-1}) by groundnut and wheat at JAU Junagadh (2014-15)

Treatment	N		P		K		S	
	Ground nut	Wheat	Ground nut	Wheat	Ground nut	Wheat	Ground nut	Wheat
Control	34.0	38.3	4.2	5.6	10.0	24.1	3.0	6.1
100% N	32.5	40.0	4.0	5.0	9.2	20.5	3.1	6.6
100% NP	42.3	61.7	5.7	9.1	11.2	32.3	3.9	9.7
50% NPK	43.1	53.1	5.5	7.4	12.9	33.0	4.0	8.1
50% NPK*	65.5	104.5	8.5	14.9	23.6	67.4	5.8	15.0
50% NPK$	47.3	67.7	6.0	9.3	14.2	44.5	4.4	10.6
100% NPK	52.2	76.6	6.8	10.5	16.0	48.3	4.5	11.0
NPK as per soil test	51.2	74.8	6.4	9.9	14.6	47.7	4.6	11.0
150% NPK	65.2	91.1	8.0	11.5	17.9	56.8	5.3	12.6
100% NPK+ $ZnSO_4$	53.6	75.6	7.2	9.9	16.7	49.4	5.1	11.3
100% NPK (P as SSP)	51.6	75.5	6.8	10.7	15.2	48.6	5.1	13.1
FYM 25 t ha^{-1} to g'nut only	58.7	91.1	7.6	15.6	22.0	64.9	5.0	12.4
LSD ($P \leq 0.05$)	7.1	13.2	0.9	1.7	2.0	7.7	0.7	1.5

*Indicates = 50% NPK+10 t ha^{-1} FYM to groundnut and 100% NPK to wheat
$Indicates = 50% NPK$ +Rhizobium +Phosphate solubilizing microorganism (PSM)

Table 5.16 Micronutrient uptake (g ha^{-1}) by groundnut and wheat at JAU Junagadh (2014-15)

Treatment	Zn		Fe		Cu		Mn	
	Groundnut	Wheat	Groundnut	Wheat	Groundnut	Wheat	Groundnut	Wheat
Control	156	231	1107	890	103	255	164	357
100% N	149	249	1082	831	101	210	156	359
100% NP	196	344	1422	1192	136	396	221	620
50% NPK	190	296	1409	1110	136	329	223	481
50% NPK*	353	692	2264	2025	280	845	540	1094
50% NPK$	234	436	1612	1370	162	483	303	672
100% NPK	232	435	1671	1417	180	519	343	737
NPK as per soil test	257	439	1537	1275	197	559	416	769
150% NPK	287	539	1867	1437	253	655	490	841
100% NPK+ $ZnSO_4$	329	602	1807	1362	215	563	412	752
100% NPK (P as SSP)	249	434	1619	1315	203	611	427	793
FYM 25 t ha^{-1} to g'nut only	338	686	2048	1983	274	786	531	944
LSD ($P \leq 0.05$)	33	73	263	205	38	79	59	116

*Indicates = 50% NPK+10 t ha^{-1} FYM to groundnut and 100% NPK to wheat
$Indicates = 50% NPK$ +Rhizobium +Phosphate solubilizing microorganism (PSM)

6. NUTRIENT DYNAMICS

NUTRIENT TRANSFORMATION is a continuous process that occurs in soil which are mediated through chemical and biochemical processes. Conversion of one form of nutrient into another is termed as nutrient dynamics. Studies conducted on nutrient dynamics are given here under.

6.1 Coimbatore

6.1.1 Nitrogen

Nitrogen is most dynamic in nature and exists in several forms in soil which are in equilibrium. Data (Table 6.1) revealed that application of fertilizers maintain larger concentration of NH_4-N and NO_3-N and total hydrolysable N than control. Application of FYM further increased the level of these fractions in soil. This indicated that application of fertilizer maintained supply of N to plant and part of applied nitrogen goes to revive different forms of N. Further fractionation of hydrolyzable N indicated that application of fertilizer N either alone or with other nutrients and organic manure maintained relatively larger amount of hydrolyzable NH_4-N and amino acid which are active fractions of N. This means if supply of N is maintained then these two forms of N will continue to supply N to plant. Low content of these two fractions in control plot support the statements.

Table 6.1 Effect of long term fertilization on nitrogen fractions (mg kg^{-1}) in soil after harvest of maize (2014)

Treatments	Inorganic N fractions			Organic N fractions					
	Exch. NH_4-N	NO_3-N	Fixed NH_4-N	Total Hydroly sable N	Hydrolys able NH_4-N	Hexo samine N	Amino acid N	Unidentified Hydroly sable N	Unidentified non hydrolysable N
Control	3.2	8.2	18.6	213.3	95.3	21.4	71.2	33.7	74.6
100% N	6.5	11.4	26.1	264.6	112.9	25.1	84.9	67.7	128.5
100% NP	6.2	11.7	26.6	269.9	117.4	25.9	87.1	69.5	178.1
50% NPK	5.1	9.6	22.9	251.5	106.3	23.9	79.0	54.0	101.1
100% NPK	6.3	11.2	26.3	269.0	125.5	27.5	94.3	68.7	181.2
150% NPK	7.1	13.1	29.4	291.4	131.7	28.7	99.5	81.5	212.3
100% NPK (-S)	6.6	11.4	26.4	263.2	121.1	26.8	91.7	68.7	171.8
100% NPK + HW	6.6	11.5	26.7	265.7	122.3	27.2	93.8	67.4	183.4
100% NPK + Zn	6.4	11.6	26.1	263.6	123.4	26.9	91.2	70.3	184.7
100% NPK + FYM	8.2	13.9	29.9	311.1	136.2	29.3	102.7	83.1	217.9
LSD ($P \leq 0.05$)	0.27	0.58	1.02	11.08	5.04	1.08	4.12	4.53	8.06

6.1.2 Phosphorus

Phosphorus also occurs in several forms in soil and changes from one form to another forms depending on soil and external supply of P. Data (Table 6.2) revealed that continuous absence of P in fertilizer schedule resulted maximum decline of Ca-P followed by Al-P and Fe-P. However, on application of fertilizer P resulted in maximum increase of Ca-P and organic-P. Even though increase in Al-P and Fe-P was also noted but with a very low magnitude. This means Ca-P is most dominant fractions in these soils which released P in the absence P supply and preferentially fixed /absorb P in this form on P application.

Table 6.2 Effect of long term fertilization on P fractions (mg kg^{-1}) in soil after harvest of maize (2014)

Treatments	Inorganic P fractions					Organic P
	Saloid P	**Fe - P**	**Al - P**	**Ca - P**	**Reductant soluble P**	
Control	6.7	14.6	13.8	51.3	13.84	257.2
100% N	8.8	20.2	14.2	55.3	15.53	291.4
100% NP	11.5	24.7	18.6	106.4	19.54	353.5
50% NPK	9.7	22.1	17.4	76.8	17.55	304.2
100% NPK	11.9	24.6	19.7	106.3	19.85	359.1
150% NPK	17.8	30.8	20.3	134.7	23.02	411.4
100% NPK (-S)	11.6	24.1	19.4	98.2	19.61	357.3
100% NPK + HW	12.1	24.1	20.8	107.6	19.81	365.5
100% NPK + Zn	12.2	24.0	20.1	103.0	19.72	374.8
100% NPK + FYM	17.7	31.3	21.7	140.6	23.64	419.9
LSD ($P \leq 0.05$)	0.67	1.97	0.72	6.01	0.82	18.9

6.1.3 Potassium

Like N, P and K is also exists in soil in several forms and maintain equilibrium amongst the fractions. The continuous application of K resulted increase in water soluble and exchangeable K in soil (Table 6.3) and did not make any change in non-exchangeable K so far. Critical examination of data further revealed decline in non-exchangeable and lattice in absence of K in fertilizer schedule. This means in absence of K supply, plant gets the K from non-exchangeable and lattice K through water soluble and exchangeable K. Therefore, due consideration has to be given to non-exchangeable K in order to predict soil health. Similarly, continuous monitoring is required to maintain supply of K vis-à-vis productivity ultimately.

Table 6.3 Effect of long term fertilization on K fractions (mg kg^{-1}) in post-harvest soil of maize (2014)

Treatments	**Water Soluble K**	**Exchangeable K**	**Non-Exchangeable K**	**Lattice K**
Control	20.9	76.3	181.6	2181
100% N	21.5	79.5	188.8	2304
100% NP	21.9	81.8	193.7	2257
50% NPK	22.7	86.9	220.4	2405
100% NPK	25.2	91.5	234.9	2473
150% NPK	26.1	100.6	252.5	2718
100% NPK (-S)	24.1	94.9	226.2	2629
100% NPK + HW	24.8	92.8	229.5	2539
100% NPK + Zn	23.5	92.2	227.1	2591
100% NPK + FYM	26.7	103.4	251.1	2758
LSD ($P \leq 0.05$)	0.75	4.45	9.34	99.30

6.2 Ludhiana

6.2.1 Nitrogen

Data on N fraction (Table 6.4) revealed that application of N along with other nutrient resulted increase in total hydrolysable N in soil. Among the hydrolysable fraction of N, majority of N remain in hydrolysable NH_4-N form. Though increase in amino acid and amino sugar was also noted but the magnitude was less. It is interesting to note that on application of FYM over NPK and application of super optimum dose of nutrient 150% NPK resulted in accumulation of N in resistant pool of N (Non-hydrolysable N).

Table 6.4 Long-term effect of fertilizers and farmyard manure on the distribution of different organic fractions (mg kg^{-1}) of nitrogen

Treatment	Hydrolysable total N	Ammonical N	Amino acid N	Amino sugar N	Unknown hydrolysable N	Non-hydrolysable N
Control	308	88.6	88.7	33.0	97.4	90.0
100% N	386	103.5	110.7	36.0	135.8	113.1
100% NP	408	116.7	114.8	39.0	137.8	114.3
100% NPK	477	133.3	143.7	53.3	146.6	118.0
150% NPK	498	137.7	153.3	58.3	148.3	144.0
100% NPK+FYM	539	147.0	163.3	61.8	167.2	174.9
LSD ($P \leq 0.05$)	8.7	12.1	6.6	6.3	3.7	2.9

Multiple regression analysis of grain yield with different fractions of N revealed that ammonia N contributed 89.5 percent yield of maize and 83.8 percent yield of wheat (Table 6.5). Inclusion of amino acid and other fraction of N resulted increase in contribution by 1% in case of maize yield however, inclusion of other fractions (Amino acid, amino sugar, UHN) did not improve the relationship with wheat yield. This means ammonical N is most important as far as yields are concerned and attempt should be made to enhance this fraction of N through agronomical and cultural practices.

Table 6.5 Relationship of organic fractions of N with wheat yield and N uptake

Parameter	Constant	Non-hydrolysable N	Ammonia-N	Amino-acid-N	Amino sugar-N	Unknown hydrolysable N	R^2
Yield of maize	-30.35	0.529					0.895^{**}
	-27.79	0.357	0.171				0.907^{**}
	-26.24	0.333	0.125	0.156			0.910^{**}
	-29.74	0.304	0.048	0.215	0.101		0.915^{**}
	-29.76	0.320	0.26	0.056	0.089	0.029	0.916^{**}
Yield of wheat	-33.46	0.525					0.838^{**}
	-33.45	0.507	0.021				0.838^{**}
	-43.25	0.648	0.320	-0.356			0.883^{**}
	-46.13	0.581	0.421	-0.152	-0.563		0.914^{**}
	-46.02	0.333	-0.033	-0.432	-0.644	-0.159	0.936^{**}

**Significant at 1% level of significance

6.2.2 Methane emission under rice-wheat cropping system

The average daily fluxes and total CH_4 emissions during rice growth were significantly affected by fertilizer applications (Table 6.6). The noticeable increase in CH_4 fluxes commenced from 37 days after transplanting (i.e.

vegetative stage) and maximum at 53 days after transplanting. However, decline in fluxes was noted at 69 days after transplanting (i.e. reproductive stage) and continued at 105 DAT, irrespective of fertilizer treatments. High emission of CH_4 coincided with the active growth stage like tillering, vegetative and reproductive stages of rice.

Table 6.6 Rate of methane fluxes (kg CH_4 ha^{-1} day^{-1}) from rice fields amended with inorganic and integrated fertilization under long-term

Treatment	Days after transplanting (DAT)						
	2	19	37	53	69	90	105
Control	0.05[a]	0.03[a]	0.06[a]	0.52[a]	0.13[a]	0.05[a]	0.04[a]
100% NPK	0.12[b]	0.16[b]	0.21[b]	1.17[b]	1.09[b]	0.11[b]	0.14[b]
100% NPK+GM	0.14b[c]	0.08[a]	0.43[c]	1.51[c]	1.33[b]	0.17[c]	0.19[bc]
100% NPK+SI	0.17[c]	0.23[b]	0.95[e]	2.59[d]	1.78[c]	0.24[d]	0.31[d]
100% NPK+FYM	0.13[b]	0.16[b]	0.66[d]	2.30[d]	1.36[b]	0.19[c]	0.23[c]

GM= green manure; SI= straw incorporation; FYM= farmyard manure
Values within a column, followed by different letters are significantly different at $p \leq 0.05$ by DMRT.

From 53 to 69 DAT, CH_4 fluxes remained at a higher level may be due to the higher root exudation (Table 6.6). Increased organic matter input through root exudates, decaying roots and differentiation of plant anatomy including development of aerenchyma were suggested to be responsible for favouring low redox potential hence increase the CH_4 flux. A highly significant correlation with labile carbon was observed at this stage (r = 0.940**). Although, decline was observed from 90 DAT to 105 DAT, CH_4 fluxes ranged from 0.04 kg ha^{-1} day^{-1} to 0.31 kg ha^{-1} day^{-1}. The rate of CH_4 emissions declined after reproductive stage in all treatments and reduced to a negligible level at harvest.

6.2.3 Methane emission, Global warming potential (GWP) and Yield-Scaled GWP

The data pertaining to total CH_4 emissions during studied period are presented in Table 6.7. Long-term fertilization had significantly higher cumulative seasonal CH_4 emissions as compared to the control. The application of 100%NPK alone resulted in 49.6 kg ha^{-1} (254%) more emission of CH_4 over the control. Among the integrated treatments, the highest CH_4 emission was recorded in 100% NPK+SI (103.1 kg ha^{-1}) followed by 100% NPK+FYM (82.7 kg ha^{-1}) and lowest in 100% NPK+GM (63.5 kg ha^{-1}). The per cent increase of CH_4 emissions under 100% NPK+SI, 100% NPK+FYM and 100% NPK+GM 108%, 67% and 28%, respectively, over the application of mineral fertilizer (100% NPK).

Table 6.7 Effect of long-term application of inorganic fertilizers and organic amendments on seasonal amount of methane emitted, global warming potential (GWP), yield-scaled global warming potential (YS-GWP) from rice fields

Treatment	Average flux (kg ha^{-1} day^{-1})	Cumulative Methane emission (kg ha^{-1})	GWP (Mg ha^{-1} CO_2 equivalent)	YS-GWP (Mg CO_2 eq. Mg^{-1})
Control	0.13±0.01[a]	14±0.8[a]	0.47±0.02[a]	0.12±0.01[a]
100% NPK	0.43±0.07[b]	49.6±8.29[b]	1.65±0.28[b]	0.28±0.04[b]
100% NPK+GM	0.55±0.04[c]	63.5±5.01[c]	2.12±0.17[c]	0.30±0.02[b]
100% NPK+SI	0.89±0.02[e]	103.1±3.46[e]	3.43±0.11[e]	0.55±0.01[d]
100% NPK+FYM	0.72±0.02[d]	82.7±2.59[d]	2.75±0.08[d]	0.40±0.01[c]

Values within a column, followed by different letters are significantly different at $P \leq 0.05$ by DMRT

The global warming potential (GWP) of CH_4 emission varied between 0.47 Mg ha^{-1} CO_2 equivalent in control to 3.43 Mg ha^{-1} CO_2 equivalent in 100% NPK+SI treatment. Application of mineral fertilizer (100% NPK) recorded significantly higher GWP (251%) as compared to the control. Among the conjunctive use of organic manures and inorganic fertilizers, the maximum GWP were recorded with application of 100%NPK+SI (3.43 Mg ha^{-1} CO_2 eq.) followed by 100% NPK+FYM (2.75 Mg ha^{-1} CO_2 eq.) and minimum with 100%NPK+GM (2.12 Mg ha^{-1} CO_2 eq.).

6.3 Bangalore

6.3.1 Phosphorus

In Alfisols availability of P has always been a problem as P is fixed by Al and Fe in acidic pH range. Data (Table 6.8) generated on P dynamic revealed that majority of applied P led to formation of complexes with Al, Fe and Ca as well. In absence of P supply decline in Al-P, and Fe- P indicate that plant absorb P from these forms. However, decline is not very perceptive, may be because of poor yield of crop in the absence of supply of P and K. Application of FYM encouraged the available P fraction. Decline in Al^{+3} and Fe^{-3} on application FYM indicated that the availability of Al and Fe is reduced to sorb P because of chelation of Al and Fe by organic complexes and moderation of soil pH on application of FYM support the hypothesis.

Table 6.8 Effect of long term manure and fertilizers application on fractions (mg kg^{-1}) of phosphorus in soil under finger millet–maize cropping system (2013)

Treatment	P Fractions					
	Available P_2O_5	Al-P	Fe-P	Occl-P	Ca-P	Total-P
Control	6.5	24.0	33.9	27.6	23.5	152.4
100% N	5.3	22.1	30.3	27.0	19.8	133.3
100% NP	53.4	92.8	102.6	66.5	61.2	498.7
50% NPK	21.7	65.2	76.5	35.92	30.9	347.4
100% NPK	48.4	96.9	115. 7	63.4	53.1	498.7
150% NPK	74.2	118.5	167.5	85.7	76.0	568.8
100% NPK + HW	46.0	91.6	119.7	65.0	58.1	504.3
100% NPK + Lime	49.1	91.4	105.8	66.2	81.2	501.5
100% NPK + FYM	94.1	76.8	84.6	65.5	63.7	551.5
100% NPK (S-free)	46.0	94.3	115.1	69.9	55.5	488.0
100% NPK+ FYM + lime	96.5	64.8	81.9	53.6	87.6	563.70
LSD ($P \leq 0.05$)	2.46	3.6	4.49	2.67	2.64	21.71

Al-P= Aluminum bound phosphorus; Fe-P= Iron bound phosphorus; Occl-P=Occlude phosphorus and
Ca-P= Calcium bound phosphorus

6.3.2 Sulphur

Sulphur exists in mineral form and availability of S is more dependent on organic sulphur. Data presented in Table 6.9 revealed that application of S resulted increase in available S and organic fraction which are reflected in total sulphur. Also decline S in organic fraction in absence of S application indicated that plant gets organic S after mineralization.

Table 6.9 Effect of long term manure and fertilizers application on fractions of S in soil under finger millet–maize cropping system (mg kg^{-1}) (2013)

Treatments	Available / Sulphate-S	Water soluble -S	Organic -S	Total -S
Control	10.41	16.37	35.69	128.77
100% N	13.16	07.29	32.58	110.47
100% NP	22.14	28.72	65.51	353.50
50% NPK	17.85	18.67	57.95	251.14
100% NPK	22.46	28.63	61.19	375.54
150% NPK	31.92	31.06	68.43	424.52
100% NPK+HW	24.57	27.04	55.34	373.68
100% NPK(S-free)	9.92	08.74	30.44	117.93
100% NPK+Lime	21.04	29.43	64.18	378.67
100% NPK+FYM	24.32	31.96	69.70	391.75
100% NPK + FYM + lime	34.77	33.87	73.15	427.76
LSD ($P \leq 0.05$)	1.00	1.14	2.60	14.78

6.3.3 Boron

In acid soil B could be limiting nutrient due to its mobility in soil. Data presented in table 6.10 revealed that application of fertilizer nutrient resulted increase in available B in soil and other fractions also, whereas there is decline in B content in plot that received only 100% N. It indicates that healthy plant growth helped in mobilizing B from soil to make it available to the plant.

Table 6.10 Effect of long term manure and fertilizers application on fractions of boron in soil under finger millet–maize cropping system (mg kg^{-1}) (2013)

Treatments	Avail-B	Ready S-B	Spa-B	Org-B	Total -B
Control	0.83	1.53	0.33	6.7	85.35
100% N	0.77	1.03	0.22	5.4	78.58
100% NP	0.92	1.52	0.33	6.86	91.89
50% NPK	0.72	1.19	0.31	4.36	82.68
100% NPK	0.91	1.53	0.31	4.46	96.25
150% NPK	0.97	1.59	0.28	6.89	98.55
100% NPK + HW	0.91	1.55	0.36	7.14	90.16
100% NPK (S-free)	0.89	1.54	0.36	6.56	92.89
100% NPK + Lime	0.98	1.63	0.35	7.16	95.84
100% NPK + FYM	1.01	1.65	0.47	7.26	123.96
100% NPK + FYM + lime	1.13	1.67	0.57	8.14	152.45
LSD ($P \leq 0.05$)	0.04	0.063	0.016	0.29	4.49

Ready S-B=Readily soluble boron; Sps-B= Specifically adsorbed boron and Org-B=Organically bound boron

6.4 Pattambi

6.4.1 Phosphorus

The P fractions (Table 6.11) revealed that application of P resulted in accumulation of P in the form of Fe-P and organic P. Application of FYM and green manuring favoured accumulation of organic form of P. Larger decline in Ca-P and Al-P in the absence of P (Control) indicated that these two forms of P are contributing more P to the plant in case of need.

Table 6.11 P fractions in Alfisols of Pattambi (Kerala)

Treatment	Al-P (mg kg^{-1})	Fe-P (mg kg^{-1})	Ca-P (mg kg^{-1})	Org-P (mg kg^{-1})
Control	19.75	108.0	9.00	156.7
100% NP	27.25	101.7	58.25	139.0
50% NPK	35.75	98.57	23.00	162.5
100% NPK	21.75	105.7	32.50	137.8
150% NPK	25.75	138.2	27.75	172.2
100 % NPK+ lime	35.00	114.5	29.75	201.0
100% NPK+ FYM	22.00	122.5	41.0	198.5
100% NPK+ Green manuring	14.00	112.5	49.5	194.2

6.4.2 Potassium

Data on K fractions in acid soils of Pattambi revealed that soil maintained very low K in water soluble forms (Table 6.12). The extraction of K through HNO_3 is larger than K extracted by H_2SO_4. This is probably due to more dissolution power of HNO_3 than H_2SO_4. But one thing is clear from the data that irrespective of extracting agent application of K resulted in relatively more extraction of K compared to control or N treatment.

Table 6.12 Potassium fractions in Alfisols of Pattambi (Kerala)

Treatment	Water Soluble K (mg kg^{-1})	H_2SO_4 Soluble K (mg kg^{-1})	HNO_3 Soluble K (mg kg^{-1})
Control	3.05	25.15	60.10
100% N	3.55	26.12	63.91
100% NP	3.55	26.89	63.91
50% NPK	4.50	27.18	64.79
100% NPK	4.65	39.38	84.52
150% NPK	5.30	50.29	101.59
100% NPK + lime	5.45	29.86	61.46
100% NPK (+ Cu)*	4.60	37.11	79.09
100% NPK + FYM	7.00	56.34	86.41
50% NPK + FYM	6.70	32.92	75.46
100% NPK + GM	8.10	38.50	90.44
50% NPK + GM	4.25	34.16	85.65

* Application of copper was stopped since Rabi 2000

6.5 Barrackpore

6.5.1 Potassium

Data on different forms of K presented in Table 6.13 revealed that application of K maintained available (Water soluble + Exchangeable) forms of K in larger quantity compared to the treatment which did not receive K over the years. Data further indicated that in the absence of K supply during last 43 years there was decline in reserve K (i.e. Non exchangeable K) which means plant derives K from this form in the absence of either K or less supply. Similar trend was also noted in the subsurface layer (15-30 cm). Thus, it indicates that plant also derived K from lower layers. Hence, it can be concluded that K supply should be made to maintain available K status in the soil.

Table 6.13 Distribution of different forms of soil K after 42 years of cropping with jute-rice-wheat (CRIJAF Barrackpore)

Treatments	Water soluble K (mg kg^{-1})	Exchangeable K (mg kg^{-1})	Non exchangeable K (mg kg^{-1})	Available K (mg kg^{-1})
Soil depth (0-15 cm)				
Control	7.6	55.0	881	62.6
100% N	8.3	52.2	764	60.5
100% NP	8.7	49.5	704	58.2
50% NPK	9.2	69.5	901	78.7
100% NPK	10.0	84.5	1003	94.5
150% NPK	12.6	91.0	1168	103.6
100% NPK + FYM	12.8	92.7	1055	105.5
Soil depth (15-30 cm)				
Control	3.9	46.0	981	49.9
100% N	4.0	40.5	796	44.5
100% NP	4.2	38.6	745	42.8
50% NPK	4.7	51.0	1004	55.7
100% NPK	5.7	55.9	1103	61.6
150% NPK	6.5	67.7	1188	74.2
100% NPK + FYM	6.4	69.7	1113	76.1

6.6 Palampur

6.6.1 Potassium

Data on dynamics of K generated in Alfisols of Palampur (Table 6.14) revealed that continuous application of K (in sufficient amount) has maintained available K in sufficiently large amount compared to the treatment which did not receive K over the years. Data further indicated that in absence of K application, K from non-exchangeable form moved out to available form to maintain the equilibrium. This means if we don't apply K then non-exchangeable K will be depleted and soil may show fatigue after few years of cultivation. Therefore, it is necessary to give due care to K supply at least in Alfisols in order to sustain soil productivity.

Table 6.14 Effect of long-term treatments on different forms of potassium (mg kg^{-1})

Treatment	Water Soluble K		Exchangeable-K		0.5 N HCl extractable-K		Non exchangeable K	
	0- 15 cm	15-30 cm	0- 15 cm	15-30 cm	0- 15 cm	15-30 cm	0- 15 cm	15-30 cm
Control	13.2	10.4	44.5	39.9	125.4	112.8	545.7	560.5
100% N	16.0	14.3	49.3	42.2	132.1	106.4	532.5	580.3
100% NP	8.9	7.7	50.5	45.5	125.4	86.3	512.8	560.4
50% NPK	14.5	8.5	22.3	50.8	121.0	114.9	528.4	532.5
100% NPK	17.7	16.2	56.2	50.2	154.8	123.5	665.8	670.6
150% NPK	25.6	22.4	59.9	54.5	180.0	167.8	710.7	734.4
100% NPK (-S)	15.7	9.6	63.4	61.8	195.6	132.2	680.6	698.5
100% NPK + HW	16.4	15.4	60.4	52.0	146.7	112.8	502.5	549.8
100% NPK + Zn	21.2	17.6	50.0	42.7	231.7	201.7	601.7	613.4
100% NPK + FYM	22.8	19.5	66.2	58.6	215.3	173.9	627.5	642.8
100% NPK + lime	18.7	13.5	58.4	52.6	174.6	142.3	643.7	645.3
LSD ($P \leq 0.05$)	3.3	2.9	8.6	5.4	34.6	30.4	36.9	53.7

6.7 New Delhi

6.7.1 Soil organic carbon

Perusal of data (Table 6.15) indicated that application of nutrient in balanced form and in right quantity maintained more in soil carbon in bulk soil, macro and micro aggregate as compared to imbalanced use of nutrient (Control, N, NP). Increase in carbon in macro and micro aggregate is due to increase in proportion of both the aggregate on application of fertilizer due to addition of carbon through residual biomass. Further increase in carbon on application of FYM supports the statement.

Table 6.15 Total soil organic carbon (SOC) in different soil aggregates (g kg^{-1})

Treatments	Bulk soils	Macro-aggregates	Micro-aggregates	Bulk soils	Macro-aggregates	Micro-aggregates
	Soil depth (0-15 cm)			Soil depth (15-30 cm)		
Control	3.29	4.12	2.98	2.13	2.54	1.72
100% N	4.05	4.98	3.78	2.64	3.71	1.95
100% NP	3.93	6.25	4.66	3.33	4.36	2.90
100% NPK	6.57	7.64	5.38	4.06	4.89	3.85
150% NPK	7.02	8.61	6.35	4.51	5.81	4.07
100% NPK + FYM	7.82	9.10	6.69	5.02	6.34	4.65
Mean	5.45	6.78	4.97	3.61	4.61	3.19

6.7.2 Potassium

Data on K fractionation presented in Table 6.16 revealed that application of K maintained larger amount of K in all the fractions compared to the treatment (control, 100% N and NP) which did not receive K over 43 years. The K content of different fractions in both the layers is more or less similar. Absence of K in fertilizer schedule resulted in decline in non-exchangeable and total K indicating plant derived K from non-exchangeable fraction. Uncultivated fallow maintained all the fraction in larger quantity except water soluble K compared to cultivated soil. This could be probably due to non utilization of K by crops..

Table 6.16 Distribution of soil K forms (mg kg^{-1}) in different soil depth as affected by long-term fertilization and manuring

Treatment	Water soluble K		Exchangeable K		Non-Exchangeable K		Total K	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Control	16.6	16.8	93	90	1273	1264	18062	18040
100% N	12.9	13.8	90	87	1213	1183	17447	17533
100% NP	15.5	14.3	84	83	1202	1176	17313	17715
100% NPK	17.3	19.4	106	100	1375	1391	18170	18242
150% NPK	19.7	20.1	109	101	1395	1387	18402	18398
100% NPK+FYM	17.4	17.2	113	108	1412	1383	18727	19272
Mean	16.6	16.9	99	95	1312	1297	18020	18200
CV (%)	6.7	8.4	5.5	6.3	2.7	4.0	3.2	8.9
Uncultivated soil	17.8	10.5	122	120	1 407	1 381	18 135	21 631

6.7.3 Boron

Data (Table 6.17) indicated that imbalanced use of nutrient resulted decline in available B and specifically absorbed B. It is interesting to note that available B and specifically absorbed B are almost similar as far as quantity is concerned whereas oxides and organically bound B is 2 and 4 times larger in quantity, respectively. Majority of B is noted in residual form. So, one thing is clear that FYM maintained larger amount of B in all the fractions in soil.

Table 6.17 Fractions of B as influenced by long-term fertilization and manuring (Values in parenthesis shows percentage of the total)

Treatment	B fractions (mg kg^{-1})					Total B (mg kg^{-1})
	Readily soluble	Specifically adsorbed	Oxide bound	Organically bound	Residual	
Control	0.75 (2.00)	0.66 (1.76)	1.49 (3.95)	2.50 (6.63)	32.3 (85.7)	37.7 (100)
100% N	0.61 (1.67)	0.60 (1.64)	1.44 (3.93)	2.63 (7.18)	31.4 (85.6)	36.7 (100)
100% NP	0.67 (1.84)	0.64 (1.74)	1.45 (3.99)	2.69 (7.38)	31.0 (85.1)	36.5 (100)
100% NPK	0.70 (1.82)	0.73 (1.89)	1.55 (4.03)	2.83 (7.34)	32.7 (84.9)	38.5 (100)
150% NPK	0.64 (1.56)	0.72 (1.76)	1.62 (3.98)	3.06 (7.5)	34.7 (85.2)	40.7 (100)
100% NPK+FYM	0.82 (1.84)	0.86 (1.92)	1.57 (3.51)	5.86 (13.1)	35.8 (79.7)	44.9 (100)
Mean	0.70	0.70	1.52	3.26	33.0	39.2
LSD ($P \leq 0.05$)	0.1	0.07	NS	0.38	NS	4.51

7. SUPERIMPOSITION

AFTER REVIEW OF RESULTS, some of the treatments were bifurcated to address the issue and answer the questions arised during the course of experimentation at few LTFE locations.

7.1 Bangalore

To maximize the yield of finger millet, study the combined effect of FYM and lime and effect of reduced dose of P on crop productivity and soil health, few treatments were superimposed as shown in Table 7.1. Data revealed that application of 5 and 10 t FYM over and above 150% NPK resulted increase in productivity of both finger millet and maize. This may be because of additive effect of FYM over their respective control. Poor yield of finger millet during 2015 and maize yield during 2014-15 is due to occurrence of acute drought season. Additional application of lime with FYM resulted in increase is productivity compared to FYM alone. The effect was more pronounced in the treatment which were starved with K (100% N or 100% NP) over a period of time in the post. On application of lime, the increase in availability of P and K probably increased the crop yield.

Table 7.1 Grain yield (kg ha^{-1}) of finger millet and maize in superimposition treatments at GKVK Bangalore

Treatments	Finger millet			Maize		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean
150% NPK	3483	2823	3153	2297	5583	3940
150% NPK, 5 t ha^{-1} FYM	3744	3266	3505	2419	6139	4279
150% NPK, 10 t ha^{-1} FYM	4109	3661	3885	2789	6417	4603
100% NPK	2803	2213	2508	1967	3681	2824
100% N, 50% P, 100% K, FYM	3007	2418	2713	2515	5694	4105
100% N, 50% P, 100% K, FYM, lime	3262	2789	3026	3380	5930	4655
100% NP	508	1420	964	964	1833	1399
100% N, 50% P, 100% K, FYM	3151	2585	2868	2709	5722	4216
100% N, 50% P, 100% K, FYM, lime	3836	3097	3467	3307	6014	4661
100% N	699	1345	1022	983	1597	1290
100% NPK, FYM	2574	1870	2222	2540	5292	3916
100% NPK, FYM, lime	3567	2433	3000	3149	5972	4561
LSD ($P \leq 0.05$)	754	247	-	312	181	-

7.2 Ludhiana

7.2.1 Utilization of accumulated P

To study the utilization of P accumulated over the years, dose of P reduced to half in plot received full dose of P and the plot which were receiving half dose of P, amount of N and K was increased to 100% (Table 7.2). The yield data reveled that if there is increase in N dose correspondingly increase in yield of both maize and wheat was noted and crop started mobilizing accumulated P. Similarly, reduction in P dose from 150 to 50 percent also did not have any adverse effect on productivity of maize and wheat. However, absence of P resulted in significant yield loss of both crops. Thus, it can be concluded that crop utilized P from soil which was accumulated on continuous application of P.

Table 7.2 Effect of long-term fertilizer application on maize and wheat grain yield (kg ha^{-1}) under superimposed treatments

Treatments	Maize			Wheat		
	2014	2015	Mean	2014-15	2015-16	Mean
50% NPK	3392	3561	3477	3833	4072	3953
100% N+50% PK	3752	4959	4356	4789	4943	4866
100% N+50% PK+Zn	3443	5050	4247	4633	5219	4926
100% NPK	4431	5541	4986	5229	5309	5269
100% NK+ 50% P	4280	5241	4761	5049	4812	4931
100% NK+ 50% P+Zn	4221	5443	4832	5011	5162	5087
150% NPK	4744	5511	5128	5211	5569	5390
150% NK+ 50% P	4581	5321	4951	5149	5132	5141
150% NK+ 50% P+Zn	4902	5504	5203	5181	5321	5251
100% NPK (DAP)	4170	5443	4807	5152	5459	5306
100% NK	3184	4454	3819	4348	4549	4449
100% NPK (DAP) + Zn	4272	5121	4697	5089	5602	5346

7.2.2 Effect on nutrient status

Data presented in Table 7.3 did not show any effect in pH, EC but effect of superimposition was noted in available status of soil carbon, N, P and K also. Perusal of data indicated that increase in N dose to 100% from 50% resulted increase in soil carbon, available N, P and K. Similarly, addition of P through DAP in P deprived plot led to increase in P status from 17.8 to 61.8 kg ha^{-1}.

Table 7.3. Effect of long-term fertilizer application on soil chemical properties under superimposed treatments in maize-wheat cropping sequence

Treatments	pH	EC (dS m^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
50% NPK	7.24	0.122	0.353	111.3	34.2	94.1
100% N + 50% PK	7.06	0.117	0.413	127.0	38.4	94.1
100% N+ 50% PK+Zn	7.13	0.133	0.420	133.3	39.7	96.9
100% NPK	7.04	0.178	0.413	125.4	59.7	143.9
100% NP+ 50% K	6.94	0.167	0.416	122.3	36.2	142.8
100% NP+50% K+Zn	6.99	0.162	0.401	134.8	38.1	143.4
150% NPK	6.77	0.135	0.413	133.3	84.4	150.6
150% N+50% PK	6.87	0.126	0.416	125.4	34.4	95.8
150% N+50% PK+Zn	6.77	0.143	0.401	120.7	35.6	100.2
100% NK	7.05	0.124	0.424	123.9	17.8	137.2
100% NPK (DAP)	6.96	0.117	0.409	130.1	61.8	142.2
100% NPK+Zn (DAP)	6.86	0.147	0.416	125.4	64.1	145.6

7.2.3 Micronutrient

As such modification of doses of N, P and K did not have any effect on status of micronutrient cations in soil (Table 7.4). However, application of Zn resulted in build-up of Zn status in soil when compared with absence of Zn application.

Table 7.4 Effect of long-term fertilizer application on micronutrients content (mg kg^{-1}) in soil under superimposed treatments in maize-wheat cropping sequence

Treatments	Fe	Zn	Cu	Mn
50% NPK	11.62	2.42	0.81	7.25
100% N+ 50%PK	14.27	3.10	0.94	9.08
100% N+50%PK+Zn	12.88	3.66	1.12	8.44
100% NPK	11.93	3.17	2.41	7.27
100% NP+50%K	12.65	2.77	3.05	8.67
100% NP+50%K+Zn	9.31	3.72	5.42	7.14
150% NPK	13.30	3.00	2.60	9.40
150% N+50%PK	12.94	3.02	3.19	10.66
150% N+50%PK+Zn	13.35	5.40	3.40	9.69
100% NK	10.67	2.13	0.93	9.78
100% NPK (DAP)	14.59	2.45	1.32	8.82
100% NPK+Zn (DAP)	15.16	5.17	3.00	10.13

7.3 Ranchi

To compare the effect of lime and FYM on grain yield of soybean and to study the effect FYM dose over and above 150% NPK, treatments were superimposed as per plan given in Table 7.5. Results obtained revealed that application of lime and FYM both increased the yield of soybean and wheat as well. But magnitude of increase in yield was much more in case of FYM compared to lime especially on superimposition in 100% NP and 100% N treatments.

Table 7.5 Effect of lime/FYM on grain yield of crops under soybean-wheat cropping sequence in superimposed treatments (Mean of 2013-15)

Treatment	Soybean	% Change over original	Wheat	% Change over original
100% NP (Original)	617	-	335	-
100% NP +Lime	981	59	3580	969
100% NP +FYM	1632	165	3818	1040
100% N (Original)	215	-	657	-
100% N +Lime	706	228	1643	150
100% N +FYM	1478	587	1804	175
100% N(S)PK	891	-	2983	-
100% N(S)PK +Lime	1899	113	3357	13
100% N(S)PK +FYM	1797	102	3100	4
150% NPK	1905	-	2945	-
150% NPK+5.0 t FYM	2105	11	3567	21
150% NPK+10.0 t FYM	2176	14	3870	31

Larger increase in yield of both the crops on application of FYM is due to additional supply of nutrients particularly P and K as these treatments were deprived of these two nutrients for quite some time. In contrast to observation recorded above, increase in yield on superimposition of lime and FYM in treatment received nitrogen through ammonium sulphate was little larger in case of lime compared to FYM. More effectiveness of lime was due to decline in soil pH because of ammonium sulphate application. This particular treatment is supplied with P and K each year and crop did not express potential yields due to low in pH. Lime did better because of increase in soil pH which increased availability of P, K in soil. Thus, results clearly demonstrated that FYM in general is better soil amendment than lime for sustaining productivity of acid soil.

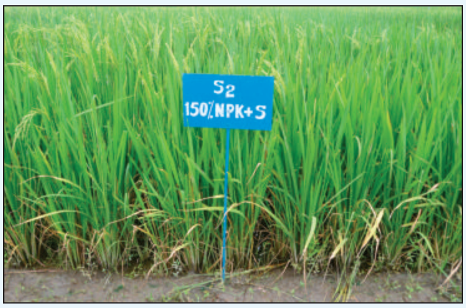
7.4 Pantnagar

At Pantnagar, Zn and S were noted to be deficient in soil. So to study individual and combined effect of Zn and S, treatments were bifurcated and the results obtained are given in Table 7.6. The data indicated that application of Zn and S even though resulted increase in yield but statistically non-significant. Application of Zn resulted relatively more increase in yield of rice but their combined effect is additive and more pronounced (Plate 7.1). Effect of both S and Zn individually was also recorded but statistically non significant. However, combined effect of both was noted. Thus, it can be concluded that both the nutrients should be supplied to crop simultaneously.

Table 7.6 Rice and wheat yields under superimposed treatments (kg ha^{-1}) (3 year's mean yields during 2012-15)

Superimposition	Original 150% NPK (1993-94)		Original 100% NPK (2003-04)	
	Grain	Straw	Grain	Straw
Rice				
-S	4200	5060	4000	5000
+S	4550	5000	4100	5200
-S+Zn	4800	5200	4500	5050
+S+Zn	5800	6260	5600	6100
+S+Zn+FYM	6300	6240	5880	6150
LSD ($P \leq 0.05$)	901	992	830	1052
Wheat				
-S	3420	4400	3350	4000
+S	3490	4450	3400	4350
-S+Zn	3580	4500	3450	4450
+S+Zn	4390	5270	3820	5000
+S+Zn+FYM	4450	5450	3990	5170
LSD ($P \leq 0.05$)	662	742	361	563

S_1= 150% NPK-S



S_2= 150% NPK+S

S_3= 150% NPK-S+Zn

S_4= 150% NPK+S+Zn

S_5= 150% NPK+S+Zn+FYM

Plate 7.1 Impact of superimposition of Zn and S (in 150% NPK) on growth and yield of rice at Pantnagar

7.5 Jabalpur

The sole objective of added farm yard manure (FYM) in graded doses over and above 150% NPK was to break the yield plateau (Table 7.7). The results showed that application of FYM over and above 150% NPK did not have much effect on yield of both the crops. Thus, it can be concluded that yield can be sustained even by supplying the nutrient through inorganic sources also.

Table 7.7 Effect of superimposition of treatment on productivity of soybean and wheat

Superimposed Treatments	Soybean			Wheat		
	2014-15	2015-16	Mean	2014-15	2015-16	Mean
150% NPK	1220	1120	1170	4560	3950	4255
150% NPK +2.5 t FYM ha^{-1}	1270	1130	1200	4760	4100	4430
150% NPK+ 5 t FYM ha^{-1}	1280	1170	1225	4790	4250	4520
150% NPK+ 10 t FYM ha^{-1}	1290	1180	1235	4820	4300	4560

Superimposition of FYM did not have any effect on pH and EC. However, increase in soil carbon and nitrogen was recorded on application of FYM, is obviously due to addition of carbon through FYM (Table 7.8).

Table 7.8 Effect of superimposition of treatment on soil test value after harvest of wheat

Treatment	pH	EC (dSm^{-1})	OC (g kg^{-1})	Available nutrients (kg ha^{-1})			
				N	P	K	S
150% NPK	7.35	0.26	8.46	271	37.2	290	36.8
150% NPK+ 2.5 t ha^{-1}	7.41	0.32	8.74	297	37.9	309	39.2
150% NPK+ 5 t ha^{-1}	7.59	0.29	8.87	305	38.1	335	40.8
150% NPK+ 10 t ha^{-1}	7.61	0.25	8.90	315	38.8	355	41.2
Initial (2014)	7.75	0.20	8.50	349	36.8	300	35.2

8. TECHNOLOGY DEMONSTRATION ON FARMERS' FIELD

INFORMATION GENERATED from Long Term Fertilizer Experiments (LTFE) conducted at different locations were synthesized and transformed into technology palatable to farmers. These technologies were demonstrated on farmer's field and the results are been given in this section.

8.1 Jabalpur

8.1.1 Response to Phosphorus and Sulphur

Farmers are using DAP continuously for many years which resulted in accumulation of P and hidden hunger of S. Data presented in Table 8.1 revealed that reduction in P dose to half did not have any adverse effect on productivity and at the same time absence of S for long time resulted decline in productivity soybean but did not effect in wheat, probably due to aerobic condition. Thus, from the results it can be concluded that P accumulated over the years can be utilized and S is needed at least during rainy season.

Table 8.1 Effect of long term application of fertilizer and manure on soybean and wheat yields (kg ha^{-1}) in farmers' field trials

Treatments	2014-15	2015-16*	Mean
Soybean			
100% NPK + 5 t FYM ha^{-1}	1393	369	881
100% NPK	1298	342	820
100% NK + 50% P	1160	333	747
100% NPK – S	962	311	637
Farmers' Practice	897	305	601
LSD ($P \leq 0.05$)	180	NS	
Wheat			
100% NPK + 5 t FYM ha^{-1}	4183	4058	4121
100% NPK	3650	3642	3646
100% NK + 50% P	3467	3575	3521
100% NPK – S	3383	3405	3394
Farmers' Practice	2933	3210	3072
LSD ($P \leq 0.05$)	335	385	

*Poor yield is due to excess rainfall (160 cm)

8.1.2 Response to Potassium

Field experiments were conducted on farmers' field to study response of wheat and soybean to applied K. Results (Table 8.2) obtained revealed that absence of response to applied K in soybean, however, response was recorded in wheat though soils were high in K status. Absence of response of K in soybean in due to poor yield of soybean. It is stranged to note that wheat responded K at higher dose.

Table 8.2 wheat grain yields (kg ha^{-1}) of FLD's on high potassium containing soils

Treatments	2014-15	2015-16*	Mean
Soybean			
Farmers' Practice	-	306	306
K (0 kg ha^{-1})	-	311	311
K (40 kg ha^{-1})	-	357	357
K (80 kg ha^{-1})	-	353	353

Treatments	2014-15	2015-16*	Mean
Wheat			
Farmers' Practice	3500	3475	3488
K (0 kg ha^{-1})	2800	3617	3208
K (40 kg ha^{-1})	3110	3867	3489
K (80 kg ha^{-1})	3460	3958	3709

8.2 Bangalore

Finger millet is staple food crop for tribal farmers of Karnataka. Farmers' were given seed of high yielding variety as well as other agricultural input. Demonstrations were carried out at their field in four villages of two different locations of Chamraj nagar district of Karnataka. The result (Table 8.3 and 8.4) revealed that balanced use of nutrient resulted increase in productivity of finger millet by 25 percent and maize by 23 percent over practice followed by them. Very high yield of maize was recorded due to hybrid variety and soil suited to maize because of very good drainage system.

Table 8.3 Average yield of finger millet in different tribal clusters as influenced by INM and farmer's practice

Name of the tribal farmer	Name of the tribal cluster	Grain yield (kg ha^{-1})	
		Farmers' practice	INM
Purani Podu	B.R.Hills, Yelandur Tq Chamarajanagar District	2550	3350
Kalyani Podu		2430	3150
Jeerige Gadde	Kollegal Tq Chamarajanagar District	2450	3040
Haavina Moole		2630	3120
Maavattur		2850	3460
	Overall Average yield	2580	3220

Farmers' practice: Only DAP @ 50 kg /acre / only FYM @ 1 to 2 tonnes /acre

Table 8.4 Average yield of maize in different tribal clusters as influenced by INM and farmer's practice

Name of the tribal farmer	Name of the tribal cluster	Grain yield (kg ha^{-1})	
		Farmers' practice	INM
Purani Podu	B.R.Hills, Yelandur Tq Chamarajanagar Di	6520	7885
Kalyani Podu		6121	7706
Jeerige Gadde	Kollegal Tq Chamarajanagar Di	6712	8023
Haavina Moole		6425	8156
Maavattur		6852	8282
	Overall Average yield	**6526**	**8010**

Farmers practice – Only DAP @ 50 kg /acre / only FYM @ 1 to 2 tonnes /acre

8.3 Jagtial

In general rice yields are larger during rabi season compared to kharif season (Table 8.5 & 8.6). Under the situation balanced use of fertilizer is required to get the potential utilization of other nutrient and also to save fertilizer without any loss in yield. For example, increase in N dose from 100 to 150% keeping P and K 100%, the yield obtained in both the seasons are maximum. Application of 15 kg extra K over farmer's practice made the difference in yield during both the season. The extra amount of P applied by the farmer did not have any benefit.

Thus, results say that balances use of nutrient not only saved the nutrient but also increased the utilization efficiency of other nutrient like N and P. Which ultimately saved the input cost and this economic saving will be added to the farmer's profit.

Table 8.5 Rice yield (kg ha^{-1}) during *rabi* (2015-16)

Treatment	N-P_2O_5-K_2O (kg ha^{-1})	Grain yield (kg 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	185-92-25	6910	-	6905	97431	90526
RDF	120-60-40	6429	-6.96	4911	90644	85733
150% N + 100% PK	180-90-60	6985	1.08	5688	98489	92801
150% RDF	180-60-40	6844	-0.95	7366	96496	89130

*Average of five farmers

Table 8.6 Rice yield (kg ha^{-1}) during *kharif* 2015

Treatment	N-P_2O_5-K_2O (kg ha^{-1})	Grain yield (kg 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	185-92-25	6498	-	6905	91619	84714
RDF	100-50-40	6564	1.01	4911	92552	87641
150% N P K	150-75-60	6639	2.16	5688	93616	87928
150% N +100%PK	150-50-40	6535	0.56	7366	92138	84772

*Average of five farmers

8.4 Raipur

Field demonstrations were conducted at tribal farmer's field on balanced use of nutrients survey revealed that farmers generally don't apply fertilizer there, if at all they apply fertilizer then only use of urea is prevalent (Table 8.7 & 8.8). Balanced use of nutrient doubled the rice yield compared to farmer's yield. Even though Raipur is not

Table 8.7 Front line demonstration on grain yield of paddy and wheat at different districts of Chhattisgarh

Treatment	Durg	Gariyaband	Koria	Mean
		Paddy (kg ha^{-1})		
Farmer's practice	1990	-	1425	2157
100% N	2890	-	-	2890
100% NPK	3660	-	3105	3382
		Wheat (kg ha^{-1})		
Farmer's practice	1000	451	1090	847
100% N	1743	-	-	1743
100% NPK	2500	1250	2092	1947

Farmers' practice (Approx 50-60 kg N through urea) traditionally wheat growing area, even then balanced use of nutrient increased the wheat yield by 2.0 – 2.5 folds and net income of the farmers' increases. Thus, results indicated that soils are having hidden hunger of P in addition to N need to be applied.

Table 8.8 Initial soil status of the selected farmers' field at different districts of Chhattisgarh

Name of District	pH	EC (dS m^{-1})	OC (g kg^{-1})	Available nutrient status (kg ha^{-1})		
				N	P	K
Durg	7.712	0.203	4.5	166.2	7.95	472.4
Gariyaband	6.852	0.228	4.49	178.3	14.12	275.9

8.5 Akola

Demonstrations conducted at farmer's field in Akola district revealed that intervention made on nutrient management resulted increase in yield of both sorghum and wheat (Table 8.9). The results also showed that application of S during kharif season improved the yield of sorghum but did not have any effect on wheat yield. Application of FYM over and above NPK also resulted increase in yield both sorghum and wheat. However, substitution of 25% N through FYM had little edge over 100% NPK in sorghum yield but did not show any effect on subsequent wheat. This indicated absence of residual effect of FYM (Table 8.9).

Table 8.9 Effect of various treatments on grain yield of sorghum and wheat (2013-14 & 2014-15)

Treatments	Yield (kg ha^{-1})			
	Sorghum		Wheat	
	2013-14	2014-15	2014-15	2014-15
Farmers' practice (Control)	2308	2694	2561	2410
RDF (P through DAP)	2870	3108	3805	2935
RDF (P through SSP)	3168	3266	3813	3090
RDF + FYM @ 5 t ha^{-1}	3683	3621	4006	3355
75% RDF + 25% N through FYM	3353	3464	3848	3139
LSD ($P \leq 0.05$)	507	269	201	241

FYM applied to sorghum only

8.6 Bhubaneswar

Demonstrations conducted on integrated nutrient management in Rayagada and Khordha district of Orissa revealed that rice yields obtained on application of nutrient on soil test based recommendation (STBR) and general recommended dose of nutrients are more or less similar and benefit also on similar footing with Rs 2000 in RDF. However, on integrated nutrient management, farmer's benefit is almost double. Thus, results indicated that integrated nutrient management is the best way to get higher yield and more benefit (Table 8.10 and 8.11).

Table 8.10 Improvement in yield and benefit in rupees in Kharif (2014)

District	Block	STBR		RDF		RDF+FYM	
		Yield advantage over FP (q ha^{-1}) (Y)	Mean Benefits (Rs.) (YxPy)	Yield advantage over FP (q ha^{-1}) (Y)	Mean Benefits (Rs.) (YxPy)	Yield advantage over FP (q ha^{-1}) (Y)	Mean Benefits (Rs.) (YxPy)
Rayagada	Rayagada	2.1-16.1 (7.93)	10,785	3.5-17.5 (10.27)	13,967	14-31.5 (23.33)	31,729
	Bissam Cuttack	3.5-17.5 (8.99)	12226	3.5-22.6 (9.83)	13,369	7-31.5 (18.59)	25,282
	Muniguda	3.5-21 (10.18)	13845	3.5-21 (12.66)	17,218	7-31.5 (19.22)	26,139
	Mean	9.04	12,294	10.92	14,851	20.38	27,717
Khordha	Bolagarh	3.5-10.5 (6.83)	9,289	3.5-10.5 (7.78)	10,581	10.5-24.5 (19.25)	26,180
	Mean	6.83	9,289	7.78	10,581	19.25	26,180

STBR= Soil test based recommendation; Parenthesis indicates mean yield; Py=Paddy Minimum Support Price is Rs. 1360/q.

Table 8.11 Front line demonstration on rice during rabi 2014-15 (Village: Bhanjakusum, Block- Sadar)

Name of Farmers	Variety	Rice Yield (t ha^{-1})			
		Farmers' practice	STBR	RDF	RDF+FYM
Nupuri Pradhan	Puja	5.0	6.4	5.4	6.8
Damnbur Pradhan	Lalat	4.0	5.2	5.0	6.0
Saranga Pradhan	Puja	3.8	5.8	5.0	6.0
Sanju Pradhan	Puja	4.0	5.6	4.6	5.6
Rabi Pradhan	Lalat	4.0	6.0	5.0	6.0
Adhikari Pradhan	Lalat	5.5	6.0	5.9	6.4
Ramesh Pradhan	Lalat	5.0	6.0	5.3	6.4
Saraswati Pradhan	Puja	4.0	6.0	5.3	6.0
Abhi Pradhan	Lalat	3.5	5.4	5.0	5.6
Chai Pradhan	Lalat	4.0	5.4	4.5	5.6
Prafulla Pradhan	Lalat	3.9	5.2	5.0	5.2
Balarsen Nayak	Puja	5.0	5.4	5.2	6.0
Kandhuri Nayak	Puja	4.0	6.0	5.4	6.0
	Mean	4.3	5.7	5.1	6.0

STBR= Soil test based recommendation

8.7 Junagadh

Demonstration conducted at farmer's field on balanced and integrated nutrient management revealed that application of $ZnSO_4$ resulted increase in yield of both groundnut and wheat significantly (Table 8.12). But the increase yield on integration of fertilizer nutrient with organic manure was much more than that of balanced used of nutrient in both groundnut and wheat. Substitution of fertilizer nitrogen to the tune of 50% by application of 10 t ha^{-1} FYM had significant effect on yield of both the crops. Thus, from the results it is concluded that integrated nutrient management is better option than the balance use of nutrient. It can also be interpreted that integrated nutrient management is always balanced nutrition, whereas balanced use of nutrient may not be always integrated.

Table 8.12 Front line demonstration (FLD) on groundnut and wheat yield during Rabi 2014-15 (Village: Bhanjakusum, Block- Sadar)

Treatments	2012	2013	2014	Pooled Mean
Groundnut pod yield (kg ha^{-1})				
100% NPK	1326	1239	1177	1247
100% NPK+ 50 kg $ZnSO_4$ ha^{-1}	1539	1461	1489	1496
50% NPK + 10 t FYM ha^{-1}	1930	1667	1737	1778
Farmers' practice	1183	1162	1022	1122
LSD ($P \leq 0.05$)	146	137	140	141
Wheat grain yield (kg ha^{-1})				
100% NPK	4228	4037	4019	4095
100% NPK+ 50 kg $ZnSO_4$ ha^{-1}	4577	4379	4345	4434
100% NPK + 10 t FYM ha^{-1}	5340	5078	4994	5137
Farmers' practice	3867	3581	3453	3634
LSD ($P \leq 0.05$)	459	426	429	438

8.8 Pattambi

Pattambi is located in an area where green manuring can be done without any additional cost and effort except seed cost. Three year's average results revealed that application of FYM and green manuring with full dose of NPK no doubt resulted in better (maximum) yield but reduction in nutrient dose to 50% with FYM and green manure, little decline in yield and gross return but is always better than sole NPK (100%). Thus, results of demonstration clearly indicated that 50% saving on chemical fertilizer can be made with little effort (Table 8.13). This practice not only saved fertilizer but also had intangible benefit on soil health.

Table 8.13 Results of the front line demonstrations at Pattambi (Kerala)

Year	100% NPK	100% NPK+ 5 t FYM	50% NPK + 5 t FYM	100% NPK+ *in situ* green manuring	50% NPK + *in situ* green manuring
Rice grain yield (kg ha^{-1}) in kharif					
2012	5350	5950	5600	6200	5750
2013	4600	5840	5100	5900	5250
2014	4240	5450	4860	5500	4970
Mean	4730	5747	5187	5867	5323
Produce cost	64328	78159	70543	79791	72393
Rice grain yield (kg ha^{-1}) in kharif					
2012-13	5600	6250	5750	6350	5800
2013-14	4300	5550	4760	5400	5200
2014-15	3920	5140	4650	4500	4560
Mean	4607	5647	5053	5417	5187
Produce cost	62655	76799	68720	73671	70543

Minimum Support Price (MSP) for Paddy = Rs. 1360 / q

9. FIELD DEMONSTRATIONS UNDER TSP

TO RAISE THE ECONOMIC AND SOCIAL status of tribal farmers of India, Government of India initiated the programme named as 'Tribal Sub Plan (TSP)' by allotting separate budget provision in on-going programmes. Accordingly, a programme was undertaken with the cooperation of AICRP LTFE centers located in tribal area. The activities carried out by different centers are given below.

9.1 UAS GKVK Bangalore

Tribal sub plan (TSP) programme was initiated by the Bengaluru Center from 2015-16 onwards. The tribal clusters at Biligiri Rangana Hills, Yelandur Taluk, and tribal villages near Kollegal taluk of Chamarajanagar district were selected for conducting demonstrations in the farmers' field. Representative soil samples were collected from the fields of tribal farmers and were analyzed for various chemical properties and nutrient status and Soil Health Cards were prepared and distributed to all the beneficiaries. Training programme on importance of integrated nutrient management and awareness on soil sampling were organized for tribal farmers in different villages. The nutrient status of soils for the selected tribal beneficiaries was assessed in Chamarajanagar district (Karnataka) in two phases (i) TSP- I Phase with implementation at (a) PuraniPodu (b) Kalyani Podu in Biligiri Rangana Hills, Yelandur Taluk and (ii) TSP- II Phase at (a) Jeerige Gadde (b) Haavina Moole (c) Maavattur in Lokkanahalli Hobli, Kollegal Taluk. In first phase there were 49 families of Soliga Tribes (ST) land holders of tribal clusters and in second phase in 53 families of Soliga Tribes land holders of tribal clusters. The inputs like seed of finger millet (GPU – 28) and maize (Hybrid – Hema); Chemical fertilizers like Urea, DAP, MOP and $ZnSO_4$ were provided. The major, secondary and micro nutrients status of soils collected from all the tribal beneficiaries fields are given in Table 9.1 and Fig. 9.1 & 9.2. In general, majority of soils (90%) are acidic in nature, 96% are low in available N, 65% medium in P and 57% medium in K status in collected from selected tribal beneficiary fields, B.R. Hills, Chamarajanagar District. The pattern of physico-chemical properties and nutrient status was almost similar in Kollegal taluk also.

Table 9.1 Nutrient status of soil in selected tribal clusters of Chamarajanagar Dist of Karnataka

a) Physico-chemical properties and major nutrient status in soil

Tribal clusters	Soil pH	EC (dS m^{-1})	OC (%)	Available nutrients (kg ha^{-1})		
				N	P_2O_5	K_2O
B.R.Hills						
Range (49 fields)	5.08-7.34	0.05-0.83	0.48-1.77	75.26-313.60	10.90-56.88	69.89-807.74
Average (49 fields)	5.80	0.18	1.19	205.57	31.05	310.60
SD±	0.53	0.15	0.37	43.29	12.33	193.78
Kollegal						
Range (53 fields)	4.04-7.32	0.03-0.44	0.27-2.25	137.9-288.5	8.79-125.24	59.40-600.36
Average (53 fields)	5.42	0.08	0.95	211.5	39.25	199.95
SD±	0.61	0.06	0.41	33.36	24.33	111.35

b) Status of S and micronutrients in soil

Tribal clusters	Available nutrients (mg ha^{-1})				
	S	Zn	Cu	Fe	Mn
B.R.Hills					
Range (49 fields)	18.57-23.66	0.56-6.35	0.23-5.29	2.46-77.38	2.77-53.56
Average (49 fields)	20.07	1.51	2.25	26.89	32.37
SD±	1.06	0.88	1.16	17.97	12.48

Tribal clusters	Available nutrients (mg ha^{-1})				
	S	Zn	Cu	Fe	Mn
Kollegal					
Range (53 fields)	34.23-56.14	0.53-2.88	0.46-6.17	5.84-62.30	4.07-53.54
Average (53 fields)	37.71	1.37	5.61	29.58	28.18
SD±	4.49	0.61	24.17	13.89	12.44

B.R.Hills (PuraniPodu and KalyaniPodu) Kollegal (JeerigeGadde, HaavinaMoole and Maavattur)

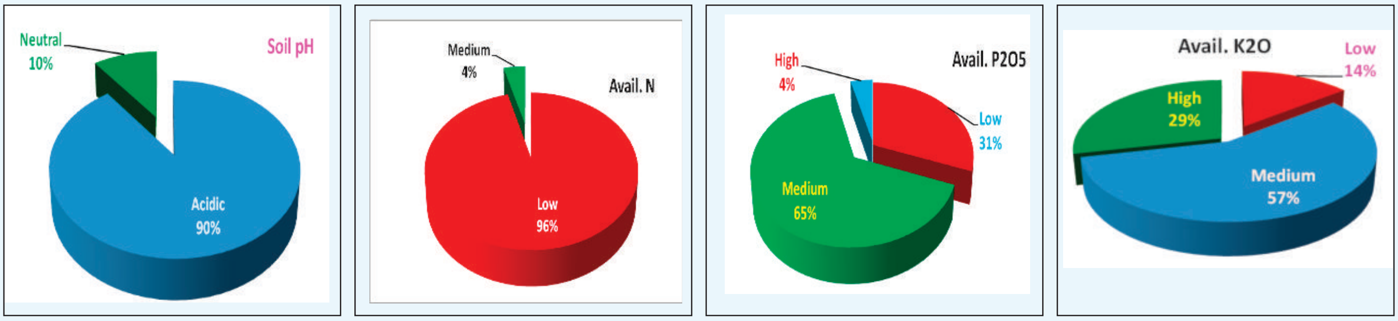


Fig. 9.1 Soil pH and available major nutrients status in soils (B.R.Hills)

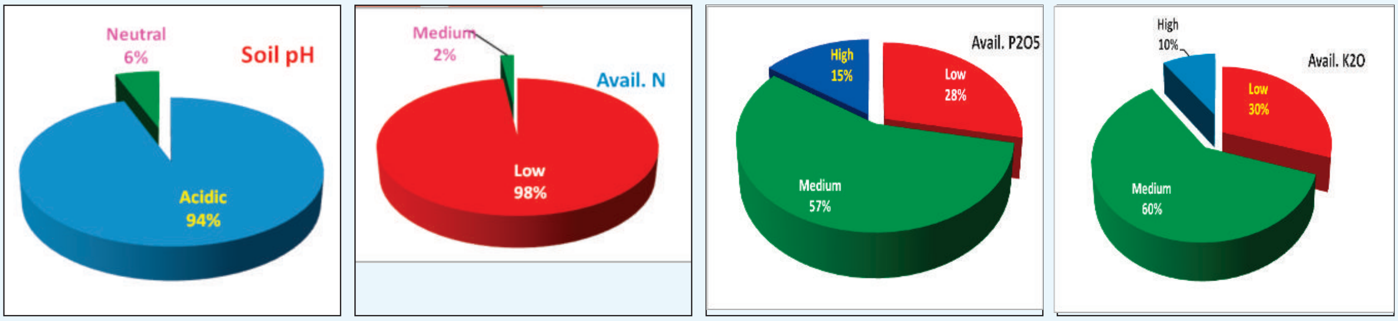


Fig. 9.2 Soil pH and available major nutrients status in soils (Kollegal Taluk)

The result of demonstration trials conducted at Tribal farmers' field indicated fairly good improvement in the crop productivity. Average yield of finger millet and maize was calculated by considering the yield from ten farmers field in each cluster (Table 9.2) and soil properties (Table 9.2). The increase in yield in finger millet was 24.9% and to 22.7% in maize over farmer's practice.

Table 9.2 Average yield of finger millet and maize (kg ha^{-1}) in different tribal areas

Tribal cluster	Finger millet		Hybrid maize	
	Farmers' practice	INM	Farmers' practice	INM
PuraniPodu*	2550	3350	6520	7885
KalyaniPodu*	2430	3150	6121	7706
JeerigeGadde#	2450	3045	6712	8023
HaavinaMoole#	2630	3125	6425	8156
Maavattur#	2850	3456	6852	8282
Average yield	2582	3225	6526	8010
Increase (%) over FP	-	24.9%	-	22.7%

*B.R.Hills, YelandurTq : # KollegalTqChamarajanagar: Farmers practice – Only DAP @ 50 kg /acre / only FYM @ 1 to 2 tonnes /acre

The farm inputs and soil health cards were distributed by the dignitaries (Plate 9.1). The honourable DG ICAR Dr S Ayyappan visited the tribal clusters at B.R. Hills in Chamarajanar District to interact with the beneficiaries in these tribal areas.

a). Distribution of soil health cards by Dr. Muneshwar Singh, PC LTFE

b). Visit of Dr. S. Ayyappan, Honorable DG ICAR to the tribal clusters of B.R. Hills, Chamarajanar District

c) Training programme on 'Importance of balanced nutrition to field crops'

d) Distribution of inputs (seeds and chemical fertilizers) to the beneficiaries under TSP

Plate 9.1 Distribution of farm inputs and soil health cards by the dignitaries

9.2 OUAT Bhubaneswar

Demonstration trials were conducted in five villages under four tribal districts covering 60 tribal farmers under the scheme of Tribal Sub-Plan (TSP) during 2015-16.The villages selected for demonstrations were Banjhakusum of Dhenkanal district, Kailash and Sadhupalli of Deogarh District, Khariadiha village of Keonjhar district and Penala village of Kandhamal district. Validation of the best performing manurial treatment of the LTF Experiment (RDF+ FYM) was implemented on farmer's field and compared with farmers' practice, RDF and soil test based recommendation. The treatments were T_1: Farmers practice; T_2: 100% RDF NPK (80:40:40- N: P_2O_5: K_2O kg ha^{-1}); T_3: 100% RDF (80:40:40- N: P_2O_5: K_2O kg ha^{-1}) + 5 t ha^{-1}FYM; T_4: Soil test based recommendation (STBR) including FYM (Table 9.3, Plat 9.2 and Fig. 9.3). The fertilizer nutrients i.e. NPK were applied in the form of Urea, DAP and MOP. Thus, on farm demonstrative trials were conducted on 60 farmers' fields in 4 districts, the yield recorded was lowest (3.43 tha^{-1}) with farmers' practice (FP). With the application of recommended dose of NPK fertilizers with splits (25% N, 100% P and 50% K at planting, 50% N at Maximum tillering stage and 25% N+50% K at Panicle initiation stage) 26.5% increase in yield enhancement was recorded over FP. The yield was further enhanced by 38.48% on an average with conjunctive use of RDF+ FYM @ 5 t/ha applied before planting. Fertilizer application on the basis of soil test results (with the adjustment of RDF *viz.*,25% more under low status, 25% less under high status situation in respect of N, P, K and O.M.) the yield recorded was highest in all the districts averaging 50.14% more than the FP. It has also been observed that farmers have realized the good effect of fertilisers and integrated use of soil test based NPK fertilizer and FYM to boost their yield (Table 9.3).

Table 9.3 Grain yield (t ha^{-1}) of *Kharif* rice of 2015 in farmer's field in four districts

District	Village	No. of Farmers	Range/ mean	Farmers' Practice*	RDF	RDF+FYM	STBR
Dhenkanal	Banjhakusum	16	Range	2.8-4.8	2.8-4.9	3.0-5.6	4.0-6.3
			Mean	3.79	4.24	4.51	4.90
Deogarh	Sadhupalli	11	Range	2.8-4.0	4.0-4.8	4.8-5.6	5.0-6.4
			Mean	3.6	4.49	5.09	5.51
Deogarh	Kailash	11	Range	2.8-4.0	3.8-5.0	4.4-5.2	4.8-5.6
			Mean	3.30	4.28	4.83	5.32
Keonjhar	Khadiadiha	16	Range	2.02-5.57	2.78-6.18	2.73-6.85	3.33-6.77
			Mean	4.28	5.01	5.53	5.80
Kandhamal	Penala	6	Range	2.07-2.37	3.57-3.88	3.63-4.01	4.17-4.47
			Mean	2.18	3.70	3.80	4.26
4 Districts	5 Villages	60	Overall Mean$	3.43	4.34 (26.5)	4.75 (38.48)	5.15 (50.14)

*NPK Dose of FP (20-30:10-15:15-20 N: P_2O_5:K_2O kg /ha); $indicates % Increase over farmers'practice

Plate 9.2 Demonstrations on farmers' field in Kandhamal and Dhenkanal; and field visit by PC (LTFE)

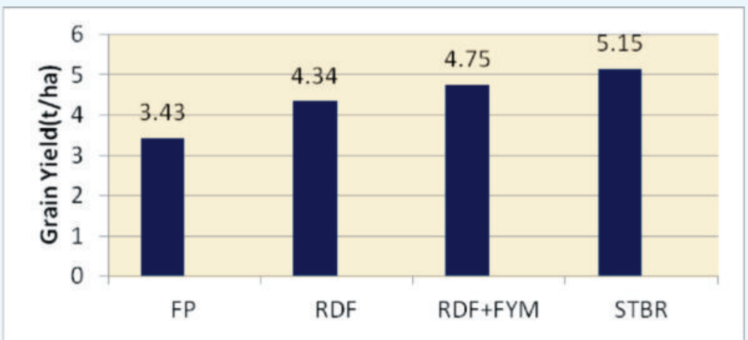


Fig. 9.3 Effect of nutrient management on grain yield over farmer's Practice

9.3 BAU Ranchi

During Kharif, 2015, altogether 30 demonstrations on maize(cv. BVM2) was conducted and treatments like N, NP, NPK, NPK + FYM and farmers' practice was taken for study (Table 9.4 and Plate 9.3). In which, 10 tribal farmers of each district namely Ranchi, Lohardaga and Khunti was selected covering an area of 15 hectare. The results showed that about 69-72% improvment in yield on application of NPK+FYM or NPK +Lime as compared to farmers practice. Application of NPK + Lime or NPK+FYM was found to be more beneficial at all the locations. Farmers participatory programme was conducted in tribal villages. The LTFE technology was demonstrated to the tribal farmers at their yields.

Table 9.4 Impact of nutrient management on maize yield (q ha^{-1})

Treatments	Ranchi	Lohardaga	Khunti	Mean (A)	Increase over FP (%)
NP	23.4	25.4	24.9	**24.7**	29.8
NPK	26.4	28.4	28.2	**27.5**	44.3
NPK+ Lime	32.3	33.6	33.1	**32.7**	71.8
NPK +FYM	30.9	32.7	31.7	**32.1**	68.6
FP (80:20:0) & FYM @2 tha^{-1}	17.9	19.8	19.3	**19.0**	
Mean (B)	**26.2**	**28.0**	**27.4**		
CD: Factor A :2.28: Factor B: 2.24 : AXB : 4.92; CV (%) 10.82					

Plate 9.3 Farmer's participatory programme and technology demonstrations

9.4 PDKV Akola

The field trials on 'Effect of nutrient management practices on productivity of kharif and rabi crops' were conducted to evaluate the effect of integrated nutrient management on productivity of crops (Plate 9.4). Field demonstrations were conducted on farmer's field in tribal area of Dharni taluka (Dist Amravati) during kharif and rabi season 2015-16. Each farmer was considered as one replication. The fertilizers were applied according to the respective treatments. There were 70 field trials with 20 on soybean, 10 on sorghum, 30 on chickpea, and 10 on wheat in different tribal areas i.e. Kara (35 trials) and Nanduri (35 trials) during 2015-16 (Table 9.5 &9.6; Plate 9.4 & 9.5). The kharif crops were sown in the month of July and harvested in October. The rabi crops were sown in the month of November and harvested in March.

Table 9.5 Treatment details

Treatments	N : P_2O_5 :K_2O (kg ha^{-1})			
	Sorghum	Soybean	Chickpea	Wheat
100% NPK (RDF)	100:50:40	30:75:30	25:50:30	120:60:60
100% NPK +FYM @ 5 t ha^{-1}	100:50:40	30:75:30	25:50:30	120:60:60
100% NP (-K)	100:50:00	30:75:00	25:50:00	120:60:00
Farmer's practice	40:30:00	15:35:00	10:25:00	40:25:00

The application of 100% NPK + FYM @ 5 t ha^{-1}recorded significantly higher grain 11.45 q ha^{-1}) yield of soybean over all the treatments. Grain yield of soybean was not influenced on application of potassium. Lowest grain yield was recorded in the treatment of farmers practice. The recommended dose of fertilizer (100:50:40 NPK kg ha^{-1}) along with FYM @ 5 t ha^{-1}recorded significantly higher grain (32.21 q ha^{-1}) yield of sorghum over control. Application of 100% NPK recorded 9.09% higher grain yield of sorghum as compared to without potassium application i.e. 100% NP which means soybean responded to applied K. The farmers practice recorded lowest yield in all the corps. The grain yield (14.38 q ha^{-1}) of chickpea increased significantly due to the application of 100% NPK + FYM @ 5 t ha^{-1} as compared to other all treatments. The application of 100% NPK recorded 13.41% more grain yield of chickpea over without application of K. The grain (29.91 q ha^{-1}) yield of wheat was influenced significantly by the application of 100% NPK + FYM @ 5 t ha^{-1}.The application of K (100% NPK) recorded significantly higher grain yield of wheat 27.22 q ha^{-1} over without application of potassium 100% NP-K. This means crops like sorghum and wheat having larger biomass responded to applied K in Vertisols.

Table 9.5 Effect of various treatments on grain and straw yield (kg ha^{-1}) of kharif crops

Treatments	Soybean	Sorghum	Chickpea	Wheat
100% NPK	994	2831	1319	2722
100% NPK + FYM @ 5 t ha^{-1}	1145	3221	1438	2991
100% NP (-K)	922	2595	1163	2535
Farmers' practice	812	2189	973	2041
CD at 5%	65	172	55.4	140.2

Thus, the application of 100% NPK + FYM @ 5 t ha^{-1} recorded significantly superior grain yield of soybean, sorghum, chickpea and wheat crops over RDF, imbalanced use of fertilizer and farmers' practice. The grain yield also influenced significantly due to the application of K along with NP as compared to without application of potassium (100% NP).

Plate 9.4 Field demonstrations in villages in tribal areas (Maharashtra)

Organized 'Field Day-cum-Training Programme' on “Integrated nutrient management in chickpea and wheat crop” at Nanduri (Tq. Dharni, Dist. Amravati) on 27 February 2016 having 94 beneficiaries and at Kara (Tq. Dharni, Dist. Amravati) on March 02, 2016 with 111 beneficiaries (Plate 9.5) . Conducted 13 field visits with wide coverage in local newspaper published eight times.

Plate 9.5 Training programme organized in villages in tribal areas (Maharashtra)

9.5 CSKHPKV Palampur

During *Kharif 2015*, field demonstrations (50 nos.) were laid out at village Balla of Dist. Kangraon 'Integrated nutrient management (INM) in maize crop at farmers' fields (*Tribe: Gaddi).* The yield data of maize is given hereunder (Table 9.7). During Rabi 2015-16, field demonstrations (50 nos.) were laid out at village Balla of Distt Kangra on integrated nutrient management (INM) in wheat crop at farmers' fields (*Tribe: Gaddi)* and data revealed increase in productivity of wheat to the tune of 218% over farmer's practice.

Table 9.7 Effect of INM on grain yield of maize in field demonstrations

Treatment	Range ($kg\ ha^{-1}$)	Mean ($kg\ ha^{-1}$)
Integrated nutrient management	3750 – 6250	5030 (218%)
Farmers’ Practice	1560 – 2810	2300

INM (N: 120, P_2O_5: 60, K_2O: 40 kg ha^{-1} + FYM 5 t ha^{-1}); FP (N: 60, P_2O_5: 24, K_2O: 16 kg ha^{-1} + FYM 5 t ha^{-1})

9.5.1 Organization of Training Programmes

9.5.1.1 Training Camps

In total, 6 training programmes were organized on balanced fertilization in different crops in district Kinnaur, Chamba, Kangra and Mandi during 2015-16 (Table 9.8 & Plate 9.6a).

Table 9.8 Details of training camps organized under TSP component

Location	Date	No. of Farmers	Tribe
Lamu (Holi), Dist. Chamba	28.10.2016	81	Gaddi
Rakh (Nagri), Dist.Kangra	11.02.2016	81	Gaddi
Chaura (Bhawanagar), Dist. Kinnaur	25.02.2016	80	Gaddi
Gunehar (Bir), Dist. Kangra	11.03.2016	80	Gaddi
Tikri (Nushehra), Dist. Mandi	19.03.2016	80	Gujjar
Gujreda (Gopalpur), Dist. Kangra	30.03.2016	80	Gujjar

9.5.1.2 Field Day

In total, two event of Field Day' were organized on balanced fertilization in maize and wheat crops in district Kangra (Plate 9.6b).

Details of field days organized under TSP component during 2015-16

Location	Date	No. of Farmers
Balla (Nagri), District Kangra	11.09.2015	42
Balla (Nagri), District Kangra	05.03.2016	50


Lamu (Holi), DistChamba (Tribe: Gaddi)


Gunehar (Bir), DistKangra (Tribe: Gaddi)


Tikri (Chauntra), DistMandi (Tribe: Gujjar)


Chaura (Bhawanagar), DistKinnaur (Tribe: Gaddi)

Plate 9.6 a. Training Programme for tribal people in tribal areas in Himachal Pradesh

Field Demonstrations **Field Day**

Plate 9.6 b. Demonstrations on INM in maize and wheat and 'Field Day' at Balla village (Dist. Kangra)

9.6 IGKV Raipur

Survey carried out revealed that nitrogenous fertilizers constitutes the major part of fertilizer consumption in tribal area selected (Chhattisgarh). Therefore, there is a scope for enhancing rice productivity with balanced nutrient application. In this direction demonstrations were conducted on farmers' fields in tribal areas of the state.

Field demonstrations were conducted in (Durg,Dhamtari, Mahasamundand Janjgir-Champa) districts of Chhattisgarh. Rice (*cv* MTU 1010, Swarna, HMT) crop was grown at different farmers' fields during June to August (Table 9.9; Plate 9.7, 9.8, 9.9) with treatments *viz*., farmer's practice (FP); application of sole N source; application of fertilizer as per recommended dose of fertilizer (RDF); application of fertilizer as per RDF + FYM. On an average 15 to 20 q ha^{-1} increase in rice productivity was achieved by application of fertilizer nutrient as prescribed as recommended dose. In all the three targeted districts, rice productivity enhanced by 31 to 47% over farmers' practice. Incorporation of 5 t FYM further increased the productivity by 13% additionally. All together application of

FYM along with NPK resulted increase in productivity of rice to the tune of 44.8, 51.6 and 67.8% in Durg, Dhantori and Janggir district of Chhattisgarh.

Table 9.9 Nutrient management (N, P_2O_5, K_2O kg ha^{-1}) effect on rice productivity (kg ha^{-1}) in Chhattisgarh

Treatments	Average rice yield (kg ha^{-1})	% increased over farmers' practice
Durg District		
Farmers Practice (65:40:15)	3511	-
Sole N (120 kg ha^{-1})	2609	(-) 25.69
RDF (120:60:40 kg ha^{-1})	4607	31.23
RDF+FYM (5 t ha^{-1})	5085	44.84
Dhamtari District		
Farmers Practice (65:40:15)	3630	-
Sole N (120 kg ha^{-1})	2670	(-) 26.43
RDF (120:60:40 kg ha^{-1})	4937	36.00
RDF+FYM (5 t ha^{-1})	5504	51.62
Janjgir-Champa District		
Farmers Practice (65:40:15)	3000	-
Sole N (120 kg ha^{-1})	2566	(-) 14.46
RDF (120:60:40 kg ha^{-1})	4421	47.36
RDF+FYM (5 t ha^{-1})	5037	67.90

Framers' practice

100% NPK

100% NPK+FYM

Plate 9.7. Effect of balanced nutrient application on rice crop growthin tribal village in Chhattisgarh

Plate 9.8 Visit by Dr. Muneshwar Singh, PC (LTFE) to the Demonstration of Farmers field at IGKV, Raipur Centre

Training | Soil health card distribution | Field visit

Plate 9.9 Training activities under TSP at IGKV, Raipur Centre

9.7 JNKVV Jabalpur

9.7.1 Rabi Season (2014-15)

9.7.1.1 FLD's on response of phosphorus

Under this programme the field trials are continuing on the three sites for second year on high P containing soils at different villages of Mandla district. The experiment was laid out on the basis of inherent high available soil P status with soybean-wheat cropping sequence on the following farmer's field:

Name of farmers	Village	Location	
Farmer 1: Shri Mahendra Yadav	Kudamelli	N-22°52.043'	E-80°13.397'
Farmer 2: Shri Teerath Prasad Yadav	Kudamelli	N-22°52.056'	E-80°13.389'
Farmer 3: Shri Arun Kumar Yadav	Kudamelli	N-22°52.056'	E-80°13.410'

The field demonstration trials were conducted as per the guidelines of Long Term Fertilizer Experiment with the selected treatments as mentioned below:

T_1 : 100% NPK + 5 t FYM ha^{-1} (FYM applied to soybean)
T_2 : 100% NPK
T_3 : 100% NK + 50% P
T_4 : 100% NPK – S
T_5 : Farmer's Practice

Crop & Variety: Wheat (GW 366)

Recommended fertilizer dose : 120:80:40 ($N:P_2O_5:K_2O$ kg ha^{-1})

Farmer's practice treatment: Farmer generally prefers to apply fertilizer @ 70 kg N and 34 kg P_2O_5 ha^{-1} (30 kg DAP per acre) to wheat at the time of sowing and two split dose of Urea @ 50 kg per acre. Out of which 25 kg urea was applied about 3 weeks after sowing and 25 kg after 2 weeks of 1^{st} split date.

Crop Productivity of Wheat

The data presented in Fig. 9.4 indicated that the treatment T_1-100% NPK+FYM produced the highest average yield (4183 kg ha^{-1}) followed by T_2-100% NPK (3650 kg ha^{-1}). The lowest yield of wheat (2933 kg ha^{-1}) was recorded in T_5-farmer's practice. Maximum increase in yield (43%) was observed with 100% NPK + FYM over farmer's practice, followed by 24% increase in yield (100% NPK) of wheat (Fig. 9.4). The data further showed that even reduction in

50% P dose with 100% NK was found to be better than farmer's practice and increase the yield of about 8% in wheat over farmer's practice.

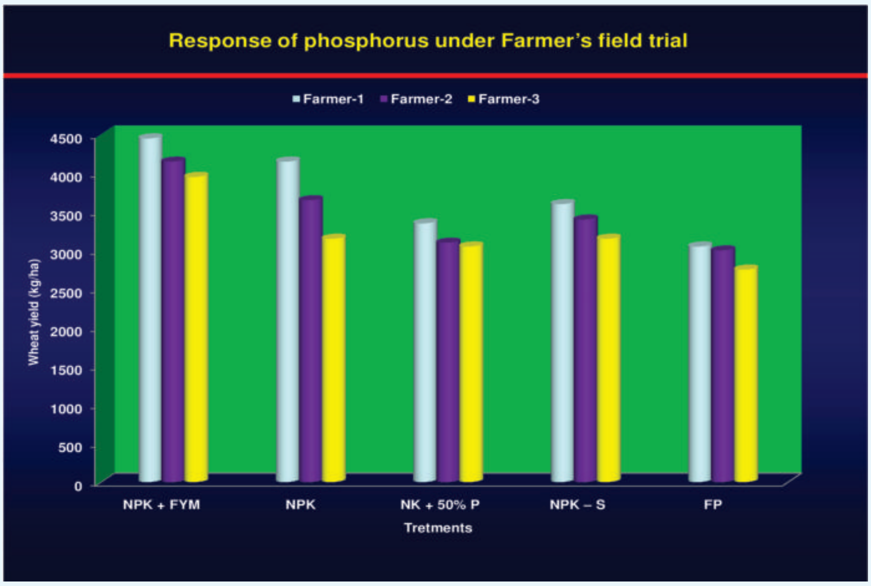


Fig. 9.4 Effect on response of applied P on grain yield (kg ha^{-1}) of wheat

Soil Status

The data indicated that the soil of selected FLD's (Table 9.10) was found to be neutral in reaction (soil pH), normal in EC, medium in organic carbon, available N and high in available P, K and S.

Table 9.10 Soil test values of various locations selected for FLD's

Treatment	pH	EC (dSm^{-1})	OC (g kg^{-1})	Available nutrients (kg ha^{-1})			S
				N	P	K	(mg kg^{-1})
Shri Mahendra Yadav							
100% NPK + 5 t FYM ha^{-1}	6.9	0.22	6.0	320	37.8	440	21.0
100% NPK	6.7	0.22	5.8	315	36.2	438	20.9
100% NK + 50% P	6.7	0.22	5.8	305	35.9	431	20.3
100% NPK - S	6.7	0.22	5.7	300	35.1	429	19.3
Farmers' Practice	6.8	0.22	5.7	297	34.4	428	19.0
Shri Teerath Prasad Yadav							
100% NPK + 5 t FYM ha^{-1}	7.1	0.19	7.0	330	42.0	414	24.0
100% NPK	7.0	0.19	6.9	325	41.6	412	23.8
100% NK + 50% P	7.0	0.19	6.9	328	41.4	410	23.7
100% NPK - S	7.1	0.20	6.8	325	41.2	410	23.5
Farmers' Practice	7.1	0.20	6.8	320	41.1	408	23.2
Shri Arun Kumar Yadav							
100% NPK + 5 t FYM ha^{-1}	7.2	0.20	6.2	325	42.5	460	22.2
100% NPK	7.1	0.20	6.2	318	41.2	455	22.1
100% NK + 50% P	7.0	0.20	6.1	315	40.8	445	20.5
100% NPK - S	7.1	0.20	6.1	315	40.6	438	20.3
Farmers' Practice	7.2	0.19	6.0	305	40.3	430	20.1

9.7.1.2 FLD's on response of potassium

To study on response of wheat to applied potassium in Vertisol was planned during rabi 2014-15. In this regard, a preliminary survey was conducted using GPS on the villages of Jabalpur and Mandla District namely Padwar (Barela), Pipariya, Kachnari, TemerBheeta, Bhaveramall, Bhilnagrimala and Chargaon Kala. The details of experimental site as mention below:

Farmer	Name of farmers	Village	Location	
Farmer 1	Shri Ramadhar	TemarBheeta	N-23°08.36.1'	E-80°00.04.6'
Farmer 2	Shri Birendra Kumar Patel	TemarBheeta	N-23°08.37.1'	E-79°59.56.4'
Farmer 3	Shri Ashok Kumar Tekam	Billnagrimal	N-23°05.16.2'	E-80°14.26.4'
Farmer 4	Smt Ramvati	Billnagrimal	N-23°05.11.5'	E-80°14.01.6'
Farmer 5	Shri RamdayalMerkam	Chergava Kala	N-23°04.11.1'	E-80°14.51.8'

Finally, five farmers were selected for field trials to study the response of potassium in crop and at following treatments were imposed in the field.

T_1 : Farmers' Practice
T_2 : K (0 kg ha^{-1})
T_3 : K (40 kg ha^{-1})
T_4 : K (80 kg ha^{-1})

In all the treatments N, P, S, Zn was applied to ensure sufficiency of these nutrients.

Farmer's practice: Farmer generally prefer to apply fertilizer @ 70 kg N and 34 kg P_2O_5 ha^{-1} (30 kg DAP per acre) to wheat at the time of sowing and two split dose of Urea @ 50 kg per acre. Out of which 25 kg urea was applied about 3 weeks after sowing and 25 kg after 2 weeks of 1stsplit date.

Recommended fertilizer dose: 120:80:40 (N, P_2O_5 and K_2O kg ha^{-1})

Crop &Variety: Wheat (GW 366)

Crop Productivity of Wheat

The data presented in Table 9.11 indicated increase in yield with sucessesive addition of K compared to without K application. It has also been deserved that maximum wheat yield incraese was noted with K_{40}/K_{80}.

Table 9.11 Effect of potassium application on wheat grain yield (kg ha^{-1})

Name of Farmers	Village	K_{80}	K_{40}	K_0	FP
Shri Birendra Kumar Patel	TemarBheeta	3650	3600	3100	2900
Shri Ramadhar	TemarBheeta	3150	3050	2950	2700
Shri Ashok Kumar Tekam	Billnagrimal	3700	3650	3150	2950
Smt Ramvati	Billnagrimal	3650	3600	3150	2600
Shri RamdayalMerkam	Chergava Kala	3350	3400	3200	2850
Mean		3500	3460	3110	2800

Table 9.12 Effect of K-application on soybean and wheat yields (kg ha^{-1})

Treatments	2014-15	2015-16	Mean
Soybean			
Farmers' Practice	-	306	306
K (0 kg ha^{-1})	-	311	311
K (40 kg ha^{-1})	-	357	357
K (80 kg ha^{-1})	-	353	353
LSD ($P \leq 0.05$)	-	NS	NS
Wheat			
Farmers' Practice	3500	3475	3488
K (0 kg ha^{-1})	3460	3617	3539
K (40 kg ha^{-1})	3110	3867	3489
K (80 kg ha^{-1})	2800	3958	3379
LSD ($P \leq 0.05$)	NS	NS	NS

Soil Status

The data indicated (Table 9.13) pH of soil was found to be neutral and normal in EC, medium in organic carbon and available N, high in available P medium to high in available K.

Table 9.13 Soil test values of various locations selected for FLD's

Treatment	pH	EC (dSm^{-1})	OC (g kg^{-1})	Available Nutrients (kg ha^{-1})		
				N	P	K
Shri. Birendra Kumar Patel						
K_0	6.79	0.19	6.3	305	33.0	415
K_{40}	6.82	0.18	6.2	300	32.9	430
K_{80}	6.75	0.19	6.1	298	32.5	450
FP	6.78	0.18	5.9	297	32.3	400
Shri. Ramadhar						
K_0	6.95	0.19	5.7	295	22.5	410
K_{40}	6.91	0.18	5.6	280	23.1	445
K_{80}	6.94	0.18	5.5	288	23.0	456
FP	6.90	0.19	5.4	278	22.4	390
Shri. Ashok Kumar Tekam						
K_0	6.8	0.21	6.6	305	24.5	420
K_{40}	6.7	0.20	6.5	315	24.8	450
K_{80}	6.8	0.20	6.4	323	24.3	470
FP	6.7	0.20	6.4	295	23.6	410
Smt. Ramvati						
K_0	6.6	0.19	5.3	305	21.2	380
K_{40}	6.5	0.18	5.5	325	22.4	470
K_{80}	6.6	0.18	5.3	327	23.1	480
FP	6.5	0.18	5.2	302	20.9	405
Shri. RamdayalMerkam						
K_0	7.1	0.21	5.9	310	19.8	350
K_{40}	7.0	0.20	6.1	335	20.6	445
K_{80}	7.2	0.21	6.0	342	21.4	465
FP	7.0	0.20	5.8	307	19.5	380

9.7.2 Kharif Season (2015-16)

9.7.2.1 FLDs on phosphorus response

Under this programme the field trials are continuing at six sites on medium P containing soils at villages Luhari, Gathora, Dhatera, Kanthi and Amkhera. The experiment was laid out on the basis of inherent high available soil P status with soybean-wheat cropping sequence on the following farmer's field:

Farmer	Name of farmers	Village	Location	
Farmer 1	Shri Ramesh Patel	Luhari	N-23°28.426'	E-079°53.668'
Farmer 2	SmtJayanti Patel	Luhari	N-23°28.490'	E-079°53.683'
Farmer 3	Shri Hari Lal Patel	Gathora	N-23°26.899'	E-079°51.837'
Farmer 4	Shri Santosh Yadav	Dhatera	N-23°23.792'	E-079°46.722'
Farmer 5	Shri Pramod Jain	Kanthi	N-23°15.038'	E-079°38.144'
Farmer 6	Shri R.P. Vishwakarma	Amkhera	N-23°12.926'	E-079°55.637'

Soil Status

The data indicated that the soil of selected FLD's (Table 9.14) was found to be neutral in reaction (soil pH), normal in EC, medium in organic carbon, low to medium in available N, low to medium in available P and high in available K.

Table 9.14 Initial and post-harvest soil test value

Farmer	pH	EC (dS m^{-1})	OC (%)	Available nutrients (kg ha^{-1})		
				N	P	K
Initial Soil Test Value						
Farmer 1	6.57	0.16	0.68	255	18.4	402
Farmer 2	6.72	0.18	0.54	206	16.5	443
Farmer 3	6.50	0.18	0.51	196	17.0	531
Farmer 4	7.65	0.19	0.58	230	8.60	490
Farmer 5	7.45	0.21	0.74	268	14.3	443
Farmer 6	7.61	0.18	0.67	251	11.5	667
Post-harvest Soil Test Value						
Farmer 1	6.60	0.14	0.65	248	16.2	354
Farmer 2	6.70	0.16	0.51	195	15.3	401
Farmer 3	6.40	0.19	0.52	190	16.2	485
Farmer 4	7.50	0.17	0.59	220	8.3	440
Farmer 5	7.40	0.18	0.73	248	13.4	398
Farmer 6	7.60	0.19	0.65	242	10.8	627

The field demonstration trials were conducted as per the guidelines of Long Term Fertilizer Experiment with the selected treatments as mentioned below:

T_1 : 100% NPK + 5 t FYM ha^{-1} (FYM applied to soybean)
T_2 : 100% NPK
T_3 : 100% NK + 50% P
T_4 : 100% NPK - S
T_5 : Farmers' Practice

Recommended fertilizer dose: 20:80:20 (N: P_2O_5:K_2O kg ha^{-1})

Crop & Variety: Soybean (JS 9560)

Farmer's practice treatment

Farmer's practice treatment: Farmer generally prefers to apply fertilizer @ 13 kg N and 34 kg P_2O_5 ha^{-1} (30 kg DAP per acre)

Soybean

The yield of soybean, in general are poor during 2015-16 due to excessive rain during this year. However, the average yield of soybean for 2014-15 and 2015-16 presented in Table 9.15 indicated that the treatment 100% NPK+FYM produced the highest average yield (881 kg ha^{-1}) followed by 100% NPK which gave 820 kg ha^{-1} yield. Reduction of dose of P did not have any adverse effect on yield of soybean.

9.7.3 Phosphorus Response (2014-16)

Results of FLD's laid out on the soils contained medium status of available phosphorus revealed that use of 50% P through SSP and full dose of N and K to soybean and wheat crops performed better over the application of fertilizer P through DAP. Under farmers' practice soybean did not do well because of application of DAP as source of fertilizer which dose not contains S.

Wheat

Data on wheat yield (Table 9.15) revealed decline in yield of wheat due to reduction in P dose to half compared to full dose. This is due to medium status of P in all the farmer's field. Absence of S also had adverse effect on productivity of wheat. Incorporation of FYM over and above NPK resulted in highest yield. Thus, yield data of soybean and wheat indicated that in INM is the best practice to sustain yield and application of P and S is also essential to sustain yield in the area.

Table 9.15 Effect of P application on soybean and wheat yields (kg ha^{-1}) on farmers' field (Average of five farmer's)

Treatments	2014-15	2015-16	Mean
Soybean			
100% NPK + 5 t FYM ha^{-1}	1393	369	881
100% NPK	1298	342	820
100% NK + 50% P	1160	333	747
100% NPK - S	962	311	637
Farmer's Practice	897	305	601
Wheat			
100% NPK + 5 t FYM ha^{-1}	4183	4058	4121
100% NPK	3650	3642	3646
100% NK + 50% P	3167	3575	3371
100% NPK - S	3383	3405	3394
Farmer's Practice	2933	3210	3072

9.6.5 Activities / Training Programme Organized

- Survey was conducted at some selected villages for the selection of site to conduct FLDs during kharif season under LTFE project during June 2015 (Plate 9.10). During survey village Khiria, Barotha, Bhidari kala, Salaia, Bamnoda, Kaladumar, Puraina, Jhirmili, Singledeep, Suhajani, Lohari, Indrana, Piparia-Gurda, Amkhera, Madai, Maniyari and Kudwari was visited and farmers were communicated regarding the integrated approach of fertilizer application in this connection, some farmers expressed their willingness to participate in programme.

- Final selection of FLD's, input distribution for sowing of soybean crop during kharif season 2015 and interaction with farmers of villages Piparia-Gurda, Suhajani, Luhari, Amkhera, Chargaonkal, Bhilnagrimal and PatanAmkhera Villages during 2nd and 3rd week of June, 2015.

- A training programme was also organized on soil testing and recommendation of fertilizer at Kanthi village on 30 September 2015 (Plate 9.11). The growth responses due to application of varying level fertilizers of ongoing field trialsof Soybean and discuss the benefits of the nutrient management. In this programme approximately 50 farmers participated.

- Fertilizers, seed etc. were distributed to the farmers in the third week of November 2015. The layout, fertilizer application and sowing of wheat crop was completed in fourth week of the November. First split dose of nitrogen was applied somewhere around third week of December 2015.

- A campaign regarding International Year of the Soil 2015 was also organized on 19December 2015 at Govt Primary School, Gathora. In this programme approximately 80 students participated. The object was to communicate village people about the importance of soil health and crop productivity and also message was communicated regarding the consequence effect of soil health on community health.

- A Field Day cum training programme was organized at Luhari village on 20-12-2015 to demonstrate the importance of soil testing for fertilizer recommendation and balance nutrient management for sustainable soil health. In this programme approximately 25-30 farmers were participated and updated the importance of soil testing for fertilizer recommendation for maintaining the soil health and sustainable productivity of the crops. It has also been suggested that if recommended dose of fertilizers along with organic manure is practiced that will be helpful for achieving high productivity and also maintaining the health of soil for succeeding crops.




Phosphorus **Potassium**

Plate 9.10 Field demonstrations on (a) soybean and (b) wheat at JNKVV Jabalpur




Plate 9.11 Training activities organized at JNKVV Jabalpur

10. AWARD, RECOGNITION & VISITS

10.1 Awards/ Recognition

10.1.1 PC Unit LTFE

- Dr Muneshwar Singh and RH Wanjari (2014) Awarded Third Prize as “Dhiru Morarji Memorial Award” for “Best Article in Agricultural Sciences 2013-14” for the article entitled “Balanced Nutrient Management: A Key to Sustain Productivity and Soil Health on Long Term Basis” published in Indian Journal of Fertilizers, Fertiliser Association of India, New Delhi.
- Dr RH Wanjari, Sr Scientist (Agronomy) (2015) Received the Outstanding Achievement Award GRISAAS 2015 (in the discipline of Agronomy) of the Astha Foundation, Meerut (UP) at RVSKVV Gwalior (13th December, 2015) (Plate 10.1).

Plate 10.1. Dr RH Wanjari receiving the Award from dignitaries during GRISAAS 2015 at Gwalior (13th Dec, 2015)

- Dr Muneshwar Singh and RH Wanjari (2016) Received the Best Poster Presentation Award in Session 03: Adaptation and Mitigation to Climate Change for the poster entitled 'Impact of Climate Change on Crop Productivity in Long Term Experiments in India'. *In* The First International Agrobiodiversity Congress in Vigyan Bhawan and NAAS Complex, New Delhi (6-9th November, 2016).
- Dr Muneshwer Singh delivered VV Mehata Memorial lecture at BAU Ranchi on 27th September 2016.

10.1.2 AICRP LTFE Centres

10.1.2.1 New Delhi

- Dr BS Dwivedi selected as Chief Editor, Journal of the Indian Society of Soil Science, New Delhi.
- Dr BS Dwivedi (2014) received IPNI-FAI Award for Excellence in Nutrient Management Research.
- Dr BS Dwivedi (2015) was inducted as Fellow, Indian Society of Soil Science.
- Dr BS Dwivedi, MC Meena and Abir Dey (2016) received Dhiru Morarji Memorial Award for Best Article in Agricultural Sciences published in Indian Journal of Fertilizers entitled “Integrated nutrient management for enhancing nitrogen use efficiency”.

- Dr BS Dwivedi (2016) received XVII Hari Krishna Shastri Memorial Award ICAR-Indian Agricultural Research Institute.
- Dr MC Meena (2015) received Golden Jubilee Commemoration Young Scientist Award of Indian Society of Soil Science, New Delhi.
- Dr BS Dwivedi was elected as Treasurer, National Academy of Agricultural Sciences since 2016.

10.1.2.2 PDKV Akola

- Jadhao, SD, Priyanka Mule, DV Mali, VK Kharche and NM Konde (2015) Received Best Poster Award in the National Seminar on "Sustainable management of land resources for livelihood security" organized by Indian Society of Soil Survey and Land Use Planning during January 28-30, 2015.
- Jadhao, SD, Jaya Tamgadge, DV Mali, SN Ingle, Priyanka Mule, VK Kharche, PA Gite and SM Jadhao (2015) Received Best Poster Award in the National Seminar on "Dryland Agriculture in Vidarbha: Priorities and Development Issues" organized by AICRP for Dryland Agriculture, Dr PDKV, Akola and Vidarbha Association for Research, Technology and Development in Agricultural and Rural Sectors (VART-DARS), Akola during March 3-4, 2015.
- Jadhao, SD (2015) Received First Prize for Oral Presentation in the National seminar on "Dry land Agriculture in Vidarbha: Priorities and Development Issues" organized by AICRP for Dryland Agriculture, Dr PDKV, Akola and Vidarbha Association for Research, Technology and Development in Agricultural and Rural Sectors (VART-DARS), Akola during March 3-4, 2015.
- Jadhao SD, RK Bajpai, VK Kharche, DV Mali, BA Sonune, PA Gite and SM Jadhao (2016) Received Best Poster Award in the State Level seminar on "Development in Soil Science: Climate Change and its influence in Natural Resource Management" organized by Dapoli Chapter of Indian Society of Soil Science during September 22-23, 2016 (Plate 10.2).
- Jadhao SD, RK Bajpai, A Tiwari, Vinay Bachkaya, VK Kharche, DV Mali and BA Sonune (2016) Received Best Poster Award in the International Conference on "Integrated Land Use Planning for Smart Agriculture –An Agenda for Sustainable Land Management" organized by Indian Society of Soil Survey and Land Use Planning during November 10-13, 2016 (Plate 10.2).

Receiving Best Poster Award at Nagpur November 10-13, 2016

Receiving Best Poster Award at Dapoli (September 22-23, 2016)

Plate 10.2. Dr SD Jadhav and DV Mali receiving the Award from dignitaries

10.1.2.3 JNKVV Jabalpur

- Dr AK Dwivedi (2016) Excellence in Teaching Award by GRISAAS-2015 at RVSKVV, Gwalior to.
- Dr AK Dwivedi (2016) Best Scientist Award-2016 at Indian Institute of Sugarcane Research (ICAR-IISR), Lucknow

10.1.2.4 PAU Ludhiana

- Dr Harmanjit Singh (2016) Golden Jubilee Award for Outstanding Doctoral Research in Fertilizer Usage 2016 by Fertilizer Association of India (FAI)

10.1.2.5 GKVK Bangalore

- Dr RC Gowda and associates got Best Paper Award (Dr. Banyal Memorial Best Paper Award 2015 by Society for Advancement of Human and Nature (SADHNA)

10.1.2.6 OUAT Bhubneswar

- Prajnyamayee Kamp, M Mandal, KK Rout, P Majhi and M. Singh (2015) Best Poster Presentation Award 2015 to "Carbon Sequestration Potential and Dynamics of Soil Organic Carbon Labile Pool Under Tropical Rice-Rice Agro-ecosystem." at 80th Annual Convention of Indian Society of Soil Science at Bengaluru on 5-8 December, 2015 (Plate 10.3)

Plate 10.3 Dr. K.K. Rout, Professor and OIC, AICRP on LTFE receiving the Best Poster presentation Award from Dr. JS Samra

10.1.2.7 KAU Pattambi

- Dr Thulasi V (2014) Best paper presentation award at Swadeshi Science congress, held at Malayalam University, Tirur, Kerala.
- Dr Thulasi V (2016) Haritham Kshoni Jwala award, organized by Haritham trus, Kerala

10.2 Visits

10.2.1 IGKV Raipur

- Dr Muneshwar Singh visited the experimental sites at IGKV Raipur as well as front line demonstrations (FLDs) conducted on the farmers' field in the districts of Chhattisgarh (Plate 10.4).

Plate 10.4 Visit by Dr Muneshwar Singh, PC (LTFE) to monitor FLDs on Farmers field at IGKV, Raipur Centre

11. SEMINARS/ TRAININGS ORGANIZED & PARTICIPATED

11.1 PC LTFE Unit, IISS Bhopal

- Muneshwar Singh and RH Wanjari (2015) Nutrient management and carbon sequestration potential of soybean-wheat and sorghum-wheat cropping systems in Vertisols. *In* National Training Programme on Climate Resilient Soil Management Strategies for Sustainable Agriculture' by Centre of Advanced Faculty Training, JNKVV Jabalpur (14 October - 3 November, 2015). pp 97-103.
- Muneshwar Singh and RH Wanjari (2016) Impact of Climate Change on Crop Productivity in Long Term Experiments in India. *In* The First International Agrobiodiversity Congress in Vigyan Bhawan and NAAS Complex, New Delhi (6-9th November, 2016).
- Muneshwar Singh and RH Wanjari (2016) Impact on Soil Health: Lessons Learnt from Long Term Fertilizer Experiments. *In* Short Course Training Programme on "Advances in microbial bio-fertilizers for sustainable agriculture in diverse soil and cropping systems". ICAR-IISS Bhopal (January 10-19, 2017).
- RH Wanjari (2014) Green Manuring for Sustainable Agriculture. *In* Winter School on 'Waste recycling and resource management through rapid composting techniques' (December 3-23, 2014).
- RH Wanjari (2014) Nutrient efficiency and sustainability of major cropping systems under long-term fertilizer experiments in India'.*In* National Symposium on 'Agriculture Diversification, for Sustainable Livelihood and Environmental Security" by Indian Society of Agronomy at PAU Ludhiana (November 18 – 20,2014).
- RH Wanjari (2014) Organic manures in integrated nutrient management for enhancing productivity and nutrient use efficiency in different cropping system. *In* Winter School on 'Waste Recycling and Resource Management through Rapid Composting Techniques' (December 3-23, 2014).
- RH Wanjari (2015) Assessment of soil quality and sustainability of major cropping systems under intensive long term fertilizer experiments in India *In* International Conference on 'Natural Resource Management for Food Security and Rural Livelihood' organized by Soil Conservation Society of India' (February 10-13, 2015).
- RH Wanjari (2015) Integrated Weed Management: Linkages with Carbon Dynamics. *In* Winter School on Advance Soil Biological Approaches for Enhancing Carbon Sequestration and Mitigate Climate change" at ICAR-IISS, Bhopal (September 2-22, 2015).
- RH Wanjari (2015) Long-Term effect of herbicides on enzymes and enzymatic activities in major soil under intensive and long term fertilizers experiments in India. *In* The 25th Asian Pacific Weed Science Society's International Conference on 'Weed science for sustainable agriculture, environment and biodiversity' at Hyderabad (October 13-16, 2015).
- RH Wanjari (2015) Potassium management strategies for finger millet in Alfisols. *In* National Conference on "Global Research Initiative for Sustainable Agriculture and Allied Sciences (GRISAAS 2015)' at RVSKVV, Gwalior (December 12-13, 2015).
- RH Wanjari (2016) Balance nutrient management sustained crop productivity in tribal areas in India: Experiences from long term fertilizer experiments. *In* The Fourth International Agronomy Congress in Exhibition Ground, ICAR-IARI, New Delhi (November 22-26, 2016).
- RH Wanjari (2016) Balanced and Integrated Nutrient Management Effects on Productivity and Sustainability in different Cropping Systems. *In* ICAR sponsored Winter School on 'Assessing Natural Resource Management, Climate Risk and Environmental Sustainability using Simulation Models' at ICAR-IISS, Bhopal (November8-28,2016).
- RH Wanjari (2016) Long-term nutrient management effects on soil health. *In* ICAR sponsored Winter School on "Assessing Natural Resource Management, Climate Risk and Environmental Sustainability using Simulation Models" at ICAR-IISS, Bhopal (November 8-28,2016).

- RH Wanjari (2016) Organic Manures in Integrated Nutrient Management for Enhancing Productivity and Nutrient Use Efficiency in Different Cropping system. *In* Short Course Training Programme on 'Advances in microbial bio-fertilizers for sustainable agriculture in diverse soil and cropping systems. ICAR-IISS Bhopal '(January 10-19, 2017).
- RH Wanjari and Muneshwar Singh (2015) Soil health management: Lessons learnt from long term fertilizer experiments. *In* MTC on 'Advances in soil health assessment and preparation of soil health cards for enhancing crop productivity and improving soil quality' at ICAR-IISS, Bhopal (December 14-21, 2015) pp. 171-177.
- RH Wanjari and Muneshwar Singh (2016) Lessons learnt from long term fertilizer experiments on soil health. *In* Training Programme on 'Soil Testing and Preparation of Soil Health Card (Under Soil Health Card Mission of Govt. of India)' Organized by Department of Farmers' Welfare & Agriculture, Govt. of M.P. in collaboration with ICAR-IISS at ICAR-Indian Institute of Soil Science, Bhopal (February 8-12, 2016).

11.2 PAU Ludhiana

- Brar BS, Dheri GS, Dhadli HS and Chaudhary Seema (2016) Carbon sequestration and greenhouse gas emissions: lessons learnt from long-term fertilizer experiment on rice-wheat cropping system. ***In*** Meeting on 'Resilience Emerging from Scarcity and Abundance'by ASA, CSSA and SSSA at Phoenix, AZ, USA (November 6-9, 2016),
- Dheri GS, Brar BS and Uppal HS (2016) Effects of long-term application of NPK fertilizer and organic manures on soil properties and productivity of rice-wheat cropping sequence. *In* National Seminar on 'Developments in Soil Science – 2016'and 8th"Annual Convention at RVSKVV, Gwalior (October 20-23, 2016).
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